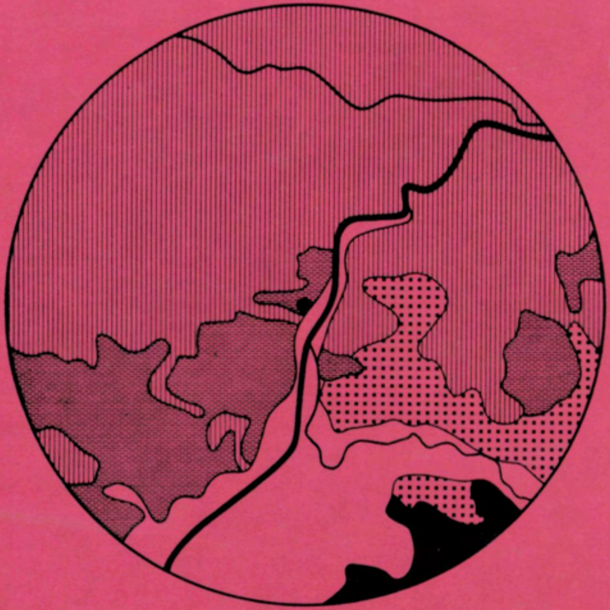
ANALECTA PRAEHISTORICA LEIDENSIA



1978

XI

ERRATA

FOUR LINEARBANDKERAMIK SETTLEMENTS AND THEIR ENVIRONMENT

A PALEOECOLOGICAL STUDY OF SITTARD, STEIN, ELSLOO AND HIENHEIM

C.C. BAKELS

ANALECTA PRAEHISTORICA LEIDENSIA XI

p. 11, fig. 1	scale unit of k: 10° C scale unit of l: 20 mm the diagrams start with the month of January
p. 29, 12th line	peat buried colluvium should read: peat buried under colluvium
p. 61, table 5	find number 325; the maximum number of spikelet bases should read as 372
p. 65, fig. 10	Opava-Kateřinky 541 should read: Opava-Kateřinky 54_1 Opava-Kateřinky 612 should read: Opava-Kateřinky 61_2 63 should read: Opava-Kateřinky 63 66 should read: Opava-Kateřinky 66
p. 84, 20th line	required for roof-supports should read: required for ridge-pole supports
p. 122, 8th line	erosion should read: corrosion
p. 133, 3rd line	fig. 15 should read: fig. 16
p. 165	The C14 date of 5840 ± 80 B.P. does not fall within zone D VII but marks the end of zone D VI
p. 168, 30th line	Chara remains should read: Cladium remains
p. 180	the first three lines of the description of Setaria viridis or S. verticillata should read: In the pit filling of no. 921 we found 22 seeds which on the one hand have a strong similarity with the Echinochloa crus-galli, found in this pit but which on the other hand are clearly more slender (L/B index 1.64 (1.5-1.8)). Similar caryopses appeared in four other samples. To some specimens
p. 184, table 16	Beginning with Bromus tectorum/sterilis all entries have been printed one line too low.

ANALECTA PRAEHISTORICA LEIDENSIA

XI

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PUBLICATIONS OF THE INSTITUTE OF PREHISTORY
UNIVERSITY OF LEIDEN

C.C. BAKELS

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CONTENTS

CHAPTER I

CHAPTER II

CHAPTER III

CHAPTER IV

CONTENTS

CHAPTER V

CHAPTER VI

APPENDIX I

APPENDIX II

APPENDIX III

APPENDIX V

I

INTRODUCTION

The study published here has been set up as a case study in human paleoecology. This term human paleoecology is a contraction of two better-known terms, namely paleoecology and human ecology. The first relates to the science which deals with the ecology of periods that belong to the past. By the second term is understood that part of ecology which focuses on man. Human paleoecology therefore relates to people from past periods. It studies prehistoric or even historic human populations in relation to their environment.

A characteristic of a vanished population is that it cannot be studied directly. This can only be done through what it has left behind. Beside remains of man himself, the records consist of traces of his activities, among which are mobile and immobile goods and, in special cases, even written sources. This is the reason why in reality the investigator does not deal with a population in the biological sense, that is with a collective group of individual organisms, but with one of the higher units of the archaeological taxonomy. One may consider units on the level of assemblage, culture, culture group or technocomplex from the taxonomic system by Clarke (Clarke 1968). However incomplete, they represent for us the living population from the past.

Like the population, the environment cannot be described directly either. What we call "environment" changes in the course of time. Some factors change slowly, others more quickly but the present can never be an exact model for the past. Therefore the environment will always have to be reconstructed. Each archaeological entity will have to be related to a reconstructed environment which is valid for the period in which the entity occurred.

It will be obvious that a study of cultural remains can never approach a direct study of a living population. Nor can a reconstructed environment ever be described with the same accuracy that may characterize the description of a recent environment. The relation between an archaeological entity and its reconstructed environment is for that reason only partly accessible to investigation. A paleoecological study can never arrive at such detailed analyses as is possible in a normal ecological study.

We have undertaken the present study to investigate what can be done in the field of reconstructions in a concrete case. We have tried to see how far we could come with a description of the relation between a given archaeological entity and its environment. It is also our purpose to indicate the limits of the results which can be obtained in the state of present research. As subject we chose four settlements which belong to the same culture: the Linearbandkeramik culture. This choice will be explained in the following chapter.

II

THE LINEARBANDKERAMIK SETTLEMENTS

The choice of the subject for our investigations was, in advance, determined by two conditions. The first was that the investigation was conducted best with an entity, the contents of which are not subject to differences of opinion within the archaeological world. The second was that an investigation like the present one proceeds more smoothly when the material on which it is based is easily accessible to the investigator. These criteria together led to the choice of four settlements, belonging to the Linearbandkeramik culture.

The Linearbandkeramik culture, LBK in abbreviation, is a generally accepted taxonomic entity. It is also known by the names "Danubian I" and "Linear Pottery Culture". The entity belongs to the Neolithic and is dated by conventional C14 dates to the second half of the fifth millennium B.C., thus forming, in as far as known, the oldest Neolithic culture in Central Europe. Its best known characteristic is the pottery with its distinctive decoration; it is this decoration that has given the culture its name (first use by Klopfleisch 1884). Further attributes are ground stone adzes, a well-defined house-plan and a particular settlement form. Furthermore, the close relation to loess soils is also often mentioned. For details and examples, we refer to a handbook like that by Müller-Karpe (1968).

The Linearbandkeramik culture has had a wide distribution within Europe. "The number of settlements of the LBK culture which have become known through finds amounts to thousands. They are concentrated around the Rhein,* the Neckar, the Main and the Maas; further concentrations exist in the area between the Upper Leine and the Saxon Elbe, in the Donau Plain of East Bayern, in North Bohemia and in Silesia. They can also be found on the Lower Oder, along the Vistula, in Western Hungary and on the Upper Dnjestr" (Müller-Karpe 1968 p. 115, our translation). From the above quotation may be deduced that the LBK – occupated area can be divided into a number of regions, since the settlements are not distributed evenly over the area between the Maas and the Dnjestr, but show a distinct clustering. This aspect is clearly shown by the well-known distribution maps (e.g. Clark 1952 fig. 45).

During the five centuries of its existence, the culture does not remain completely identical in form. It is known that the pottery repertory, the shape of the stone adzes and the plan of the houses changed to some extent in the course of time. It is usual to divide the LBK into a number of phases on the basis of changes in the pottery. It is apparent that the shape and the decoration follow their own evolution in each region, resulting in the difference between the regions becoming greater and greater. In its early phases the LBK is conspicuously uniform; regional variants are found in the later phases. The number of phases distinguished differs per region and the transitions from one phase to the next are virtually nowhere synchronous. But in spite of the regional developments, the LBK remains a well-defined entity. There are many more similarities than differences.

* Geographical names are given according to "The Times Atlas of the World 1955".

The second requirement: accessibility of the material, could be met because the study of the LBK culture is among the projects of the Institute of Prehistory, University of Leiden, the institute to which we are attached. When we began our study, this institute was working on the publication of two LBK settlements in the Dutch province of Limburg, namely Stein and Elsloo.* At the same time excavations took place in the LBK settlement "Am Weinberg" in Hienheim, Landkreis Kelheim, Bayern, West Germany. So it was obvious to choose the settlements Stein, Elsloo and Hienheim as the subject of this study. We have added the settlement in Sittard, province of Limburg, Netherlands, because the material is also available in Leiden, namely in the Rijksmuseum van Oudheden. An additional advantage is that all four settlements were excavated by the same archeologist, prof. dr. P.J.R. Modderman, and in the same way.

So we have worked with four settlements from two regions. Sittard, Stein and Elsloo lie in that part of the Dutch province of Limburg, which is called Southern Limburg. They belong to a concentration of settlements, which is bounded by the river Maas and its tributary the Geleen. The occupational history of this region seems to start, as far as the LBK is concerned, in the years before 4400 B.C. and seems to end rather abruptly in the years between 4100 and 4050 B.C.* The total duration is circa 400 ± 50 years (Modderman 1970 p. 201). A younger and an older LBK are distinguished, each subdivided into four phases by Modderman. The first phase of the older LBK, called Ia, is, however, absent from Southern Limburg. Phase Ib is rare. It belongs to the above-mentioned early phases, in which the LBK shows a uniform character throughout Europe. The paralellisation of Ic and Id with phenomena in other regions is more difficult, because regionalization has set in. The younger LBK, with phases IIa-IId, is clearly a regional variant. Absolute dates cannot be given for the different phases, because C14 dates are not accurate enough for this purpose (Modderman 1970 p. 200).

Hienheim, Ldkr. Kelheim, lies on the left bank of the Donau in a region which belongs to Niederbayern. It is the area that Müller-Karpe has called "the Donau Plain in East Bayern" (see above). The traces of occupation in Hienheim are dated by C14 between 4300 B.C. and 3900 B.C. The settlement is succeeded without hiatus by a settlement of the Stichbandkeramik (Middle-Neolithic). In contrast to Southern Limburg, the occupation does not end abruptly. The different phases in the occupational history of Hienheim are still being defined at the moment, so that a division into phases cannot yet be given.

In this publication we shall not give more information about the results of the excavations in the settlements, but we refer to the appropriate publications. For Sittard, Stein and Elsloo, these are the publications by Modderman from 1958/1959 and 1970 (Modderman 1958/1959 c, Modderman 1958/1959 d, Modderman 1970). Two provisional publications are available at the moment of the excavation in Hienheim (Modderman 1965/1966, Modderman 1969). The first part of the final report is being printed (Modderman in press). The material from the excavations in Sittard, Stein and Elsloo is now stored in the Rijksmuseum van Oudheden in Leiden. The finds from Hienheim can be studied in the Prähistorische Staatssammlung in München. The original drawings of soil traces and material are not available in these museums, but can be found in the archives of the State Service for Archaeological Investigations in Amersfoort (Sittard, Stein and Elsloo) and in the Institute of Prehistory in Leiden (Hienheim).

* From Elsloo a cemetery is also known.

* All dates in this study are based on non-calibrated C14 dates.

It results from the above, that the choice of the four LBK settlements Sittard, Stein, Elsloo and Hienheim was determined on the one hand by the fact that they belong to a culture about which few misunderstandings are possible, and on the other hand by the fact that the material and documentation were in Leiden during the investigation. We realize that the four settlements chosen need not represent the LBK culture. It would not be correct to see them as a random sample. That was not our intention either. But we do think that the settlements may be compared to each other. If sufficient similarity would be found in the relations of these four settlements to their environment, this might lead to ideas about the relations between LBK settlements and their environment in general. The validity of these could be verified by a study of a real random sample.

III

THE ENVIRONMENT

III. 1 GENERAL OBSERVATIONS ON THE RECONSTRUCTION

The first question with which we are faced in the reconstruction of an environment, is what exactly it is that we are to reconstruct. The environment of a human population is a notion which is difficult to define. It is a complex of living and inanimate elements, from which we shall have to make a choice. We have the advantage that we study populations of a species to which we belong ourselves, namely mankind. This permits assumptions as to those factors which are of primary importance to the existence of man. We think of the following elements: climate, relief, hydrology (with particular reference to drinking water), vegetation (especially the higher plants) and fauna (animals which are visible with the naked eye). The presence of other, similar, but also of different populations (groups of people with the same, respectively a different, way of life) is deemed important as well. To this, aspects must be added from geology (e.g. the presence of mineral resources) and sometimes pedology. Relief, hydrology, geology and pedology can be combined under the heading: the substrate. The above factors together constitute the "environment" of mankind which we shall consider. It is these aspects which we shall try to reconstruct.

A second question is how large the area should be, of which we have to reconstruct the environment. In our opinion, the size of the area to be described will depend strongly on the size of the population, or the taxonomic entity, which we wish to examine. The reconstruction of the environment of a cultural group or of a technocomplex in the sense of Clarke (Clarke 1968) requires the description of a quite different area than the reconstruction of the environment of a site assemblage. As our study is in the first instance concerned with the latter, we shall restrict ourselves to a consideration of an area around a settlement.

A settlement is, regardless of its size or its span of life, the centre of the daily existence of the population in question. Starting from the settlement, different activities are undertaken, but in principle the inhabitants return to the settlement each day, to sleep there. The area which can be visited daily is therefore limited. We refer to this area by the term "home range", a term originating from animal ecology. Besides "home range" the term "territory" also exists. In general, "home range" is used when the area of activity has rather vague boundaries or is overlapped by the area of another individual or group; territories are clearly defined. Both terms can be used to describe human behaviour. For the area around a settlement, which is visited more or less daily, we prefer to use "home range". It is the environment within the home range, which is of primary importance to the inhabitants of the settlement and which must be reconstructed anyhow. The environment outside the home range is of less evident importance.

How large is a home range? Theoretically, the maximum size comprises a circle with a radius of 6 hours walking distance, on the assumption that off-site activities are only carried out in day-light and that the length of the day is 12 hours. The question is whether a limit of 6 hours' walking distance, calculated in this way, has any real meaning. What really counts in determining the size of a home range is the time man is willing to devote to travelling to and from the place where he wants to carry out an activity. If the travelling time had a certain limit, which is anchored in human behaviour, we should rather use this limit as a determinant for the size of a home range. It appears that such a limit indeed exists for travelling times, at least as far as economic activities are concerned. Concerning the radius of action of cultivators Chisholm says (Chisholm 1968 p. 131): "A point which emerges from the preceding discussion ... is the frequency with which the same orders of magnitude keep on recurring among peoples of widely different technical achievements and inhabiting areas with markedly different physical characteristics." For the area in which the economic activities of a settlement are carried out, Vita Finzi and Higgs have introduced the term "site territory": "Site territory – the territory surrounding a site which is exploited habitually by the inhabitants of the site" (Vita Finzi & Higgs 1970 p. 7). On the basis of Chisholm's work, they define the site territory of farmers as: "the area which lies within one hour's walking distance from the site". The site territories could be different per main type of economy. Higgs defines the site territory of hunters and gatherers as: "the area which lies within two hours' walking distance from the site" (Higgs 1975 p. IX). This definition is based on the work of Lee (Lee 1969). However, Chisholm has used little material about swidden systems* in his study, whereas Lee's work deals exclusively with !Kung Bushmen, so that we are not willing to adopt the definition given by Higgs and Vita Finzi without any research of our own. For this reason, we have tried to collect more data on hunters/gatherers and swidden cultivators. The material which we have collected is brought together in table 1. Almost all entries relate to obtaining food and thus to the site territory. We gain the impression that for the site territory of the hunters/gatherers mentioned, a circle with a radius of two hours' walking distance is a quite acceptable estimate. As far as swidden cultivators are concerned, the figures mostly relate to the distance to the fields or the area where fields can be made. The distance from the fields to the settlement indeed lies within a circle of one hour's walking distance in most cases. But all populations mentioned in table 1 also obtain materials and food from the wild. If these economic activities are to be included in the consideration, the radius will exceed the above-mentioned one hour's walking distance. E.g. the distance which the Hanunóo are willing to cover to their fields is one hour's walking distance, but two hours' walking distance for getting rattan (Conklin 1957). Two hours' walking distance, as for hunters/gatherers, seems to us a safer estimate for the size of the site territory.

For most of the groups examined, the home range seems to coincide with the site territory. The home range, however, can be larger, e.g. when the boundaries set to the subsistence activities are crossed for social activities in the widest sense of the word. Something like this can be observed with the Bemba (Richards 1939). We cannot yet estimate the size of the home range in such cases, as we have too little information at our disposal. Anyhow, the Bemba easily walk a distance of 25 km for making visits. For lack of better information, we shall use, for the time being, the theoretical home range with a radius of six hours' walking distance.

Thus we distinguish three zones of activity around a settlement: a site territory with a radius of two hours' walking distance, a home range with a radius of six hours' walking distance, and the world beyond. In that part of the home range, which lies outside the site territory, perhaps other aspects of environment are of importance to the population than in the area on which it depends economically. We assume that in the outer zone of the home range mainly the presence of other human groups and the way to get there are of importance. This means that in the reconstruction of this part of the environment, attention will be paid to the presence of other settlements and to the passableness of the terrain, whereas such aspects as the

* Under swidden systems we understand systems with forest-fallow cultivation and bush-fallow cultivation which means that the plots of land are left fallow for a number of years sufficient for the forest or bush to regain the land.

specific composition of flora and fauna will be of lesser importance. If, however, raw materials, which are not present within the site territory, occur within the home range, this must be noted.

On the basis of the above-mentioned considerations, we arrive at a three fold division of the environment around a settlement:

1) an area with a radius of two hours' walking distance, the environment of which must be reconstructed in detail.

2) a zone with a radius of six hours' walking distance, of which the topography, the location of other settlements and the presence of essential raw materials must be reconstructed.

3) the area beyond, the environment of which need not be reconstructed in the first instance.

It depends on the available means of transport and on the speed which can be maintained, what two hours' walking distance and six hours' walking distance will mean in real distances.

Unfortunately, nothing concrete is known about the means of transport which the Linearbandkeramik culture had at its disposal. Of course we may assume that people could travel on foot. The distance which can be covered on foot varies with the relief and the burden to be carried. We count with a walking speed of 5 km/h with a light burden on more or less even ground, and with 3 km/h with a heavy burden in mountainous terrain. As the areas examined by us are not particularly mountainous, in the present study we reckon with 5 km/h; that means that two hours' walking distance equals 10 km and six hours' walking distance equals 30 km. These are probably maximum values.

It is improbable that the LBK knew of carts, but the use of a means of transport such as the travois or the sledge may not be excluded. Probably, the possible use of these means of transport hardly influenced the radius of action. A travois is accompanied on foot. The sledge may carry persons. This transport can be fast when one possesses fast draught-animals and a good gliding ground in open terrain. The LBK and the landscape at that time did not meet these conditions. The domesticated horse was not known and few dogs were found. In wintertime, snow might have provided a gliding ground but open terrains, which are necessary for maintaining speed, were not yet present (see p. 38). Travois and/or sledge may have played a part in the transport of goods, but probably this was not faster than a journey on foot.

It is not impossible that the LBK possessed boats and could thus travel by water. It is true that boats or oars have never been found in a LBK context, but that tells nothing, because in most settlements the find circumstances are not suitable for preserving organic material. Vessels are known, however, from the Mesolithic and the Middle-Neolithic. The type of boat, of which we think, are dug-out canoes and possibly boats of wood covered with hides. These boats were probably paddled. It is difficult to find out how fast these vessels were. Until the thirties of this century, dug-out canoes were used in the Voralpengebiet. These are not distinguishable from prehistoric boats (Paret 1930). Although ample descriptions of these subrecent vessels exist, not a single publication contains data about their speed (Brunner 1903, Mitzka 1933). Anyhow, they were not fast. Mitzka mentions that if punting was possible, this was always faster than rowing (paddling) (Mitzka 1933 p. 52). To get some insight in the speed of paddled boats, we have tried to collect data about different types of boats. The boat of wood and hides, which was built in 1971 as a possible model of a Scandinavian ship from the Bronze Age, made 2.8 knots with a crew of 6 rowers, that is 5 km/h (Johnstone 1972 p. 272). The Hawaiian double canoe built for Finney made 3 knots with 8 paddlers, that is 5.6 km/h, in calm weather on a smooth sea (Finney 1967 p. 150). Table 1 mentions two groups which use boats. The women on the Maroni River go by boat to the remotest gardens. To a one way trip they devote two hours or little more and cover a distance of slightly less than 10 km (Kloos 1975 verbal information). The Iban travel by canoe to fields which are at a distance of somewhat more than 1.5 km from their house (Freeman 1970 p. 161). When the fields are further away, the agricultural activities are undertaken from a secondary house. These secondary houses are located up to a distance of 11 km from the primary settlement (Freeman 1970 p. 164); Freeman mentions elsewhere that the secondary houses may even be located at two to three hours' travelling from the primary settlement (Freeman 1970 p. 161). The data on the Maroni River Carib women and the Iban relate to travelling on rivers. It is evident that down-stream the speed is higher than up-stream. As in our considerations both way trips have to be made, the advantages of a fast trip down-stream are cancelled out by the trip up-stream.

From the few figures at our disposal, we get the impression that travelling, even with rather specialized boats as the Hawaiian double canoe, is not much faster than walking. At present, a radius of action of 10 to 30 km seems to be acceptable for possible LBK boats.

The above considerations have answered the question how large the area will be which we intend to reconstruct around the LBK settlements Elsloo, Stein, Sittard and Hienheim.

Within a radius of 10 km we shall reconstruct as completely as possible the environment which we presume to have been important to the settlement. This reconstruction comprises aspects concerning climate, substrate, flora, fauna and human settlements. Within a radius of 30 km we shall consider only the topography and the presence of human settlements. A priori, we shall reconstruct nothing beyond the 30 km boundary. Important factors beyond the 30 km boundary will come to light when we will have a closer look at the relationship man-environment.

Table 1. The size of the area, which is visited daily from a settlement: some data from the literature on hunters/gatherers and swidden cultivators.*

Human group	*Type of economy*	*Radius of action or "territory"*	*Way of travelling*	*Author*
Anbara Australia	hunters/ gatherers	50 km²	on foot	L.R. Hiatt 1968 p. 101
Australian aborigines	hunters/ gatherers	10-13 km	on foot	A.A. Yengoyan 1968 p. 187
Women from Arnhemland Australia	gatherers	6-8 km	on foot	M. McArthur 1960 p. 130
Pitjandara women Australia	gatherers	5 km	on foot	N.B. Tindale 1972 p. 245
Kung Bushmen Botswana	hunters/ gatherers	10 km	on foot	R.B. Lee 1969 p. 61

* In a large number of cases the radius of action is given in real distances and not in hours' walking distance. For a correct judgement of the data, the passableness of the terrain should be mentioned. It was impossible, however, to compare the geographical descriptions from the literature studied. We assume that in one hour's walking distance, a distance of 5 km or less is covered.

Human group	*Type of economy*	*Radius of action or "territory"*	*Way of travelling*	*Author*
G/wi Bushmen men women Botswana	 hunters gatherers	 24 km 8 km	on foot	G.B. Silberbauer 1972 p. 290 p. 287
Hadza women Tanzania	gatherers	hour's walk	on foot	J. Woodburn 1968 p. 51
Birhors India	hunters/ gatherers	4-8 km	on foot	D.P. Sinha 1972 p. 377
Copper Eskimo Canada	hunters	8 km	on foot	D. Damas 1972 p. 23
Bemba Zambia	swidden cultivators	for cultivation a few km for fishing up to 16 km for visiting up to 25 km	on foot	A.I. Richards 1939 p. 18 and Table E
Yako Nigeria	swidden cultivators	120 km^2	on foot	C.D. Forde 1968 p. 161
Kapauku New Guinea	swidden cultivators	45 min = 1.8 km	on foot	L. Pospisil 1963 p. 87
Tsembaga New Guinea	swidden cultivators	orthographically 8.2 km^2 to gardens: 20 min walk down hill and 30 min walk up slope	on foot	R.A. Rappaport 1968 p. 33 and Table 5
Iban Borneo	swidden cultivators	up to 1.5 km slightly further than 1.5 km	on foot by boat	D. Freeman 1970 p. 161
Hanunóo Philippines	swidden cultivators	6 km^2 one hour's walk to garden = 1 km with heavy load 2 hours' walk for a coil of rattan	on foot	H. Conklin 1957 p. 12 Plate 29
Lamet Indochina	swidden cultivators	2.48 km walking speed 3 km/h	on foot	K.G. Izikowitz 1951 p. 40
Maroni River Carib women Surinam	swidden cultivators	45 min 2 hours or more	on foot by boat	P. Kloos 1971 p. 26
Kuikuru Brazil	swidden cultivators	6-8 km	on foot	R.L. Carneiro 1956 p. 232
Average Amazonian cultivators Brazil	swidden cultivators	5 km	on foot	R.L. Carneiro 1956 p. 232

III. 2 THE CLIMATE

The present climate of the area in Southern Limburg, which we investigated, is recorded by the climatological stations at Beek and at Buchten. These stations used to be located at Maastricht (until 1953) and at Sittard (until 1949) respectively. The use of the records of the present locations presents some disadvantages. The station at the airport of Beek is located on a very exposed plateau, so that it is not really comparable with the conditions at Sittard, Stein and Elsloo. It is true that its predecessor Maastricht lies beyond the 10 km radius, but its location corresponds better to that of the LBK settlements.* Moreover, the former stations have longer series of observation than the new ones. Therefore, we shall refer to the stations Sittard and Maastricht.

For Hienheim, the nearest climatological station is at a distance of 30 km at Ingolstadt. There is another station at Regensburg. The station Ingolstadt probably provides the most useful data, as Regensburg is located within the rainshadow of the Frankische Alb.

The most relevant climatological data relating to temperature and precipitation are brought together in the climatic diagrams of figure 1. These diagrams are taken from the work of Walter and Lieth (Walter & Lieth 1960 and 1964). It can be concluded from the diagrams that the precipitation in the Southern Limburg area is spread more equally over the year than the precipitation in the valley of the Donau near Hienheim. Besides, winters are much more moderate in Southern Limburg. The area around Hienheim clearly has a more continental climate than the area around Sittard, Elsloo and Stein. Wind-direction and wind-force are not incorporated in the diagrams. In Southern Limburg, the wind is usually south-west to south-south-west in the months from July to February. In the months between March and June the wind may blow from any direction, except from the south-east. The winds are of moderate force. In the valley of the Donau near Hienheim, the winds are usually from the south-west. Their force varies from weak to moderate. Storms occur rarely.

The climate was different at the time of the LBK. The second half of the fifth millennium B.C. falls within the postglacial climatological optimum or hypsothermal (~6000 - ~1000 B.C.) and more precisely within the so-called Atlantic (~6000 - ~3000 B.C.).

Data about earlier climatic periods are taken from four sources of information. The first source is the investigation of subfossil flora and fauna. There are some species of plants and animals of which it is known that their area of distribution is limited by certain climatological factors. For example ivy (Hedera helix L.) appears unable to survive when the average temperature of the coldest month is below 1.5° C (Iversen 1944). The eggs of the pond turtle (Emys orbicularis L.), which are incubated by the warmth of the sun, do not hatch in areas north of the 20° C July-isotherm in France and the 18° C July-isotherm in Eastern Europe (Degerbøl & Krog 1951). When subfossils of such organisms are found in deposits in areas where they no longer occur at present, conclusions may be drawn regarding the earlier climate of the find site. Another biological method is the study of tree-rings, as the thickness thereof is among other things determined by the climate. A climate, which is favourable to a certain tree, usually leads to the growth of thick rings. Glaciology is a second source of information. The advance or retreat of glaciers indicates changes in climatological factors as temperature and precipitation. Geomorphology provides further data, e.g. the grain-size distribution of cave deposits is dependent on the climate. A fourth type of in-

* One LBK settlement: Caberg, is located at a distance of 1,5 km.

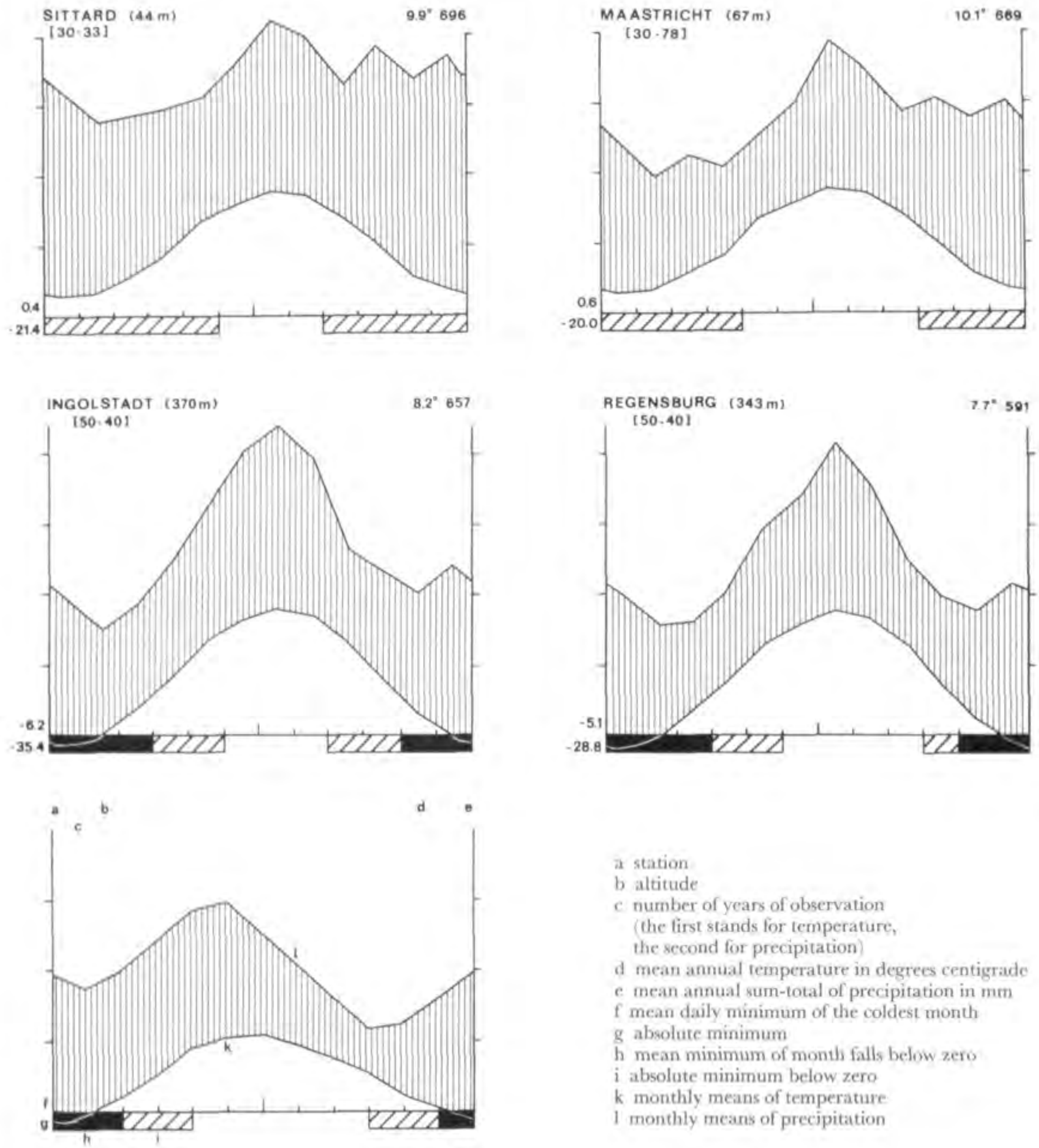


Fig. 1. Climatic diagrams of the weather stations at Sittard, Maastricht, Ingolstadt and Regensburg. The diagrams are based on data up to 1940 inclusive. According to Prof. Dr. H. Walter the use of more recent data wouldn't make any essential difference (Walter 1975, written information).

formation is obtained by the examination of the ratio of the oxygen-isotopes 018 and 016, e.g. in $CaCO_3$, or in ice. The 018-016 ratio in remains of, for instance, foraminifera depends on the temperature of the water in which these planktonic species lived. An example of this method for climate reconstructions is the investigation of undisturbed sections of globigerina ooze in ocean bottoms. The oxygen-isotopes ratio in the ice of ice-caps depends on the temperature of the air during the formation of the ice. The ice-cap of Greenland has been studied in this fashion.

So far the two areas, of which we want to reconstruct the climate, have provided no useful data which, as indicated above, could inform us about the climate in the Atlantic. Therefore we have to use what is known about the Atlantic in a larger area, namely Central and Western Europe. The most concrete data are provided by the investigation of flora and fauna. Glaciology and geomorphology also provide information. The 018-016 method has not yet been helpful.

Iversen calculated the summer and winter temperature of Djursland (Denmark). By means of the presence of pollen of mistletoe (Viscum album L.), ivy (Hedera helix L.) and holly (Ilex aquifolium L.) in peat deposits from the Atlantic, he arrived at the conclusion that the average temperature of the warmest month must have been about 2° C higher than the present temperature, whereas the average temperature of the coldest month must have been about 0.5° C higher than at present (Iversen 1944). The findings of Degerbøl and Krog with respect to the pond turtle (Emys orbicularis L.) confirm the occurrence of a summer temperature 2° C higher in Denmark during the Atlantic (Degerbøl & Krog 1951). For Great Britain, Conolly and Dahl were able to conclude from the fossil distribution of a large number of arctic and montane plants, that summers during the Atlantic were warmer by 2 to 3° C than summers in our time (Conolly & Dahl 1970).

Figures applying to Central Europe are mentioned by Mania and by Fuhrmann (Mania 1973a, Fuhrmann 1973). Their observations concern mollusc faunas. The following table, taken from Mania, relates to the Saale- and Middle Elbe-area:

Table 2. The Atlantic climate according to Mania 1973a.

	present climate	*estimated situation during the Atlantic*
average annual temp.	+ 8° to + 9° C	circa + 9° to + 11° C
average temp. July	+ 16° to + 18° C	circa + 18° to + 20° C
average temp. January	— 3° to — 1° C	circa — 1° C
average annual precipitation	450 — 650 mm	circa 550 — 700 mm

In Central and West Sachsen Fuhrmann distinguishes, as is usual in the Central European pollen analysis, two periods within the Atlantic: an "Alt-Atlantikum" from 5600–4000 B.C. and a "Jung-Atlantikum" from 4000–2500 B.C. During the Alt-Atlantikum, the average annual temperature was circa 1° C higher than nowadays, whereas the optimum with 1 to 2° C higher temperatures was reached during the Jung-Atlantikum. The climate ressembled the present climate in the south-eastern part of Central Europe. According to Fuhrmann, a strong submediterranean influence is characteristic for this period. Unfortunately his Saxon mollusc faunas provide no information about the precipitation.

In the Alps, pollen diagrams have shown that during the Atlantic the tree-line was a couple of hundred meters higher than at present (Firbas 1949). In the Alt-Atlantikum the tree-line at Graubünden was 150 m higher than nowadays (Heitz 1975).

As a result of the above it may be assumed for floristic and faunistic reasons, that summers in Western and Central Europe were 1 to 3° C warmer than in our days. Winters were warmer too, and as a whole the climate probably was wetter as well.

Additional data are provided by glaciology. The alpine glaciers were of rather small size during the hypsithermal. It cannot always be determined whether a small size is related to a higher temperature or to less precipitation. Besides, the topography of the glacier valley influences the speed of growth of the ice-tongue. According to Mercer, however, small glaciers in temperate areas react mainly on differences in temperature and they can be used for information about this factor (Mercer 1967). It may be concluded from the small size of the alpine glaciers that it was rather warm during the Atlantic. However, the value of the difference in temperature between then and now is difficult to estimate.

Geomorphology provides strong indications that it was not only warmer but also wetter. On the basis of a great number of observations, mainly in Poland and Czechoslovakia, Starkel concludes: "Geomorphological data have established that the Atlantic period was of humid character with rainfall all the year round, with warm winters (no traces of frost processes in Central Europe) and with the mean annual temperature about 2° higher than that of the present day. Fluvial deposits bear witness to the occurrence of periods of heavy rain of long duration" (Starkel 1966 p. 26).

In much of the literature quoted so far, the Atlantic is described as a single climatological period. However, Firbas already divided the Atlantic into two parts (Firbas 1949) and in the above-mentioned article of Fuhrmann different temperatures are calculated for these two parts (Fuhrmann 1973). Frenzel shows that probably much more variations can be distinguished in the climate of the Atlantic Period (Frenzel 1966 fig. 4). To these oscillations belong the cool Misox-oscillations of Zoller, which lasted from 5500–4500 B.C. (Zoller 1960). However, these oscillations have not yet been observed generally. According to the data gathered by Frenzel, the period 4500–4000 B.C. in which we are interested, belongs to a relatively warm phase within the Atlantic. Therefore all above estimates concerning temperatures and precipitation are probably applicable to the period which we examined and can be used for the reconstruction of the climate.

For the reconstruction of the climate, we base ourselves on the work of Lamb (e.g. Lamb et al. 1966, Lamb 1971 and 1974). This author starts from surface temperatures which have been reconstructed for a certain period in a certain area, because these data are the most reliable and often the only available concrete data. Lamb plots the surface temperatures of the coldest or the warmest month on a world-map of the period in question. On the basis of the surface temperatures, he subsequently charts the temperature of the upper air, starting from the principle that the present relation between surface temperature and temperature of the upper air also applied in the past. From the second temperature chart, the vertical thickness of the lower half of the atmosphere is calculated and charted by means of the density of the air. This 1000–500 millibar thickness chart leads to the reconstruction of the corresponding upper winds and the pattern and the intensity of the circumpolar vortex of the upper westerlies, which determine the weather in our areas. Subsequently, Lamb uses the process, with which the synoptic charts of the upper air are converted into weather charts near the surface, in order to reconstruct the weather system at sea level. The result of this method for the period around 4000 B.C. is shown on maps in an article from 1966 (Lamb et al. 1966).

Characteristic for the circulation type in the period under consideration is its zonal character. Besides, the circumpolar vortex of the upper winds is concentrated around the pole. The depressions followed, at least in summertime, a course which lies more to the north than the present course. The climate in Western and Central Europe was therefore more influenced by the subtropic anti-cyclones. The result was that summers were warmer with more sunshine. Because of the marked zonal circulation, polar airstreams did not penetrate into Western and Central Europe. This circumstance and the fact that this weather type was combined with mainly moderate south-western winds and with high sea-temperatures, caused relatively warm winters. Another consequence is a higher relative humidity of the air and more precipitation. Especially in wintertime, the influence of the humid winds was also exerted in Central and Eastern Europe. The climate can be described as oceanic and summer-anticyclonic.

The model developed above for the climate during the Atlantic is based on scanty data. It provides, however, an adequate explanation for what has become known about the Atlantic. For this reason, we can use it for the reconstruction of the climate in Southern Limburg and around Hienheim.

On the basis of temperature values obtained elsewhere in Europe, we assume for both areas that summers were probably 2° C warmer. This means that the July-temperature at Sittard, Stein and Elsloo averaged 20° C. At Hienheim it was also 20° C. The "correction" for the winter-temperature is more difficult to make. Perhaps 1° C must be added to the temperature of the coldest month, so that the average temperature was 3° C for Southern Limburg and —1° C for Hienheim. The season to be considered as winter probably lasted less long and at Hienheim the period of frost was perhaps considerably shorter. Of course, the average annual temperature was higher than at present. For Southern Limburg we estimate it at 12° C and for Hienheim at 10° C. The summers were more or less anticyclonic and could therefore have been sunnier. Under these circumstances the weather was tranquil. It is difficult to say something about the wind-force in winter. There was more precipitation than nowadays and perhaps it was spread differently over the year. As the summers are considered to have been reasonably dry, much of the precipitation must have fallen in wintertime. This flattens the curve of the precipitation in the climate diagrams. Lamb has demonstrated that it is sometimes possible, though with many reservations to calculate the amount of precipitation from the estimated temperature (Lamb 1965, Lamb et al. 1966). For this purpose, one requires regression equations of rainfall versus temperature, based on statistically significant correlation coefficients between both quantities (Lamb et al. 1966 p. 188). Lamb calculated for England that circa 4000 B.C. the precipitation amounted to 110 to 115% of the present value.

For the calculation of the regression equation he used records from the year 1740 on. As we have at our disposal a long series of observations in the Netherlands too, we carried out Lamb's calculation with Dutch figures. We used the monthly means of the air-temperature in ° C at Zwanenburg-Utrecht-De Bilt, converted to De Bilt, and the monthly means of the amounts of precipitation at Zwanenburg, converted to Hoofddorp, as gathered by Labrijn, complemented with the records up to 1974 (Labrijn 1945 and 1948). These series of records start in 1735. We calculated the correlation coefficients between the precipitation expressed in % of the 1921–1950 means and the temperature in ° C for the pairs: annual precipitation-annual temperature, precipitation in June/July/August-temperature in June/July/August, precipitation in December/January/February-temperature in December/January/February, precipitation in September to May-temperature December/January/February and precipitation in September to June-temperature December/January/February. Unfortunately, none of the calculated correlations was higher than | 0.4| . So no clear relation could be found for the Netherlands between precipitation and temperature. Such calculations have not yet been carried out for Germany.

Independently from Lamb, the average annual precipitation in the Atlantic has also been estimated by

Mania (Mania 1973a). According to Mania, the Atlantic was 8–22% wetter than now. This percentage relates to the Middle Elbe and Saale-area. It is of the same order of magnitude as Lamb's estimate. This may be coincidence: many more independent observations are necessary. If, however, we want to say something about the precipitation in the Atlantic, we must, for lack of better, work with an estimated precipitation of circa 110% of the present precipitation. When we increase the present annual precipitation of Sittard by 10%, we arrive at circa 770 mm. For Hienheim this figure becomes approximately 730 mm. It is obvious that these precipitation values must be handled with the greatest possible care.

The differences between the present climate and that at the time of the LBK settlements are obvious. The wet winters and the warm, long summers, with perhaps much sunshine, gave the climate a slightly mediterranean character. This is in accordance with what Fuhrmann concluded in Sachsen (Fuhrmann 1973). At that time too, however, the climate at Hienheim was different from that in Southern Limburg. Especially the winters were colder and in general the climate had a more continental character.

The reconstruction provides, of course, only a global impression of the climate. The climate at a certain place within the area studied, such as at the location of a settlement, is strongly influenced by local factors. The degree of exposure is of great importance and also the influence of the vegetation and the substrate should not be underestimated. For instance the presence of fringes of trees around a settlement can modify the micro-climate within that settlement considerably. The soil exerts an influence by its warmth conductivity, which co-determines the risk of night frost and the like. We must therefore consider the possibility that local variants, which cannot be reconstructed by means of the data used by us, existed in the climate.

III.3 THE SUBSTRATE

By "substrate" we understand a number of abiotic environmental factors which are interrelated, namely geology, hydrology, relief and soil. These factors will be discussed in the following, first for the area in Southern Limburg and then for the one around Hienheim.

SOUTHERN LIMBURG

The deeper geological subsoil of the area around Sittard, Stein and Elsloo consists of deposits belonging to the Tertiary. they are shown in the "Geologische Overzichtskaart (kwartair afgedekt) 1:100000". (Kuyl 1971). North of Sittard there are sands and gravels from the Pliocene. Sediments from the Oligocene and the Miocene can be found more to the south. The Oligocene comprises glauconitic sands and some clay-layers. The deposits from the Miocene consist of fine sands, in which seams of lignite may occur. The southern limit of the formations from the Tertiary is formed by the limestone deposits of the Upper Cretaceous. This limit extends itself along the small stream, the Geul. The limestone formation lies just outside the 10 km zone around the LBK settlements.

During the Pleistocene, the older deposits were covered for the greater part by deposits from the river Maas. Because the area belongs to the periphery of the Ardennes, it was subject to uplift in this geological period. As a result a terrace landscape originated. Three main terraces can be distinguished, namely the Higher Terrace, the Middle Terrace and the Lower Terrace.* Several steps can be distinguished in these

* Nowadays these names are only of local use. For the correllation with the lithostratigraphy the reader is referred to the explanation of the "Geologische overzichtskaarten van Nederland 1:600000" (Zagwijn & van Staalduinen 1975).

terraces. The Higher and the Middle Terrace consist mainly of sand and gravel. The material originates for the greater part from the Ardennes. The Lower Terrace consists of finer sediments, namely sand, silt and clay. The terraces of the river Maas broadly determine the present relief (de Jong 1967 pp. 319 and 320).

During the Saale- and Weichsel-glaciations, the relief was planed down by the deposit of loess and eolian sand on the Higher and Middle Terrace. The loess deposits are limited to the area east of the river Maas. The thickness of the loess mantle varies. The largest deposits are on the Middle Terrace, where the thickness may amount to 8–15 m. The loess deposit is much thinner on the Higher Terrace. North of the Roode Beek there is very little loess. It is sandy and contains much terrace gravel. West of the river Maas the terraces are covered with a very thin layer of eolian sand. For a more detailed description of the Quaternary deposits we refer to a publication of De Jong (de Jong 1967).

Nowadays the Lower Terrace is covered partly with Holocene alluvial silts and clays. These are also present in the Holocene valleys. The thick layers of loam and clay in the Western and Central European river-valleys originated, in as far as we know, in the Middle Ages and later (Huckriede 1972). They are the result of important anthropogene influences. The age of the loams and clays in the river-valleys will often have to be taken into account for the reconstruction of a landscape. Paulissen's investigation of the Maas-valley shows, however, that the Maas deposited loams and clays during the entire Holocene. It is true that the intensity of the alluviation varied with time. The alluviation was minimal during the Atlantic. The sedimentation increased continuously after this period. More and more coarse silt was deposited, which Paulissen attributed to the increasing deforestation of the loess areas upstream (Paulissen 1973 p. 246). The nature of the filling of the Maas-valley, however, has not changed essentially since the Atlantic. The bed material of the river itself consists of a coarse gravel. The diameter of the blocks is 80 cm at the most (Paulissen 1973 p. 87). At low discharges parts of the gravels fall dry. These gravels were certainly present during the Atlantic.

There are no other reasons either to assume that what can be seen on the recent geological map is different from the situation during the Atlantic. Figure 2 shows those sediments which are visible at the surface nowadays. In our opinion, this map gives a correct representation of the geological aspect of the substrate in the period of LBK occupation. The legend unit "Tertiary and older" comprises mainly Tertiary sands in the eastern part of the map and represents a complex of slope deposit and chalk along the small stream Geul. The legend unit "Remaining Pleistocene" mainly concerns terrace gravels of the Higher Terrace.*

The same figure shows the d r a i n a g e p a t t e r n. The most important river is the Maas. The entire region is drained by this river. It has a very irregular discharge; low water-levels may occur especially in summer. The Maas has a number of tributaries within the area under consideration. At the west side these are from south to north the Heeswater, the Zijpbeek and the Bosbeek. At the east side, the Maas receives water from the Geul, the Ur and the Geleen with the Roode Beek. The upper courses of the Geleen and the Roode Beek divide themselves into a great number of smaller streams and so-called dry valleys. The latter do not have a permanent water course cut carry water only after heavy rainfall or during the melting of a layer of snow. Because of the great number of valleys and dry valleys, this landscape is strongly dissected. This can

* For the sake of completeness, it is to be observed that in the north-eastern area these terrace gravels were not deposited by the Maas, but by the Rhein.

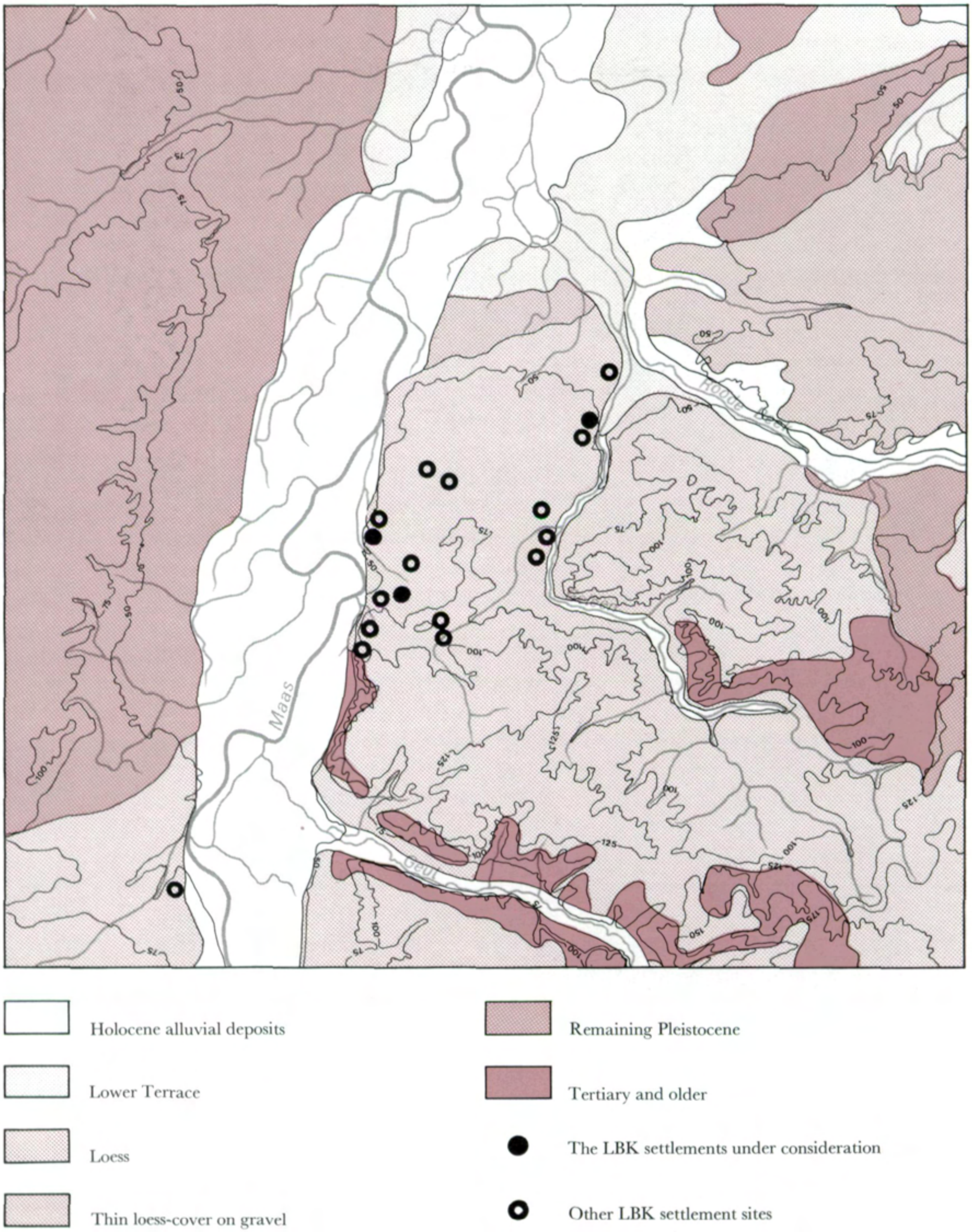


Fig. 2. The substrate within a radius of 10 kms around the LBK settlements in Southern Limburg. Scale 1:200 000.

be seen in figure 2 by means of the course of the contour lines. The dissected landscape coincides with the loess-covered Higher Terrace. It seems that the drainage pattern was not subject to changes during the Holocene. The water courses were already in their present valleys at the time of LBK occupation. The meander system of the Maas was already active during the Atlantic (Paulissen 1973 p. 123). The position of the meanders has changed of course. According to Paulissen, the Maas has moved noticeably to the east (Paulissen 1966 p. 127). This means that Elsloo and Stein are situated much closer to this water course at the present time than during the LBK occupation. It is impossible to reconstruct the exact course of the Atlantic river.

In the area under consideration, the surface water is restricted mainly to flowing water. But west of the Maas there are a few small lakes. Some of them now have a depth of 1.5 m (Willems 1975 verbal information). The subsoil consists there of a little permeable layer of loamy sand, which has become entirely impermeable by the formation of a strongly cemented iron-B-horizon on which rain-water stagnates (Lamberts 1958). The question is whether such cemented horizons and thus the lakes existed already during the Atlantic. An indication that at least some of the lakes existed during the Subboreal may be seen in the fact that a concentration of Neolithic artefacts has been found around the water (Willems 1967).

The dry valleys require a closer consideration. They are a rather general phenomenon in the Central and Western European loess areas. Although some valleys may have originated comparatively recently, e.g. in the Subatlantic (Fuhrmann 1973), it is generally assumed and also demonstrated that they date from before the Holocene (Stevens 1934, Schalich 1973). Therefore the dry valleys of Southern Limburg already existed in the period of LBK occupation. It is imaginable that these valleys were not dry valleys at that time, but carried water all around the year. An argument in favour of this view could be that the climate was probably wetter during the Atlantic (see III. 2). In this connection we should like to make the following remarks. According to our climate reconstruction, there would have been more precipitation. Since temperatures were rather high, this precipitation occurred mostly in the form of rain. A part thereof disappears by evaporation (evaporation from the earth's surface) and by transpiration (evaporation by means of plants). Another part joins the ground water (infiltration) and is drained underground. The rest runs off over the surface. Evaporation and transpiration (together called evapotranspiration) are not only dependent on the available moisture (rainfall) but also on the temperature, the wind speed and the relative humidity. As the temperature was higher during the Atlantic than in our days, the evaporation was possibly also more important than at present. Turc has developed a formula, with which the evapotranspiration can be calculated approximately from the annual rainfall and the annual temperature (Turc 1954). When the evaporation is known, it can be deducted from the precipitation, so that the quantity of water can be found which represents the annual runoff. The application of Turc's formula on recent data and data of the reconstructed climate shows that the annual runoff was about the same in both periods. It is therefore improbable that the valleys regularly had to carry more water all the year around because of the increased rainfall. Moreover, the possible difference between the Atlantic and the present rainfall must be attributed mainly to an increased precipitation in winter. The calculation provides no information about greater water discharges in winter, but it is obvious that in summertime the valleys must have been just as dry as nowadays.

On the other hand the question arises whether the calculation of the evapotranspiration by means of Turc's formula does not need a correction in our case in connection with the changes in vegetation. Nowadays the loess is almost entirely deforested, whereas during the Atlantic it was covered with dense deciduous forest (see III. 4). Deforestation has a pronounced effect on the hydrological cycle. This effect has been studied in the Hubbard Brook Experimental Forest, New Hampshire, USA. After a series of very accurate observations concerning the hydrological cycle of an area covered with deciduous forest, all vegetation was removed from a part of this area. The deforestation took place in the winter of 1965–1966. The effect is described as follows: "Deforestation had a pronounced effect on runoff. Beginning May 1966, runoff from the cut watershed began to increase over the levels that would have been expected if there had been no cutting. The cumulative runoff for 1966 exceeded the expected amount by 40 percent. The largest difference was recorded during the four months from June through September, when the runoff was 418 percent higher than the expected amount. This difference is directly attributable to changes in the hydrological cycle resulting from the removal of the transpiring surface. Accelerated runoff has continued through the succeeding summers." (Borman & Likens 1970). Although the loess is used as agricultural land and is therefore not completely bare throughout the year, as was the experimental area in New Hampshire, the transpiration has probably decreased considerably in comparison with the Atlantic. Especially in the months of summer probably less rather than more water would remain for runoff.

The application of Turc's formula and the remarks concerning a possible correction of the calculated evaporation as a result of the deforestation lead to the conclusion, that it is improbable that the dry valleys carried water around the year during the Atlantic. One more remark should be made, namely that so far we have not taken into account the fact that the valleys were deeper in former days (see page 20). Their valley floor could have been at the level of the water table. We assume, for the following reason, that during the Atlantic the water table was at the present level. Since the loess and the terrace gravels underneath are permeable, a minor increase of the rainfall, especially when spread equally over time, will have led to an increased infiltration, though this does not necessarily involve a considerable rise of the water table. We assume that an increase of the rainfall by 10% in this area with permeable rocks has little influence on the level of the water table. The surplus of infiltrated water contributes to an increased runoff, be it not directly. The water table is very deep nowadays, much deeper than the base of the eroded loess.deposits, the so-called colluvium, which fills the dry valleys (Stiboka 1974 verbal information). In our opinion it is therefore not likely that the valley floor of the dry valleys reached the water table in the Atlantic.

If the above assumptions are correct, they lead to the conclusion that during the Atlantic the dry valleys discharged less, rather than more water than today during the growing period, that is late spring, summer and early autumn. In wintertime the situation might have been the same as it is now. This would also apply to the discharge of the rivers and small streams, which carry water continuously.

For the water table we assume, in view of the geological subsoil, that it has not changed much since the Atlantic. This means that a high water table occurred only on terrains within the Lower Terrace and the valles of the rivers and small streams. In the remaining area the level was at least 1 meter under the surface. For detailed data we refer to the soil map 1:25000, sheet 59, 60 west and 60 east (Stiboka 1970).

In addition to the geological subsoil and the drainage pattern, figure 2 also shows the relief. As stated above, the relief is determined broadly by the terraces of the Maas. The terrace edges are clearly visible in the field as steep slopes. The northern limit of the Middle Terrace east of the present course of the river is an exception. At this place the Middle Terrace merges barely perceptibly into the Lower Terrace. Outside the terrace edges the accidented terrain is limited to the south-eastern and southern part of the map shown in figure 2. This relief is mainly the result of the numerous small stream-valleys and dry valleys.

Otherwise this area is rather even. The height of the relief has been planed down considerably since the Atlantic by erosion and accumulation. Particularly in the loess area, this process has had great influence. Loess is extremely susceptible to erosion. The valleys are filled up with deposits of eroded loess, sometimes with a thickness of several meters: the so-called colluvium. Also lower places, which do not belong to a valley-system, are often partly filled up with colluvial material. The process of erosion and colluviation must have started as the result of the first agricultural activities and therefore during the Neolithic. This has been established by Schalich on a loess-plateau the "Aldenhovener Platte", which is located 30 km east of the area under consideration (Schalich 1973). But the process only became important in the Roman era; it is continuous to the present day (Scheys 1955, van den Broek 1958/1959, Schalich 1973). Therefore the thick colluvia in the valleys date from after the period under consideration. This means that the small valleys and the dry valleys could have been up to a few meters deeper at the time of LBK occupation. The surface of the plateaus was of course higher in that time. The difference with the present must have been considerable, especially in the dissected landscape.

Soil formation has taken place in the different sediments in the course of time. On the loess, Parabraunerden (Orthic Luvisols) were developed. The complete profile has been maintained in flat terrains only. On slopes, the A-horizon and a part of the B-horizon have disappeared because of erosion. The argillic horizon lies at the surface here. In the valleys only a weakly developed Braunerde (Eutric Regosol) originated on the colluvium. The area with a thin cover of sandy loess on gravel also shows a Parabraunerde or a Braunerde. But where the loess is very sandy, the soil is slightly podzolized. The sands west of the Maas are characterized on our sheet of the map by a Podsol-Braunerde, Braunérde-Podsol (Leptic Podzols) or even a Humuseisen-Podzol or Humuspodsol (Humic Podzols) (Tavernier & Maréchal 1958, Lamberts 1958, Lamberts & Baeyens 1963, Munaut 1967). There are places where the podzol is very pronounced, and places where it has hardly developed. In the areas with fluviatile sands and gravels of the Higher Terrace, there are weakly developed Podsol-Braunerden (Dystric Cambisols). The Tertiary sands show Humuspodsole with very thick Albic horizons (bleached material). The Lower Terrace comprises a mosaic of different soils, since several different steps can be distinguished within the terrace. The water table differs from place to place. On the terrains with the highest water level local peat formation even occurred, which led to Anmoorgleye (Humic Gleysols). A variety of hydromorphic soils prevails in the low parts. In the dryer parts the deposits with a fine texture formed Parabraunerden; the more sandy sediments formed weakly developed Podsol-Braunerden. The Holocene deposits in the river valleys show no or almost no profile development, Auenböden or Fluvisols. Depending on the regularity with which they were inundated, they are either calcareous or poor in lime. For details we refer to the Soil Map of the Netherlands 1:50 000, sheet 59, 60 west and 60 east (Stiboka 1970).*

The present soils have developed under the influence of many factors. The main ones are climate, hydrology, flora and fauna, man and certainly also the time during which these five factors could exert their influence. A recent soil map can therefore not be used without reservation to represent the situation in any particular prehistoric period.

* Ing. H. de Bakker at Wageningen advised us with respect to the nomenclature to be used." In soil science there is still no uniform international terminology, nearly every country has its own system of soil classification. In the last few years the FAO has developed a system for the Soil Map of the World 1:5 000 000 (FAO 1974) which in its turn is leaning heavily on the widely discussed U.S. system (S.S.S. 1973). For this publication we advise the use of the German system (Mückenhausen et al. 1962)" (de Bakker 1976 written information).

For the situation at the time of LBK occupation, we may assume that the Holocene deposits in the river valleys showed as little profile development as nowadays. The history of the soil development in the Late Pleistocene deposits, however, is difficult to reconstruct. On the loess, the soil formation begins directly after its deposition. By accumulation of organic matter, produced by the vegetation an A-horizon was formed. Water with dissolved CO_2 and organic acids, produced by the vegetation and by decay of organic matter, causes a decalcification of the upper part of the soil. After decalcification weathering of other minerals starts, during which clay minerals and free iron oxide are formed. Eluviation of clay, which is possible after decalcification, causes a decrease in clay content in the surface horizon. The clay illuviates in a lower level and forms the so-called argillic horizon or Bt. The question is how far this process of clay illuvation had advanced at the time of LBK occupation. Van den Broek concludes from his observations at Sittard, that the clay illuvation layer continued through the filling of the pits from the LBK period, instead of being interrupted thereby (van den Broek 1958/1959). Scheys writes about the Neolithic in a nearby loess area in Belgium: "Soils on eolian loess were practically as eluviated as . . . they are nowadays." (Scheys 1962 p. 64). He made this observation in a loess section covered by colluvium at Rosmeer. On and in the upper horizon of this section there were LBK artefacts. This does not necessarily mean that the colluviation occurred during or just after the LBK occupation; the argillic horizon may also date from some time after the LBK. However, in the same section Scheys observed that the pits of the LBK were dug through the A2-horizon into the clay illuviation layer. Therefore the clay illuviation at this spot dates from before the LBK, at least for an important part (Scheys 1962). In the loess area which is adjacent to ours in the east, Schalich also found that the development of the Bt took place before the LBK occupation (Schalich 1973 p. 14). Van den Broek's observation could not be confirmed here, neither in the field nor by means of thin sections (Geenen 1975 verbal information). With Scheys and Schalich we assume that the clay illuviation zone in Southern Limburg was already present, at least to a certain extent, in the period under consideration. It is not inconceivable that the clay illuviation continued after this period.

The history of the podzol-development in the eolian sands has become known to some extent by the examination of buried profiles, which have been dated archeologically or palynologically (Scheys 1963, Munaut 1967). In general it is assumed that the Humus- und Humuseisenpodsole developed only after the Atlantic (Munaut 1967 p. 154 and the literature quoted there). The podzol-development must have been weak, as under the oldest known barrows only a very weak podzol profile can be seen in most cases. These barrows date from the Late-Neolithic, which means that the profiles are 2000 years later than the profiles which we intend to reconstruct. For the interpretation of the profiles under barrows we refer to an article by Modderman and to the literature quoted there (Modderman 1975). It appears from the above that the eolian sands carried a very weakly developed Podsol-Braunerde at the most during the LBK.

Practically nothing is known about the soil development in the other Late Pleistocene sediments. We assume that developments as in the loess and in the eolian sand took place. The only indication concerning the higher, sandy part of the Lower Terrace is perhaps present as a buried soil under a barrow at Swalmen, a place not far north of our region. Under the Late-Neolithic barrow Bosheide 1 a Podsol-Braunerde was found (Lanting & van der Waals 1974). But this profile, just as the buried profiles on the eolian sand, dates from 2000 years after the period under consideration.

No data are available on the soil profiles of the older deposits. We presume that the Tertiary sands were strongly podzolized.

With geology, hydrology, relief and soil profiles, the main aspects of the substrate have been discussed. In this discussion certain types of landscape have been mentioned. Finally we give a summary of the classification which we use for the substrate in the Atlantic. We distinguish:

1) A dissected loess landscape. The landscape is characterized by many deep valleys, particularly dry valleys, and a few flat parts. On the small plateaus between the valleys the water table is deeper than 120 cm. In the loess a soil with an argillic horizon has developed.

2) A loess plateau. This rather flat terrain with a very thick loess deposit has its southern border near the terrace edge towards the Higher Terrace; in figure 2 this terrace edge lies in the area between the 75 m and 100 m contour line. In the west it is limited by the valley of the Maas, in the east by the Geleen, running parallel to the terrace edge of the Higher Terrace. The northern border is formed by a strip of thin loess on gravel. The water table is deeper than 120 cm. A soil with an argillic horizon has developed already in the loess.

3) An area with thin eolian loess on terrace gravel. A virtually undissected landscape, with the water table deeper than 120 cm. The soil probably already has the characteristics of the type of soil with an argillic horizon, although a slightly podzolized soil is not excluded.

4) An eolian sand area, hardly dissected, with in general a water table which is more than 2 m deep in summer. A few small lakes were probably present. The soil profile is at the most a Podsol-Braunerde.

5) A river-valley landscape, comprising both the Lower Terrace and the present valley of the Maas. The landscape is strongly dissected by small streams. The water table varies from place to place. Wet parts are not rare. At many places a soil profile has hardly developed. Perhaps the higher parts already show a slightly podzolized soil or a soil with an argillic horizon.

6) A landscape of sands and gravels which belong to the Higher Terrace. This landscape is hardly present in our area. We have not studied it in detail.

7) A landscape of Tertiary sands. Probably this landscape does not play an important part either. It is strongly dissected and has for the greater part its water table at a great depth. The soil profile is not known. A strongly developed podzol is not excluded.

HIENHEIM

The geology of the area around Hienheim is described in the explanatory books that accompany two sheets of the Geological Map of Bayern 1:25000, namely numbers 7136 Neustadt a.d. Donau and 7037 Kelheim (Schmidt-Kaler 1968 and Rutte 1962). We take the following description from this work: the subsoil of the area consists of marine limestone deposits from the Jurassic. Two facies can be distinguished within these limestones: reef limestones and fine-grained, stratified sediments. The latter are also described as Plattenkalke and Schieferkalke. The stratified sediments were developed in depressions between the reefs. The deposits from the Jurassic were planed down by erosion in the Lower Cretaceous. The area must have been above sea-level at that time. In the Upper Cretaceous it was covered with fluviatile deposits: the Schutzfelsschichten. Afterwards the sea penetrated again and a series of glauconitic sands, clays and limestones developed. At the end of the Upper Cretaceous the sea withdrew and a period of strong erosion began, which lasted until the Miocene. The deposits from the Cretaceous were removed almost everywhere, although locally remnants consisting mainly of residual loams remained. The area between the present course of the Donau and the Alps sunk considerably during the Tertiary. A large fresh water sedimentation basin developed: the Molasse-basin. This basin was filled slowly with erosion material from the Alps. Large quantities of gravels, sands and clays were deposited, which at present are to be found mainly south of the Donau. North of this river the Molasse-deposits have disappeared almost entirely by erosion.

The present drainage system originated in the Pleistocene. The Donau has been flowing in its present valley since the Riss-glaciation. As a result of tectonic movements and strong climate oscillations, terraces were formed by the tributaries of the Donau, the Abens and the Ilm, and later also by the Donau itself. Several terrace steps can be distinguished, of which only the latest, the so-called Lower Terrace, is still of some size to-day. The terrace material consists of gravels with varying quantities of sand.

Part of the area was covered with loess and eolian sand during the Riss- and Würm-glaciations. The deposits of loess were practically limited to the left bank of the Donau. Near the river the thickness of the deposits does not exceed 4 m and becomes less further away. The loess areas cover only a small area on the right bank where mainly eolian sand was deposited.

The valley of the Donau was filled up with fine-sandy sediments in the Holocene. In old stream channels more clayey sediments were deposited. Peat development could occur locally in abandoned meanders. The age of the Holocene river deposits has not yet been investigated systematically. Undoubtedly, much material originated in historic periods (see p. 16). In the valley of the Feckinger Bach we were able to establish by means of pollen analysis that an alluvial deposit with a thickness of circa 2 m originated in the Subatlantic (Bakels, own observations). As the deposits of the Donau have a more sandy development at the base, whereas the silt content increases upwards (van de Wetering 1974), we assume that the sediment, which was at the surface at the time of LBK occupation, was more sandy than the present one. For the rest we presume that the geology of the area has not changed significantly since the Atlantic.

The present situation is shown in figure 3. In order to make the map legible, the deposits from the Jurassic, the Cretaceous and the Miocene have been brought together into one legend unit: Tertiary and older. North of the Donau this legend unit mainly represents Jurassic limestones and the products of limestone weathering. An exception is an area east of the Altmühl, where there is still much material from the Cretaceous and the Miocene. In this area some loess occurs locally. It can be recognized in figure 3 by the presence of these small loess areas. South of the Donau, the legend unit "Tertiary and older" refers to deposits from the Miocene in the area between the Donau and the Abens. The Miocene is also situated south and south-east of the eolian sand. Further the legend unit represents limestone from the Jurassic. The legend unit "Remaining Pleistocene" relates almost entirely to the eolian sands.

The map shown in figure 3 is based partly on already published sheets of the Geological Map of Bayern 1:25 000, namely the sheets no. 7136 Neustadt a.d. Donau and no. 7037 Kelheim (Schmidt-Kaler 1968 and Rutte 1962). Dr. H. Schmidt-Kaler of the Bayerisches Geologisches Landesamt was so kind as to complete the missing parts.

The whole area is drained by the Donau. This river is fed for a substantial part by the tributaries which originate from the Alps. A sudden increase in water supply may lead to flooding. The considerable narrowing of the valley where the river breaks through the Jurassic reef limestones has the effect of damming up the river. As a result the valley upstream is completely inundated in times of large water discharges. The Donau has only a few tributaries on the map sheet under consideration. At the right or southern side these are the Ilm, the Abens and the insignificant Feckinger Bach. On the left bank the Kels-Bach and the Altmühl discharge into the Donau. The mouths of the Ilm and the Abens were displaced downstream in the years 1950 in order to reduce the watersurplus in the funnel-shaped part of the Donau. The river was diked in the same period.

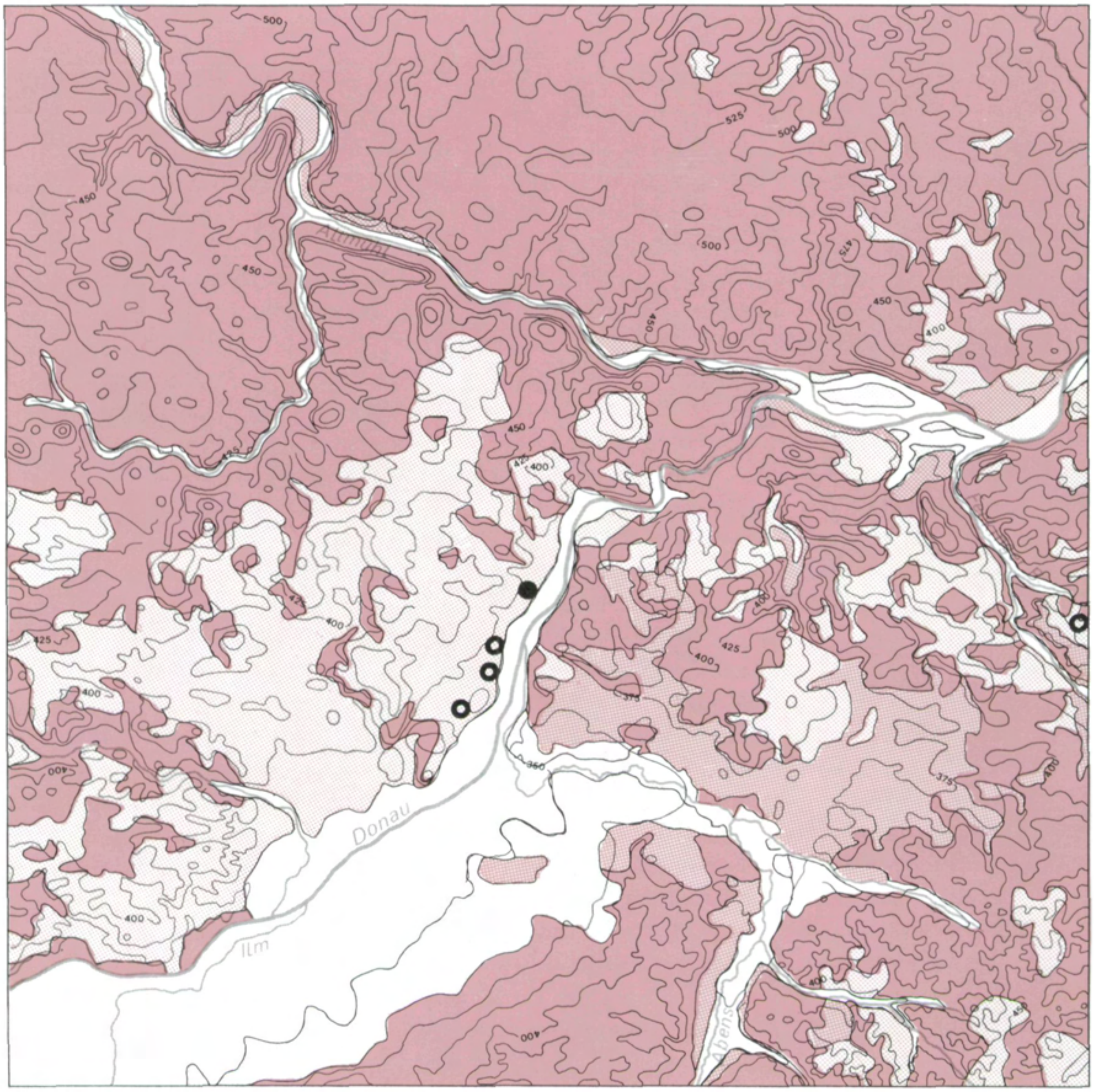


Fig. 3. The substrate within a radius of 10 kms around Hienheim. Scale 1:200 000. For the legend see fig. 2.

Besides stream-valleys there are also dry valleys. These are found mainly in the loess area on the left bank of the Donau. As in Southern Limburg they carry water only during heavy rainfall or in times of melting snow. They are filled partly with colluvial material.

In addition to rivers, there are springs which are not connected to the surface drainage pattern. These springs are partly the result of the issue of karst-water from the Jurassic limestone. The sulphureous springs of Bad Gögging, 4 km south of Hienheim, are of this type. In general, however, the karst-water contains no hydrogen sulphide and provides excellent drinking-water. A second type of spring owes its existence to the presence of impermeable layers of clay in the subsoil. These clays belong to the formations of the Cretaceous or the Miocene. The springs from the Miocene supply the largest quantity of water. In addition to springs there are also wet places and pools, which originated because rainwater could not penetrate through clays just under the surface. These pools are of small size.

Most of the surface water is found in the area with Miocene deposits in the southern part of the map sheet. The limestone area is very poor in water resources.

There are no reasons to assume that the pattern of the drainage was essentially different at the time of LBK occupation. The remarks on p. 18, which relate to Southern Limburg, also apply to the deforested loess in the surroundings of Hienheim. This means that the dry valleys carried water only incidentally, just as at present.

There remains the question to what extent the vast fenlands in the valley of the Donau and its tributaries have influenced the water discharge of the Donau. These peats are now for the greater part artificially drained, but undoubtedly they had a great capacity for water storage before the drainage. As far as can be established, the vast fenlands already existed during the Atlantic. We may assume that much water evaporated at the surface of these fenlands, especially in summer. The summer discharge of the Donau may therefore have been less important than it is nowadays. Besides it is possible that because of the influence of the fenlands, the discharge of the river was more regular. The inundations, which now characterize the Donau-valley, may have occurred far less frequently.

We have also tried to show the relief in figure 3. It appears from the contour lines that there was almost no flat land. The few river-valleys in the limestone area have entrenched themselves very deeply. The limestone area itself is often described as a plateau, but it is, however, one with a rolling surface. This applies also to the area with formations from the Cretaceous, the Miocene and the Jurassic, to the loess and to the eolian sand. The area of the Molasse is usually referred to as the "Tertiary Hilly Country". But the slopes of the hills in the area under consideration are very gentle, so that here too rolling landscape is a better term. Only the Lower Terrace and the wide Holocene valley of the Donau can be described as even ground. Both are separated from each other by a very clear terrace edge, which is visible as a step in the landscape. The difference in height can be several meters.

It is not known to what extent erosion and accumulation have modified the relief of Jurassic limestone, Cretaceous, Miocene and eolian sand since the Atlantic period. Slightly more is known about loess, the sediment most sensitive to erosion. The erosion and the colluviation resulting therefrom must have started before or during the LBK occupation. In Hienheim a pit of this culture was found, which was dug through a thin layer of colluvium. The erosion gradually led to "considerable changes in the geomorphology of the landscape in loess areas like the surroundings of Hienheim" (van de Wetering 1975a). Much of the eroded loess was carried into the valleys; we may therefore assume that the largest among them were several meters deeper. The relief of the loess-layer between the dry valleys has been planed down by erosion and colluviation. Van de Wetering has reconstructed the original surface of the level ground, a loess-covered remnant of one of the river terraces, on which the settlement Hienheim was located. In his reconstruction, he starts from the assumption that the intact loess profile is decalcified everywhere to the same depth and that the level where the calcareous loess begins can be used as a fixed point. He makes the reconstruction with the reservation that this is indeed the case and in fact no indications to the contrary have been found.

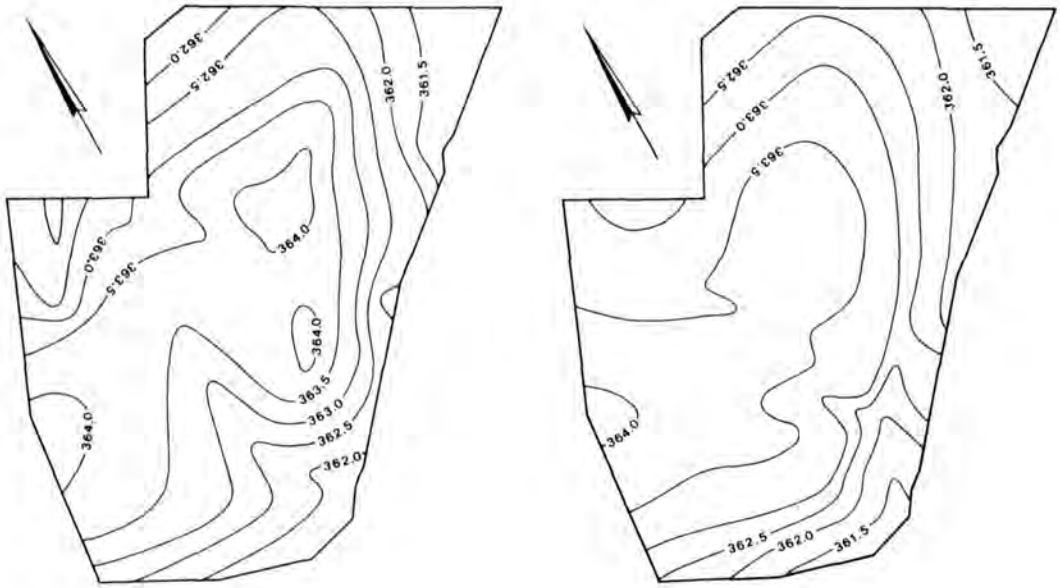


Fig. 4. Contour map of the settlement area "Am Weinberg" near Hienheim. Scale 1:5000. Left: reconstruction of the original relief. Right: recent situation.

Van de Wetering determined the extent of decapitation of the soil profile and the thickness of the covering colluvial layer. He added the missing part to the decapitated profiles and he subtracted the colluvium from the covered profiles. Figure 4 shows the reconstructed contour lines next to the recent ones. The reconstruction of the original relief probably corresponds to the situation at the time of the LBK settlement, since the colluviation must have been very slight in this period.

On the relatively level settlement ground, the remainder of a river terrace, the differences between present and past are not very great, it is true, but are yet clearly present. As mentioned above, level ground is rare in the area around Hienheim. If the original relief of the entire loess landscape were mapped, it might appear that the area had an even more rolling character than nowadays.

The different rocks have each developed their own type of soil. On places with Jurassic limestones, where a calcareous sediment comes to the surface, different types of Rendzinas prevail. This is the case at places where a sand-like weathering product of the Jurassic dolomite limestones (the so-called dolomite sand) occurs and at places where the residual loam on the limestone is very thin. Rendzinas are rare in the area under consideration and are found mainly on slopes. An ABC-profile has developed in the thicker residual loams. In these loams a great variety of soil types can be observed, as the complicated geological history of limestone area has led to a very complicated soil genesis. Erosion remnants of younger sediments often remained behind on the limestone, and were mixed with the loamy weathering products of the limestone. An argillic horizon is often present in these soils. Pseudogley-phenomena (surface-water gley) are not rare.

As for the deposits from the Cretaceous, the Miocene and the Pleistocene, the profile development strongly depends on the silt- and clay-content. Where the parent material consisted of calcareous deposits, it has been decalcified to some depth. Loamy sands and loams therefore led to the development of soils with an argillic horizon. These soils are found in deposits from the Cretaceous and the Miocene, as well as in the loess. The sandy facies from the Cretaceous and the Miocene, the eolian sand and the terrace deposits high above the water table show Podsol-Braunerden and Braunerde-Podsole. Humuspodsole and Humuseisenpodsole are not present. A very weakly developed podzol is sometimes present on the sands from the Cretaceous and in the eolian sand.

In a large part of the Lower Terrace the water table is so close to the surface that a Gley is the result. Where peat development occurred on these wet grounds, Anmoor and Anmoorgleye (Humic Gley-sols) developed.

The Holocene river deposits hardly show any soil development; some humus has formed in the relatively dry parts. The deposits of the Donau are richer in lime than those of the Abens.

Data relating to the above soils can be found in the pedological contributions to the explanatory book which accompanies the geological map sheets 1:25000 no. 7136 Neustadt a.d. Donau and no. 7037 Kelheim (Diez 1968, Kohl 1962) and in the explanatory book to the pedological map of Bayern 1:500000 (Vogel 1961).

In the surroundings of Hienheim the sediments from the Jurassic, the Cretaceous and the Miocene have been at the surface for a long time. It is not known to what extent the soils in these sediments have changed since the Atlantic. For lack of information we assume that a profile had developed in any case. In these deposits, where the anthropogene influence has perhaps never been very great, as the land on them is not used intensively nowadays, this profile was perhaps not much different from the present one. We also assume that the Lower Terrace and the Holocene river deposits showed profiles similar to the present ones. The history of the soil profile in the eolian sand, a relatively young formation, is unknown. The development of a podzol in these sands is closely related to the presence of pine-trees (Hohenester 1960). As these trees do not seem to have been part of the forest on the eolian sand during the Atlantic (see p. 41) we assume that there were no podzols yet.

In the case of the loess we do have some information. Van de Wetering observed the following at Hienheim: "There has been at least some illuviation of clay in natural soil profiles before the Bandceramic culture. Red burnt papules of oriented clay are found in pieces of red burnt loam in bandceramic pits." According to him it was not impossible that the loess showed the following soil profile: "The profile was decalcified to a certain depth, possibly the present depth, and had a B-horizon with at least some clay illuviation." (van de Wetering 1975a). Since there was already a soil type in this rather young sediment which resembled the present one, it is our opinion that the recent soil-map can be used globally as soil-map of the area around the Hienheim settlement.

It appears from the above that we may distinguish the following types of landscape:
1) An area with loess. It is limited broadly to the left bank of the Donau. The thickest deposits are along the Donau-valley. The thickness of the deposit decreases rapidly to the north. The area is divided by dry valleys and outcrops of reef limestone into small landscape units which themselves have a rolling surface. The water table is deep. At some places where only a thin cover of loess is present, impermeable, mostly Miocene, layers of clay are just under the surface. For this reason there are a few wet places in the loess. Springs of karst-water can also be found. A soil with an argillic horizon had developed already around 4000 B.C.

2) A limestone area, partly covered with weathering loams. The ground is hilly and poor in water resources. The surface water is limited to some rivers, karst-springs and places where rain-water stagnates on impermeable sediments or residual loams. The soil development shows much variation. The area with the limestones is situated mainly in the north-western part of the map sheet shown in figure 3.
3) An area with eolian sand. It is situated exclusively south of the Donau, on a subsoil of Jurassic limestone and Miocene deposits. The eolian sands themselves are entirely permeable; the water table depends on the depth at which the impermeable layers in the material underneath are situated. The ground is hilly. No real podzols were developed yet in the Atlantic.
4) An area with river deposits. It is the only level ground in the surroundings of Hienheim. It comprises deposits from both the Donau and the Abens. With the exception of a few higher parts, this area was inundated more or less regularly until recently. In the lower parts there is hardly any soil development.
5) An area with loamy sands and sandy loams, which belong to the deposits of the Molasse-basin. The ground is hilly. The groundwater stagnates on impermeable clays, the depth of which determines the water table. The latter is usually far below the surface, but can reach the surface at some places and then forms a spring horizon. Several small rivers rise in this area. Depending on the loam-content, a slightly podzolized soil or a soil with an argillic horizon has developed in the sediments. The area with the deposits from the Miocene Molasse-basin is situated mainly in the southern part of the map shown in figure 3. The unit lies for the greater part outside the 10 km zone around the LBK settlement.
6) An area with a mosaic of Jurassic limestones, deposits from the Cretaceous and Miocene sands and loams. There are a few springs in this area; for the rest it is rather dry. The soil development is dependent on the parent material and therefore heterogenous. The area is confined to the north-eastern part of figure 3 and limited by the Altmühl and the Donau. It is not represented within the 10 km zone around Hienheim.

III. 4 THE VEGETATION

A reconstruction of a vegetation is usually based on the interpretation of pollen diagrams, complemented, if possible, with data from wood analysis and seed examination.* In the following, we shall try to reconstruct the vegetation of the landscapes described in the preceding paragraph by means of this kind of data.

SOUTHERN LIMBURG

In Southern Limburg, we are confronted in the first place with the two loess landscapes, the terrain with eolian sand and the area with a thin loess cover on gravel, as well as the river valley landscape, which comprises both the Lower Terrace and the Holocene valley of the Maas. The Tertiary sand and the Higher Terrace are hardly represented within the 10 km radius around the settlements. We shall discuss the loess plateau and the dissected loess landscape together, since both plateaus and valleys are included in our study, and since we feel that the size of the plateaus has no relevance to the vegetation on it.

In the loess landscape the number of deposits which are suitable for pollen analysis is not large. The plateaus are too dry for the conservation of pollen. The colluvium in the dry valleys is unsuitable for the same reason, so that we are dependent on the peaty deposits in the stream valleys. Unfortunately, the

* Sometimes faunal assemblages can be used for this purpose.

valley deposits are also rarely ideal for pollen analysis, since they are frequently interrupted by hiatuses, resulting from shifts in the stream bed and the consequent erosion of the older sediments.

The loess landscape is nowadays completely deforested. Where not covered by houses or industrial plants, it is used as arable. The valleys support grasslands. The first diagram from this area, however, already showed that the region has been covered with forests. This diagram relates to Broeksittard and was published in 1953 by Belderok and Hendriks (Belderok & Hendriks 1953). Unfortunately, it is too summary to be used for a vegetation reconstruction. A few years later, Janssen examined 35 sloughs in the area covered mainly with loess and 7 such places on the edge of the loess area and the valley of the Maas. It appeared that only 14 out of these 42 sloughs were suitable for pollen analysis (Janssen 1960). At the same time, Van Zeist took samples from peat covered with colluvium near Sittard (van Zeist 1958/1959). As the loess area of Southern Limburg has hereby been studied sufficiently for our purpose, we dit not think a new investigation necessary. It is possible, however, that somewhere there is peat buried colluvium, which might provide good results.

Janssen used the zonation of Firbas for the division of his diagrams. Unfortunately, he added no C14 dates to his diagrams. The transition from Firbas VI to Firbas VII, however, is generally dated to around 4000 B.C., so that for a reconstruction of the vegetation during the LBK, we should use the data from the last part of zone VI and perhaps the beginning of zone VII. Zones VI and VII, which are also referred to by the names of Older Atlantic and Younger Atlantic, are present in 6 of Janssen's 14 diagrams. They are characterized by high percentages of Tilia (lime), Corylus (hazel) and Alnus (alder). Zone VII distinguishes itself from Zone VI by the first occurrence of Fagus (beech) in small percentages.

In Van Zeist's diagram, the Boreal is followed by a zone with a small percentage of Fagus and a considerable amount of Tilia, Corylus and Alnus. This zone corresponds to Janssen's zone VII. To the beginning of this zone at Sittard belongs a C14 date of 3130 ± 80 B.C. (GRO–1660), so that this part of the deposit is too recent to serve directly for a reconstruction of the vegetation around 4000 B.C. It seems that zone VI is absent at Sittard.

Zone VI is represented only in the diagrams Leiffenderven and Brommelen. The Leiffenderven is in the valley of the Roode Beek, 10 km east of Sittard. Brommelen is in the valley of the Geleen, 5 km north-west of Heerlen. The other 4 diagrams from Janssen's publication in which the Atlantic is present, begin either with zone VII (Rimburg), or zone V is followed directly by zone VII (Cortenbach 2, Voerendaal 1, Voerendaal 2). The hiatus in the deposits of the former lake, in which the borings Cortenbach and Voerendaal are situated, is probably larger still, since the attribution of zone VII to Firbas VII is unlikely to be correct. At Cortenbach 2, Centaurea cyanus was found in "VII" and Juglans at Voerendaal 1; these species do not usually occur until the Sub-Atlantic. The Rimburg core was taken in the valley of the Wurm, a small stream beyond the limits of the map of figure 2, some 7 km north-east of Heerlen. The small peat deposit Voerendaal/Cortenbach is located in the valley of the Geleen, 4 km west of Heerlen.

In the Leiffenderven only 20 cm of deposit belong to zone VI. Moreover, the surroundings are but partly covered with loess. In the Brommelen diagram, the lowermost 25 cm belong to zone VI. Consequently there is not much material to base a reconstruction of the vegetation in the loess landscape on. However, in both the Leiffenderven and Brommelen diagrams there appears to be such a continuity between zones VI and VII, that we can also use zone VII for our reconstruction, provided we leave Fagus (practically the only difference between the two zones) out of consideration.

It is clear from Janssen's and Van Zeist's work, that the entire loess area, the plateaus included, was forested. Janssen has summarized the vegetation during zones VI and VII in the following description:

1) Vegetation of the bog itself: Thelypterideto-Alnetum
2) Margin of the bog: Alno-Ulmion with Tilia cordata dominant, Alnus, Corylus and Quercus, often rather few Ulmus
3) Slope and Plateau: Quercus, Corylus. Janssen considers this vegetation an association of the Carpinion (Janssen 1960 p. 70 and 107)

We shall give a short description of these vegetation types.

1) The Thelypterideto-Alnetum Mörzer Bruyns et Westhoff 1951 is a synonym here of the Carici elongatae-Alnetum W. Koch 1926 em. R.Tx. et Bodeux 1955. It is an alder carr, a forest which is described as a low forest community with a relatively dense undergrowth of herbs on a subsoil which is moderately rich in nutrients and in which the water table varies from slightly under to slightly above the surface (Westhoff & den Held 1969). Alder (Alnus glutinosa) is the dominant tree species in this carr. But it may also have birch (Betula pubescens) and alder buckthorn (Frangula alnus). The forest is often hard to penetrate. The soppy peat and the rather dense undergrowth make the alder carr very unattractive to pass through. Remnants of this forest type are still present here and there in the area which we are discussing. The photograph of figure 5, however, was taken elsewhere, namely in the Broekhuizerbroek in Central Limburg. This splendid carr probably does not represent the prehistoric alder carr exactly. We assume that the original forest looked much less like a coppice. Alders can develop into much heavier trees.

In view of the rareness of Atlantic peats in the loess area, the alder carr was probably limited to small areas in the stream valleys.

2) The Alno-Ulmion from Janssen's publication is a synonym of the Alno-Padion Knapp 1942 em. Medwecka-Kornaś mscr. 1956 apud Matuskiewicz et Borowik 1957. It is a collection of mixed deciduous forests which accompany rivers and small streams. The vegetation is influenced by the ground-water. The different types of forest which are considered to belong to the group, contain a wealth of tree species, including alder (Alnus glutinosa, only at high ground-water levels), ash (Fraxinus excelsior), sycamore (Acer pseudoplatanus), elm (Ulmus carpinifolia) and oak (Quercus robur). The trees, and in particular ash and oak, can grow very tall and thick. Usually, the canopy of the forest is layered: under the very tall trees, a series of less tall trees is present. Below the trees, there are many species of tall and low shrubs, and the soil is covered with low herbs and bulbous plants in spring and with tall plants in summer. It can be difficult to penetrate in such forests. The Alno-Padion is hardly present in Southern Limburg nowadays. For that reason, the photograph of figure 6 is from a more northern location: the Linschoter Bos.

Within the loess area, the Alno-Padion probably formed narrow strips along the rivers. Given the pollen diagrams, there was very much lime and surprisingly little ash. The ash is usually underrepresented by its pollen, but ash ought to have been retrieved in higher percentages if it had been in any degree common. Besides few ash pollengrains three of the four diagrams show little elm as well. The elm only grew along the Geleen near Sittard in acceptable numbers. If the elm were represented to an important degree in the other valleys, its pollen would undoubtedly have been found in the examined deposits since the pollen rain of the elm represents this tree accurately (Heim 1970). At least on the loess, the Alno-Padion would therefore have been significantly different from the recent association. However, the possibility exists, that the interpreted deposits are slightly too young after all. They could date from the period after a possible elm decline (see IV. 2 p. 76) and the role of the elm in the original vegetation could therefore be underestimated. Janssen thinks the chance is real that the deposits were indeed formed after 4000 B.C. The series of deposits in the Leiffenderven might even contain an unnoticed hiatus between zones V and VI (Janssen 1976 personal information).

Fig. 5. Recent alder carr in the "Broekhuizerbroek", prov. Limburg, Netherlands (photo: E.E. van de Voo).

Fig. 6. Recent river-valley forest, the "Linschoterbos", prov. Utrecht, Netherlands (photo E.E. van der Voo).

Fig. 7. Recent hornbeam-forest, the "Savelsbos", prov. Limburg, Netherlands (photo: J.Th. ter Horst).

3) By far the greatest area was covered by forests of the Carpinion betuli (Issler 1931) Oberd. 1953. To the Carpinion betuli belong the climax vegetations of the dryer, nutrient-rich soils. In Southern Limburg we are dealing with forests of the association Stellario-Carpinetum (R.Tx. 1937 pp.) Oberd. 1957 This association is still present here and there in Southern Limburg. It is shown in figure 7. Hornbeam

forests have been described amply by van den Broek and Diemont, from whom we take the following, slightly condensed passage (van den Broek & Diemont 1966 p. 35, our translation).

"In addition to the major wood species – ash (Fraxinus excelsior) and oak (Quercus robur) –, wild cherry (Prunus avium) and hornbeam (Carpinus betulus) form – frequently in large numbers – a particular component of the tree layer. It is by no means excluded that because of thinning or clearance, the easily spreading ash with its large germination percentage and its rapid growth ousted the oak and other species with a slower growth and slower spreading. The common elm (Ulmus carpinifolia) and the sycamore (Acer pseudoplatanus) may sometimes be dominant in the tree populations, but they have a minor presence. The grey poplar (Populus canescens), the silver birch (Betula verrucosa) and the beech (Fagus sylvatica) are even less general and are rarely represented in any numbers. The small-leaved lime (Tilia cordata), the wych elm (Ulmus glabra) and the birch (Betula pubescens) are of little importance in the composition of the forest, as are the Norway maple (Acer platanoides) and the sessile oak (Quercus petraea), which are positively rare. Under the mantle of these trees thrives a luxuriant and diverse growth of shrubs, amongst which especially Corylus avellana (hazel), Cornus sanguinea (cornel) and Rubus fructicosus coll. (bramble) predominate. Among the large number of herbs, grasses, ferns and mosses, the great number of spring-flowering plants which flower before the trees and shrubs have fully unfolded their leaves is conspicuous."

The question is whether the above description of a recent Carpinion is applicable to the forest in the Atlantic. If we share the assumption of Van den Broek and Diemont that the important numbers of ash are the result of anthropogene influences, the climax forest would consist mainly of oaks. The hornbeam was not yet present in our part in the Atlantic. This is in agreement with Janssen's findings, who reconstructs a forest consisting of oak and hazel on the plateaus. Nowadays the hazel belongs to the shrub-layer. We do not wish to accept this reconstruction without further considerations.

According to Munaut, there was no oak forest on the sandy soils west of the Maas in the Atlantic, but a lime forest (Munaut 1967). Munaut founds his opinion on the interpretation of a series of pollen diagrams taken from soils (see below). But sand is not the optimal substrate for lime-trees. The species to be considered, namely Tilia cordata and possibly Tilia platyphyllos, prefer not too wet, but neither too dry, nutrient-rich loams (Oberdorfer 1970). They do very well on a loess substrate, even one with a deep water table. Therefore we think it improbable that the lime would have occurred on sand, but not on loess during the Atlantic. If the lime was indeed predominant over the oak on the sand soils, it must have been the most dominant species on the loess as well.

A second point is that, according to Janssen, the lime was dominant in the Alno-Padion. The lime, and particularly Tilia cordata, can indeed be found in the dry variants of the Alno-Padion. Tilia cordata, however, is considered generally as a character taxon of the Carpinion betuli, which means that the species can be used to distinguish the Carpinion from the Alno-Padion (Westhoff & den Held 1969). This is why we wonder whether the high percentages of Tilia pollen (mainly Tilia cordata, according to Janssen) in the pollen diagrams of Brommelen, Rimburg and Sittard (30-60% Tilia calculated over a tree-pollen-sum without Alnus) really represent only the situation in the valleys. If the lime was dominant in the Alno-Padion, it must also have been a major component of the "Carpinion" forests on the loess plateaus.

If Munaut's and Janssen's interpretations are correct, and for the moment we have no reason to believe they are not, the loess plateaus should have had not an oak-, but a lime- or at least an oak-lime-forest. Oak and hazel came second in this kind of forest. They grew in places where, for one reason or another, there was enough light for their development. It is difficult to provide proof for this reconstruction. The pollen of the lime is always strongly underrepresented in the pollen-rain and is rarely retrieved at more than a few hundred meters from the tree. In order to demonstrate both the presence and the dominance of Tilia on the plateaus, we should have to have spectra or diagrams from soils on the loess at our disposal. Unfortunately, the latter have provided no Atlantic pollen so far. Oak and hazel are usually well represented regionally by their pollen, which is why they are indeed recognized by means of pollen diagrams.

The possible reconstruction of the forest on the loess plateaus as a lime forest is, by the way, in agreement with Iversen's ideas about the Atlantic climax forests on the rich, dry soils. "...lime was much more frequent and oak was much more scarce than the pollen diagrams would appear to suggest. From this we may draw the conclusion that lime was the dominant tree in the primeval forest of the Atlantic period." (Iversen 1973 p. 65).

Lime forests are absent almost everywhere nowadays, probably as a result of competition from the beech and the fact that lime prefers just those soils which are most suitable for agriculture. Therefore it is very difficult to give a description of the Atlantic lime forests. This is, moreover, also true for the Atlantic forests in general. Iversen makes an attempt: "... when after some difficulty we have penetrated the thick undergrowth of the forest edge (a forest edge like this occurs mainly along water-courses or along clearings caused by human influence, C.B.), the interior strikes us as a contrast: a world of naked trunks, thicker than those we are accustomed to see today. There is no undergrowth. Young trees stand here and there in tight clusters, some of them dead or dying, others on the way up towards the opening in the tree canopy. Under such clusters of young trees it is even darker than usual. Some suppressed shade-trees also occur sparsely: their tops are flat and the height marks the moment at which a small hole in the canopy was closed by neighbouring trees. Now they vegetate through the decades, doggedly awaiting a new opportunity. As we walk in the gloom of the primeval forest we feel as though we are cut off from life. It is because of the dead and dying young trees and the fallen, rotting old trunks among which we walk, whilst high up in the tree canopy life unfolds in its inaccessibility. The uniformity is tiring. The vegetation on the forest floor is strikingly sparse." (Iversen 1973 p. 71). The trees in such forests have no side branches until a great height. The trunk is column-shaped and everywhere of equal thickness. This vegetation is easy to pass through, but when the trees are in foliage, it is very dark. All herbs present are therefore spring-flowering. If the reconstruction is correct, the Atlantic "Carpinion" was a different, more monotonous forest than the one described by Van den Broek and Diemont.

In the above, we already mentioned the vegetation of the second landscape: the s a n d a r e a west of the Maas. In this area Munaut has sampled a series of six soil profiles on the Mechelse Heide at Mechelen aan de Maas. The substratum consists for the greater part of terrace material (sand with a mixture of gravel). The deposit of eolian sand is very thin at this location. The area is covered today with a heather vegetation. The samples were taken from a Humuseisen-podsol. Only in one of the six profiles is part of the Atlantic pollen preserved. In the other five, the diagram begins in the Sub-Boreal. According to Munaut, the Atlantic which is still present, must be placed at the end of this vegetation period. In the pollen, Tilia is dominant with an average of 87% (calculated over an upland pollen-sum). Tilia, by the way, is also dominant in the Sub-Boreal. Munaut concludes from the diagrams that the plateau of the Mechelse Heide was, at the end of the Atlantic, entirely covered by a dense lime forest (Munaut 1967 p. 75 and 76). This description undoubtedly applies to the entire Atlantic. The profile of the Mechelse Heide is not the only one to show the Tilia-dominance. All Munaut's diagrams from sandy soils in Northern Belgium show high percentages of Tilia. We shall not discuss these in detail, because they are outside our area, but the analyses can be found in Munaut 1967. The diagrams, according to Munaut, allow no other conclusions than that *the sand soils west of the Maas were covered with dense lime forests. It is impossible to specify the lime* species. It would also appear from the diagrams that oak never played an important role in the area; according to Munaut the tree grew mainly on the transitional strip between the lime forest and the alder forest, which here too was present in the valleys, in a vegetation therefore, that must be considered to belong to the Alno-Padion. Hazel was represented to a modest degree.

With respect to the minor presence of oak-trees we must point out that, according to Havinga, the oak-pollen in the diagrams which we quoted, has not been interpreted correctly. The oak-pollen would have disappeared partly because of selective corrosion, so that relatively too few oaks would have been incorporated in the vegetation reconstruction (Havinga 1974, and other authors). Munaut, however, does not agree with Havinga's opinions. We ourselves have never observed selective corrosion to such an extent that it would favour Tilia without this being noticed, but the possibility remains that there were more oaks than is assumed on basis of the pollen diagrams.

In the area of loess on gravel and also in the areas with terrace gravel or Tertiary sands, which are of lesser importance to us, we have no pollen diagrams at our disposal. On analogy with the area west of the Maas, we feel that we may assume a lime forest on the thin loess covers. It is highly improbable that the lime occurred on the nutrient-poor Tertiary sands. We may imagine that these soils supported an oak-birch forest. The trees of this forest were perhaps not developed optimally. Too little is known of the terrace deposits in the north-eastern part of the area under study to justify speculation. They were undoubtedly covered with forests.

The final landscape to be discussed is that of the Lower Terrace and Holocene alluvial deposits. Although we speak of a single landscape, this is not quite true in this case. The landscape consists of numerous small units. Relatively small parts of high and low grounds, consisting of sands or clays, form a kind of mosaic. Therefore the Soil Survey Institute divides the lower terrace area into four sub-areas: 1) the older river-sand landscape (higher part) which is well drained and is in use as arable; 2) the older river-sand landscape (lower part) which is used mainly as grassland; 3) the river-clay landscape which, dependent on the water table is used partly as grassland, partly as arable; 4) the younger river-clay landscape, a part of which is flooded regularly. (Stiboka Bodemkaart van Nederland, blad 59, 60, 1970). The recent use of the soil shows already that not only the substrate, but the level of the ground-water is of great importance to the vegetation in this area.

We know of two diagrams from the young river-clay area, which contain a zone that must be considered as Atlantic. The most completely published diagram is that of Meeswijk (Paulissen 1966, diagram by Coremans, interpretation by Mullenders). The diagram relates to a filling of an abandoned channel of the Maas. In view of a C14 date of 3260 B.C. (Lv–284) for the centre of the deposit, the peat developed during the last part of the Atlantic. The surrounding landscape was covered entirely with forest, in which the alder was dominant. The second diagram is from an abandoned meander of the Maas near Maaseik. The peat deposit was analyzed by Munaut, but he did not prepare the results for publication. Some details are mentioned by Paulissen (Paulissen 1973 p. 122 and 123). According to Munaut, the deposit dates from the beginning of the Atlantic. Alder, ash, oak, lime and elm are well represented in the pollen. A percentage of

11.5 is given for the elm. Unfortunately it proved to be impossible to trace the original data, so that further details cannot be given here (Munaut 1976 written communication).

Although peat-development occurred here and there in the other sub-landscapes, we know no other diagram that offers information about the Atlantic. Deposits from this period are probably present somewhere in the area. The topmost centimetres of a diagram by Florschütz of the Gulickshof could be of an Atlantic age (Florschütz 1941). But recent agricultural intervention has made many deposits unsuitable for pollen analysis. We think that the landscape, as well as the other landscapes under study, was covered by forest during the Atlantic. The wet strips along the Maas and the numerous streams undoubtedly carried the Carici elongatae-Alnetum (proven at Meeswijk?), which here covered a rather large area. Where the land was flooded less often, different associations of the Alno-Padion developed, dependent on the water table. The Carpinion betuli replaced the forests of the Alno-Padion on the higher grounds. We assume that Tilia was abundant here as well.

The vegetation of the different landscapes, as reconstructed above, represents the vegetation of the areas untouched by man. If a part of the vegetation is removed by human activity, changes occur. One consequence of the removal of trees is that more light can penetrate to the ground. When primeval forest is cut, a series of herbs are the first to profit thereby. Then shrubs start to grow. Subsequently the tree population restores itself in several phases: first the light-demanding species, which are usually fast growing. The shade-giving trees come last. Each forest type and each intervention have their own series of succession. The recovery is predictable to a certain extent (Horn 1975, among others). The first stages of new growth can be completed quickly, but it may take a long time to reach the original vegetation. The speed at which a forest regenerates itself after an intervention, depends greatly on the type of intervention. Horn states that: "Patchcutting, the harvest of local groups of trees while leaving a large area of uncut forest around them, should result in a more rapid return to the stationary stage than the cutting down of all the trees or even "high-grading": the removal of all commercially valuable trees."

The presumed seral stages of the reconstructed forests will not be discussed further here. These in as far as they occur recently, can be found in the publication by Westhoff and den Held (Westhoff & den Held 1969).

At the beginning of this section sources of information other than pollen diagrams were mentioned. These are hardly available in the area and period under consideration. However oak-wood in the form of charcoal was found in the settlements (see p. 121). More research has been done for the Aldenhovener Platte, a loess plateau dozens of km to the east. Charcoal of the following trees was found here in a LBK settlement: Ulmus sp. (elm), Fraxinus excelsior (ash), Quercus sp. (oak), Corylus avellana (hazel), Pyrus pyraster (pear) or Malus silvestris (apple) or Crataegus sp. (hawthorn), Sorbus sp., Prunus sp., Prunus spinosa (blackthorn), Acer sp. (maple) and Picea (spruce) (Schweingruber 1973). All these tree species belong to the Atlantic Alno-Padion or to one of the seral stages of the Carpinion; only the occurrence of Picea is not in direct agreement with the vegetation reconstruction given here. It is assumed generally that the spruce is not indigenous. Our area does not include its natural range. The find, however, is too small to determine whether the charcoal originates from a local tree or from an imported piece of wood.*

* It is possible that the spruce charcoal represents a contamination.

If the above reconstruction of the vegetation in the different landscapes is correct, we arrive at the conclusion that the aspect of the area around Sittard, Stein and Elsloo at the time of the foundation of these settlements was quite different than nowadays. The whole land was forested, even those parts which are covered with heather today. The lime was a very common tree and the oak had a far smaller share in the forest than is usually assumed. The occupants of the settlements undoubtedly modified the vegetation by their activities (see p. 123). Part of the climax forest was perhaps replaced by different seral stages. In spite of these activities, the land will have remained forested, at least during a great part of the period under consideration, since the pollen diagrams give no indications of large scale deforestation. We shall come back to this on p. 125. Further, we wish to observe that our reconstruction of the vegetation as a dark deciduous forest does not necessarily mean that the first LBK inhabitants found no clearings at all. Especially British scientists have recently pointed out that the indigenous Mesolithic population may also have made clearings in the forest vegetation (Smith 1970, Simmons 1975). Uncontestable proof thereof has not yet been provided, we feel, but it is a possibility which must be taken into consideration.

HIENHEIM

Four of the six landscape units, which have been discussed in section 3 of chapter III, are present within a radius of 10 km around Hienheim, namely: the loess landscape, the limestone region, the terrain with eolian sand, and the river valley. The Miocene deposits and the region with alternately Jurassic, Cretaceous and Miocene are beyond the 10 km radius. We might restrict ourselves in the reconstruction of the vegetation to the first-mentioned four units. There is a special reason, however, why the Miocene deposits are added to the list. This is that we have not succeeded so far in obtaining information about the vegetation history of the loess landscape. In the meantime something has, however, become known about the vegetation of the sandy loams which belong to the fresh water sediments of the Molasse Basin. From the viewpoint of phytosociology, these loams are, to a certain extent, comparable with the loess. The climax vegetation could be a Galio-Carpinetum on both soils (see below). We shall therefore try to reconstruct the vegetation on the loess via the vegetation on the Miocene loam.

As just mentioned, it has not yet been possible to study the vegetation on the loess directly. The search for pollen-bearing deposits in the loess area was until recently unsuccesful. Test sampling in a slough near Arresting, a village 3 km north-west of Hienheim, provided no subfossil pollen. One of the many abandoned meanders in the Donau valley perhaps contains a suitable deposit of the correct age, but it is a thankless task to look for a particular meander which was abandoned in the Atlantic. However, in the stream valley of the Feckinger Bach, in the middle of a loess region, a series of peaty and humus-rich deposits which could lead to a positive result were found. The investigation of this series has not yet been completed. As all stream deposits, it shows hiatuses and it is not impossible that precisely the Atlantic is absent. But a pollen diagram representing the vegetation of the Miocene deposits is available, namely the diagram of the Grosse Donaumoos south-west of Ingolstadt, which is discussed in Appendix I. This diagram relates to the vegetation of a landscape of sandy loams and loamy sands. The sampling in question took place at a distance of 55 km from Hienheim.

Both the loess and the sandy loams are used nowadays as arable, the greater value being attributed to the loess. The loamy sands are used for forestry and are in most cases covered with conifers. The potential vegetation, that is the vegetation with which the sediments would have been covered if man had not intervened, is deciduous forest in all three cases. The data relating to the potential vegetation have been taken from Seibert's work (Seibert 1968). This author has composed a map of the potential vegetation of Bayern on the basis of the soil map and the contour map. The knowledge of the interrelation between certain soil types, altitude and plant communities is the result of experience acquired in the examination of natural and relict vegetations. The loess and the sandy loams would have been covered nowadays with an oak-hornbeam forest (respectively with a Galio-Carpinetum Oberd. 1957 typicum and a Galio-Carpinetum Oberd. 1957 luzuletosum).* The loamy sands would carry a beech-forest, namely the Luzulo-Fagetum Meus. 1937.

The Galio-Carpinetum is the more continental equivalent of the Stellario-Carpinetum which is discussed on p. 34. It is a deciduous forest with many species, in which oak (Quercus robur and/or Quercus petraea) and hornbeam (Carpinus betulus) are predominant. Beech (Fagus sylvatica) also belongs to this vegetation, as well as the small-leaved lime (Tilia cordata). Pine (Pinus sylvestris) and spruce (Picea abies) do not belong to this type of forest which, however, includes shrubs and herbs. The Galio-Carpinetum luzuletosum grows on less alkaline soils than the Galio-Carpinetum typicum.

The Luzulo-Fagetum is a forest type which is present on weakly acid soils. Hornbeam and lime do not grow here. Beech is predominant in the forest community. Besides, there is oak, pine, spruce and also fir (Abies alba). Only few shrubs are present and the field layer is relatively poor in species.

Of course the potential vegetation of the area with the sandy loams and the loamy sands also shows transitions between the Galio-Carpinetum luzuletosum and the Luzulo-Fagetum.

The question is whether the vegetations mentioned above already existed during the Atlantic. When we study the Atlantic (zones VI and VII) in the pollen diagram of the Donaumoos, it is immediately striking that the area was densely forested in that period, since very little pollen from terrestrial herbs was found. Low percentages of herbs point to a closed forest. It appears further that of the trees, beech, spruce and fir are almost, and hornbeam is entirely, absent. Therefore the Atlantic forests were clearly different from the present ones. It is improbable that the Luzulo-Fagetum already existed. The Galio-Carpinetum certainly comprised no hornbeam and no or almost no beech.

The tree pollen originates for the greater part from oak and pine. In addition to these two, we have observed elm (Ulmus), lime (Tilia), ash (Fraxinus) and some maple (Acer). Among the shrubs, hazel (Corylus avellana) was certainly important. For the rest hardly any pollen of a shrub vegetation was found, though this does not mean that there was none. The pollen of shrubs and herbs almost never lands outside the forest and probably for that reason it is underrepresented in the deposits of the Donaumoos. Moreover, shrubs and herbs do not always flower optimally in the shadow of trees.

It is impossible to gain knowledge of the vegetation of the sands and the loams separately via a pollen diagram such as that of the Donaumoos. The pollen rain is always a mixture of the pollen of all vegetation types present. We imagine, however, that the pines occurred mainly on the sandy deposits and were part of an oak-pine forest. The birch may have played a minor part in these stands. On the loams, the oaks were not mixed with pines, but with deciduous trees, among which were limes. The share of the lime in this forest type was perhaps greater than the diagram suggests at first glance, because lime pollen is always underrepresented in a deposit like the Donaumoos. Besides oak and lime, hazel was present in rather large quantities. Maple, ash and elm may have been present in this forest, but these trees will have had their main distribution in a zone bordering the swamp. The forests here visualized on the sandy loams during

* The vegetation units are indicated in this sub-section according to the nomenclature of Oberdorfer (Oberdorfer et al. 1967).

the Atlantic may certainly be considered to belong to the group of deciduous forests on the dry, rich grounds, the Carpinion betuli Oberd. 1953.

As said above, the pollen diagram of the Donaumoos is used in order to reconstruct the Atlantic vegetation on the loess via the detour of the vegetation on the sandy loams. We believe that the loess was also densely covered with an oak-forest belonging to the Carpinion. It is quite possible that lime played a rather important part in this forest. The loess around Hienheim would then have supported a more continental variant of the forest which was present in Southern Limburg in the same period. The exact share of the oak is unknown.

The reconstruction of the vegetation on the loess as a dense deciduous forest differs strongly from the original opinions on this vegetation as developed mainly by Gradmann (Gradmann 1898, 1901). Gradmann's hypothesis was that a so-called "Steppenheide" or "Waldsteppenheide" would have grown on the loess, i.e. a dry vegetation with few trees and many herbs. This reconstruction was soon criticized strongly and finally rejected in favour of a dense forest (Firbas 1949 and the literature quoted there). The reconstruction here is in agreement with the latter.

The potential vegetation in the limestone area consists, according to Seibert, of beech forests, except for those places where the slope is very steep. Even at present, the limestone is covered largely with the Lathyro-Fagetum Hartm. 1953 typicum, a tall forest in which beech is predominant. Other deciduous trees are present in the forest community, but they are clearly less numerous. Oak (Quercus robur), ash (Fraxinus excelsior), maple species (Acer sp. among which Acer pseudoplatanus) and cherry (Prunus avium) are mentioned, among other trees. The forests are dark and have a low undergrowth of spring-flowering herbs and of some grass species.

Where thick layers of residual loams have been formed on the limestone, a slightly more acid variant of the Lathyro-Fagetum, namely the Lathyro-Fagetum Hartm. 1953 melampyretosum develops. The difference with the Lathyro-Fagetum typicum can be noticed mainly in the field layer. Nowadays the loams are covered only partly with forests. The rest is used as arable or pasture.

The southern slopes are too warm and too dry in summer for an optimal development of the Lathyro-Fagetum and the forest changes into a thermophile beech forest: the Carici-Fagetum Moor 1952. In addition to beech, the tree layer comprises, among others, yew (Taxus baccata). The deciduous trees cannot reach optimal development because of the dryness, and the long, straight trunks of the Lathyro-Fagetum are completely absent here. Shrubs are usually well represented.

On very steep slopes, the beech is normally absent. These slopes are characterized by the Clematido-Quercetum Oberd. 1957: a forest with oak and many other deciduous trees. The trees remain small. Contrary to the beech-forest, this type of vegetation is difficult to traverse. It can still be found nowadays around Hienheim, although most slopes have been deforested and are used for sheep. In this case a steppe-like herb vegetation is present and juniper is the only tree able to maintain itself.

It is obvious that the above-described beech-forests were not present during the Atlantic, since the beech was not yet present on a large scale in that period (see Appendix I).

Unfortunately only one pollen diagram was available for the reconstruction of the vegetation in the region of the Jurassic limestones. This diagram does not even come from the limestone areas of the Frankische Alb, but from a comparable landscape at the foot of the Schwäbische Alb. It is true that near Hienheim, and again in the valley of the Feckinger Bach, a peaty deposit is available, in which pollen of the required vegetation could be present, but this deposit has not yet been analyzed. Therefore we will attempt to utilize the diagram of the Langenauer Donaumoor near Ulm, which was published by Göttlich (Göttlich 1955, diagram D.I.).

The Langenauer Donaumoor is a vast fen, situated in the valley of the Donau between the Jurassic limestone deposits of the Schwäbische Alb and the present river bed. The boring D.I. took place at circa 500 m from the margin of the fen in the immediate vicinity of the limestone area. At this point the limestone is partly covered with loams which are to be considered as residual loams. The diagram comprises the older part of the Atlantic: Firbas zone VI. The interpretation of the measured pollen rain is not simple. During period VI the fen itself supported a very wet swamp vegetation, in which lime was precipitated. There were no trees. All the tree pollen comes from the margin of the fen or from further away. Oak, pine and hazel appear to have provided most tree pollen, with oak clearly in the first position. Birch, elm, lime, ash and a surprizing amount of maple play a part. Spruce and fir are hardly present yet; beech is absent. Alder is represented with only 5% of pollen (percentage calculated on basis of a tree pollensum minus Corylus). Göttlich interprets all deciduous tree pollen as originating from forests in the Donau valley. It would be a forest type of a rather dry location, rich in nutrients, in which alder played a very minor part. It may be questioned, however, why Göttlich has not included the vegetation of the areas outside the valley in his considerations. When the site of the sampling is examined, a considerable part of the pollen rain could have come from the higher limestone and loam areas. It is difficult to say which pollen originates from the river valley and which from the higher terrains. It may be that some of the oak and the hazel stood in the limestone area, where lime and ash can also have been present. Moreover, we think it possible that a considerable part of the vegetation was formed by maples. The high percentage of maple pollen in the Langenauer Donaumoor is not present in the Heiligenstädter Moos, which also represents the vegetation of the Donau valley (see Appendix I), but the differences can be due to purely local factors. Göttlich says nothing about the pine. The percentage with which the pollen of this tree is present is too high to be attributed to long distance transport. The location of this tree species is difficult. It may have grown in the valley, but also in some place outside it.

It is obvious that the diagram of the Langenauer Donaumoor is not sufficient for the reconstruction of the vegetation in the margin of the Schwäbische or the Fränkische Alb. It may be assumed that, in absence of the beech, an oak-forest covered the limestone and the loams. This forest undoubtedly contained also other species, such as maple though for lack of data, this cannot be proved.

The third area to be discussed is that with the eolian sand. The eolian sands are covered nowadays with a so-called sand steppe pine forest of a slightly continental character. It is an open forest with a rather rich field layer (transition from a Leucobryo-Pinetum Matusz. 1962 to a Cytiso-Pinetum Br.-Bl. 1932) (Hohenester 1960). The relative richness of the vegetation is connected with the high mica-content of the local eolian sand. Hohenester assumes that the pine has always been part of the vegetation on the eolian sand and was therefore also present during the Atlantic. The pines would have been mixed with deciduous trees: he mentions oaks, among others (Hohenester 1960). Our pollen diagram of the Heiligenstädter Moos cannot support this viewpoint. The Heiligenstädter Moos is situated at 1 km from the eolian sand area. Not enough Pinus pollen was found in those zones of the diagram which must be attributed to the Atlantic to allow the conclusion that pine was present in the vicinity (see Appendix 1). Pinus pollen has a good distribution and would certainly be present in larger numbers if pine had been a local tree species. It is therefore improbable that there were already many pines on the eolian sand in the Atlantic. Probably, mainly deciduous trees grew in these regions. For the rest we cannot reconstruct the vegetation on the eolian sand, because the pollen of this area cannot be distinguished from that of the river valley.

Finally, we shall try to reconstruct the vegetation of the Donau valley.

The low parts of the river valley are used nowadays as meadows. Before the diking and regulation of the Donau and its tributaries, the land was often inundated. Even now, this phenomenon occurs several times per year. But on only slightly higher parts, the water table is already sufficiently below the surface to enable agriculture to be practised. Until recently, these soils too were inundated at very high water-levels.

The Lower Terraces of the Donau and the Abens are for the greater part very wet. The wet parts owe their existence to the presence of impermeable Miocene clays near the surface, so that the water table is high. The few dry parts are used as fields which, however, have little value, because the terrace sediment dries out quickly and is poor in nutrients. The wet parts are often peaty and are used as grassland.

In the past too, the hydrology will have determined which vegetation was to be found in the different parts of the composite landscape unit "river valley". The recent potential vegetation within the area is forest. Seibert's map shows three vegetation types (Seibert 1968). The valley would bear an ash-elm forest (Querco-Ulmetum minoris Issl. 1924), a forest belonging to the Alno-Padion discussed on p. 30. For the wet Lower Terrace, Seibert mentions an alder-ash forest (Pruno-Fraxinetum Oberd. 1953) or possibly a spruce-alder forest (Circaeo-Alnetum glutinosae Oberd. 1953). These forests grow on wetter locations than the ash-elm forest. They too belong to the Alno-Padion. On the very dry parts of the Lower Terrace, Seibert locates an elm-oak-hornbeam forest (Ulmo-Carpinetum Pass. 1953), which belongs to the Carpinion betuli. However, in agreement with the soil map, he mentions loams as the substrate for this forest, whereas we are dealing with sands, so that the description is not applicable to our region, where a poorer type of oak forest may be considered instead.

Because of the small scale of the vegetation map, Seibert could not take into account the many nuances which forests in a river valley can shows as a result of the varying water table and frequency of inundation. Besides forests of the Alno-Padion, also alder carrs (Carici elongatae-Alnetum W. Koch 1926) would occur on the very wet places in the region under study. Some remains of the Carici elongatae-Alnetum and the Alno-Padion are still present in the region.

The vegetation which was present in the Donau valley during the Atlantic can be deduced to a certain degree from the pollen diagram of the Heiligenstädter Moos, a former, dead river channel at 8 km south of Hienheim. This channel came to lie outside the water course in the Atlantic and was slowly filled up with calcareous gyttja and peat. The hydroseral stages described in Appendix I: open water with Myriophyllum among other plants, a belt of reed, reedmaces etc., a dense vegetation with tall sedges and finally an alder carr, could probably all be found in the river valley, in ox-bow lakes, during the Atlantic. Besides information on the strictly local vegetation, the pollen diagram also provides information on the vegetation of the surroundings. The non-local pollen rain probably came from the dry part of the Lower Terrace and from the Holocene river valley.

Here again, it is difficult to distinguish the vegetation of both parts of the surrounding landscape. It is plausible that a richer vegetation occurred on the Holocene deposits than on the rather poor, dry terrace sands. We think that there were forests of the Alno-Padion on the Holocene deposits. This forest type belongs on young, nutrient-rich, mineral soils which are flooded periodically or which are influenced by vertically moving ground-water. In our opinion, these environmental requirements were met by the substrate in the river valley proper. The plant species found are not contradictory to this reconstruction. Mention may be made of the presence of shrubs like Ligustrum (almost certainly L. vulgare), Cornus sanguinea, Sambucus nigra and Viburnum opulus. These plants must have stood in the immediate vicinity of the basin, as the pollen of these shrubs would otherwise not have been observed. As location for the shrub flora, only the relatively wet, loamy Holocene river valley comes into consideration. The species are found nowadays in the Alno-Padion, among others. The specific composition of the Atlantic river valley forest could possibly be different from the present one. For example relatively few pollen grains of ash are found in the Heiligenstädter Moos. It is difficult to attribute this phenomenon exclusively to the poor distribution of this pollen. According to many authors, the ash is underrepresented by its pollen (Heim 1970 and the literature quoted there). Andersen thinks that the counted number of pollen should be multiplied by 2 in order to obtain a correct picture in comparison with other species (Andersen 1973). If the ash had been present in the river valley on a very large scale, we should have counted more than the 1 to 2% (calculated over an upland pollensum) which were actually found. Moreover, the pollen curve is discontinuous. The ash seems to have been present in the Atlantic river valley forest in far smaller numbers than the present remains of the forest type suggests. Moreover we point at the behaviour of the elm. Elm trees are more or less numerous in the beginning, but disappear partly from the valley forests around 4300 B.C. Thus, the composition of the forests did not remain constant during the Atlantic.

The vegetation of the Lower Terrace is not recognizable in the pollen diagram as a separate category. As already stated, the rather rare, sandy, dry part of the terrace sediments is situated adjacent to the Heiligenstädter Moos. Perhaps the pollen of the birch and some of the pollen of the oak and the hazel originate from this area. We might imagine a not too luxuriant oak forest here. The low parts of the Lower Terrace were undoubtedly covered with forests from the Alno-Padion. The soil here is not as poor as on the dry places, because the ground-water supplies nutrients and lime. On places where the water stagnated, an alder carr could have been present, in which the thin peat layer which is found here and there on the Lower Terrace developed.

The occurrence of pollen of a certain category of light-demanding herbs gives reason to assume that there were clearings at some places in the forests. At least, this was the case in the direct surrounding of the Heiligenstädter Moos (see p. 157 and p. 161 of Appendix I). We cannot tell whether the clearings in the forest vegetation were general or were restricted to the banks of basins with open water. The latter would be the case if the clearings were the result of beaver activity, as was suggested on p. 161.

It appears from the above attempt to reconstruct the vegetation around the LBK settlement Hienheim, that we have been able only to reconstruct the forests in the Holocene river valley and the forests in the Tertiary hilly country to a certain degree. The remainder of the description is based on assumptions.

The investigation of macro-remains adds little to our knowledge. The determination of the charcoal found in the settlement only provides proof for the presence of certain tree species. Dr. F.A. Schweingruber found charcoal fragments of oak (Quercus sp.), pine (Pinus sp.), alder (Alnus sp.), cherry (Prunus avium) and not further identifiable Pomoidea (to which group the apple belongs). Pollen of all these trees was found in the investigated sediments.

It is obvious that much more research will have to be conducted before a reasonable description of the vegetation in the area around Hienheim can be given. The pollen diagrams of the Grosse Donaumoos and the Heiligenstädter Moos were the beginning of this task. Several diagrams will have to be made to allow the picture of the vegetation on the higher grounds to rise above the stage of guesswork. We hope to discuss this subject again in a later publication.

III. 5 THE FAUNA

Although the word fauna in the limited sense is used only for the qualitative aspects of the animal world in a certain area, we should like to include the quantitative aspects as well in the heading "fauna". We do so, because there is no generally used pendant of the botanical term "vegetation."

The purpose of a reconstruction of a fauna is to establish a list of all those creatures which lived in a given area in a given period. It also aims at establishing the number of each species. There are, to our knowledge, two ways to reach these goals. The first method is to study the animal remains; the second method is the reconstruction of the animal world through the reconstructed landscape and its vegetation.

In the first method the difficulty arises that the presence of faunal remains such as skeletal remnants, is strongly dependent on the composition of the substratum in which they ended up after their death. Thus calcareous skeletons are conserved only in calcareous or very dry environments. Elsewhere they dissolve after a shorter or longer time, depending on their size. The result is that in many areas there is no skeletal material available for study at all and that in other areas selective corrosion plays an important part. Something like this applies to horn and chitin. The study of faunal remains therefore seldom results in a complete list of species.

The second, indirect method works through the reconstruction of biotopes (natural environments of animals). First the landscape is reconstructed as far as possible without animals and then it is estimated which animals and how many of them could live in that landscape. Of course, this method can be used only if one has an idea about the animal species which lived in the period under consideration and about their biotopes.

If we wish to establish which animals there were around the LBK settlements in Southern Limburg and around the LBK settlement Hienheim, it transpires that there are very few animal remains to inform us. Assemblages of subfossils, which date from the Atlantic and which originated independently of man, are almost entirely absent in both examined areas. The assemblages known consist of small freshwater mollusks, ostracods and the like: faunas which are of little relevance to our study. The available fossil assemblages are restricted to anthropogene assemblages in waste, particularly to the filling of pits. This has the consequence that the remains found always represent an anthropogene selection from the wild fauna. Probably not even all animals gathered by man are represented in the waste concentrations, since we may expect to find only relatively large remnants there. Parts of small animals were probably never thrown into the waste pits because they were too small to be handled as waste. Remnants of grass-hoppers and caterpillars are therefore more likely to be found in coprolites than amongst general rubbish. An investigation of pits filled with waste therefore can never provide more than a very incomplete list of species. Besides there is a quite different problem in that some animal remains may have been imported.

For Sittard, Stein and Elsloo we do not even have the above-mentioned anthropogene assemblages at our disposal. The loess, in which the refuse pits are located, is decalcified too deeply to allow the preservation of bones and the like. The only settlement in the far surroundings where bonus were found, is the LBK settlement Müddersheim, LdKr. Düren, BRD, located 65 km south-east of our find sites.*

The animal remains of Müddersheim have been described by Stampfli (Stampfli 1965). His list of species of wild animals comprises: hamster, horse, wild boar, red deer, roe deer, aurochs, buzzard and freshwater mussel (Unio sp.). Of each species only a few specimens were found. It is to be doubted whether the hamster dates from the LBK period. This burrowing animal may have died later in his burrow under

* We leave Köln-Lindenthal out of consideration, because the bones which were excavated there are described too summarily.

the ground. But an argument in favour of dating this animal in the LBK period is that only one fragment has been excavated. (From Köthen-Geuz, Kr. Köthen, DDR, hamster bones are known which undoubtedly belong to a LBK bone assemblage, as these bones are charred (Müller 1964).)

As Müddersheim is not all that far away from Sittard, Stein and Elsloo and, moreover, as it is located in a similar landscape, we expect that the species found by Stampfli were also present around the settlements which we are studying. The original fauna, however, must have comprised far more species, as only six species of mammals have been found. Nowadays Southern Limburg boasts 45 species and subspecies of mammals living in wild state (IJsseling & Scheygrond 1950 p. 124). As it is known that a number of mammal species have disappeared from the Netherlands in historic times (elk, bear, wolf, beaver) or have become completely extinct (aurochs, horse), the number of species was probably slightly higher. Many of the indigenous mammals are small animals such as mice and bats. These small animals are absent in the finds, at least if the hamster is left out of consideration. It is surprising that the remains of animals which date with certainty from the period of LBK occupation belong to Europe's biggest land animals: the ungulates. Of the six ungulates which were perhaps indigenous: horse, wild boar, red deer, roe deer, elk and aurochs, five are represented. But the category of carnivores, which also includes big animals, is entirely absent. The finds from Müddersheim therefore provide a very incomplete and unreal picture of the original mammal fauna. There are five possible reasons for this: 1) the sample is much too small, 2) the small bones of small animals were perhaps not always noticed during the excavation, 3) the bones of small animals have disappeared through selective corrosion, 4) the remains of animals other than mammals did not end or only rarely ended up in pits, 5) mainly ungulates were hunted. The assumption under 1) is undoubtedly true. For 2) it must be borne in mind that no sieving took place at the excavation, so that it is not excluded that small objects were overlooked. The other three possibilities cannot be judged in this material.

Animals, other than mammals, have hardly been mentioned yet, but it will be obvious that the single buzzard and freshwater mussel underrepresent the remaining fauna. Therefore the excavated bone material in no way provides an approximation of the fauna around the settlement.

As mentioned in the beginning of this section, there exists a possibility to reconstruct the fauna of an area by means of its biotopes. In section 3 the different landscapes around the settlements have been listed. In section 4 an attempt was made at reconstructing the vegetation within the landscapes. A description of the fauna of the area may now be attempted. We start from the assumption that the animals which live in Southern Limburg at present, with the exception of more or less recently imported species, were also represented in the Atlantic fauna, provided that their biotopes were there. For the latter it may be assumed, in agreement with many archeozoologists, that the biotopes of the different species have not changed essentially (Boessneck 1958, Müller 1964, Clason in press). We may add to the list of recent species those animals of which it is known that they disappeared from the area in the historic period. The above assumptions are deemed to be justified, because the period to be reconstructed is within the history of fauna a very recent one. In section 3 five landscapes which occurred within a radius of 10 km around the settlements were distinguished: two loess areas, an area with thin loess on gravel, an eolian sand area and a river valley landscape. The river valley landscape comprises in fact a mosaic of different landscapes and will therefore have had several biotopes including both running and stagnant water, bank zones, carrs and valley floor forests.

At Müddersheim only the freshwater mussel gives evidence of animal life in the water. But the aquatic environment must have accomodated many other animal species, among which a great variety of fish.

Crayfish must have lived in the river banks, between bared tree roots. The varied fauna of the bank zone is not present in the scanty material from Müddersheim. In this zone live frogs, pond turtles, water-birds, small mammals such as the ground vole, bigger mammals such as otter and beaver. Really big animals are found in the carrs: wild boar, which is represented in the remains, and in summer perhaps elk. The latter prefers dryer ground in winter. Of course, the carrs also accomodate smaller animals. Valley floor forests are layered, as is described on page 30. Sufficient light penetrates in the woods to allow the growth of shrubs and herbs. Such forests are usually characterized by a fauna which, for a forest area, is relatively rich in species. We expect to find snails, many bird species, mice, bats, roe deer and aurochs, that is animals preferring an open forest with understory vegetation.

The two loess landscapes, the sand area and the area with thin loess on gravel were, according to our reconstruction, covered with a tall, dark forest with little understory vegetation (p. 35). Only a few animal species can live in this type of vegetation: squirrels, martens and birds in the trees, on the ground some mouse species, foxes, red deer, bears, wolves and also wild boar, provided there is water in the vicinity. (All these animals can also be present in the lighter forests.) The picture changes as soon as open spaces are formed in the forests. By the presence of openings between the tree-tops the forest takes on certain characteristics of open forest: growth of shrubs and tall herbs. The vegetation of the open places will attract the animals of the lighter forest type.

Some of the animals which could perhaps be found around the LBK settlements Sittard, Stein and Elsloo have now been mentioned. The enumeration is not meant as a complete reconstruction of the fauna. It will be obvious that the final goal mentioned in the beginning of this section: a complete reconstruction, has degenerated to a series of quotations from books describing recent faunas, such as the Zoogdierengids by Van den Brink (van den Brink 1972), from which much of the above has been taken. One remark should be made. Here, as in many similar sketches (e.g. Iversen 1973) relatively too many mammals have been mentioned. But the fauna comprises many other species, the existence of which should not be forgotten.

As for the quantitative aspects of the fauna, it is impossible to reconstruct the numbers of all the species. We restrict ourselves to some specific animals and more precisely to those ungulates of which bones have been found. This choice is arbitrary. In important finds it might be useful to consider the numbers of species which are not found in the settlement. It could be that all species, which are not represented in the find material, were so rare that they could hardly be hunted. It is also possible that some species were generally present, but that they were not hunted for one reason or another. As has already been said on page 45, the material of Müddersheim is not voluminous enough to allow such conclusions, which is why the ungulates, the presence of which is certain, have been chosen. Even this restricted task appears to be very difficult and almost impossible.

A first problem is that both horse and aurochs are extinct. Data concerning the density of the populations in question, i.e. the number of individuals per surface-unit, are not available and can obviously no longer be obtained. The reconstruction of the numbers of the other three species: red deer, roe deer and wild boar, presents quite a different problem. Although they are not extinct, their natural densities in the forests of Central and Western Europe are also unknown, because these densities have been influenced strongly by man for a long time. These three species, being specified as game animals, have been favoured, certainly in the historic period, at the expense of their natural enemies, the large carnivores. Real primeval forests, where there is still a natural balance, do not exist in Europe anymore (Westhoff 1967). The only numbers which we can present as population density, thus relate to protected game animals. These densities are probably too high for the circumstances under study.

The maximum density which roe deer can reach before damaging the vegetation beyond recovery (the so-called economical density) is, according to Ueckermann, 3–11 individuals per 100 ha. A density of 3 applies to the least favourable biotopes and 11 to the extremely favourable biotopes. Daburon gives a density of 3 to 8 for the French forests (Ueckermann 1957, Daburon 1963). These authors state that the density depends strongly on the ratio deciduous forest – coniferous forest, but also on the quantity of forest edge and open places present in the area. The more margins and clearings, the denser the roe deer population. Grass-covered clearings are less favourable than places with tall herbs (Klötzli 1965). It is obvious that a good picture of the openness of the landscape is necessary for determining the density of the roe deer population. Ueckermann gives directives by which the value of a certain landscape for roe deer can be estimated (Ueckermann 1957 p. 29). A dense deciduous forest on loess and also a dense forest in a river valley belong, according to this system of values, to the areas with a minor roe deer population, namely three individuals per 100 ha at the most. Nowadays such a population is considered too small for hunting purposes. The population will increase as the landscape becomes more open. If there are also red deer in the area, as was the case around Sittard, Stein and Elsloo, the number of roe deer will be smaller than the above-mentioned density of 3 per 100 ha. For each red deer there is one roe deer less. The fact that only one red deer is equivalent of one, much smaller, roe deer is attributed by Ueckermann to the circumstance that the food of red deer is only partly identical to that of roe deer.

In another publication, Ueckermann provides figures about the economical density of red deer. According to his system of values, there would be less than 1.5 individuals per 100 ha in our area (Ueckermann 1960 p. 32). Daburon agrees with Ueckermann's viewpoint (Daburon 1963). One red deer per 100 ha is considered as just enough for hunting purposes.

We are, at the moment, unaware of any such studies for wild boar. We expect that there were only a few individuals per 100 ha. In the river valleys the boar population will have been larger than on the plateaus, in view of these animals' great need for regular mud-baths.

The assumption in section 4 that there were few oaks on the sand and the loess, could also lead to the conclusion, that the valleys were more attractive to the boar. Beeches were not or hardly present in the period under consideration, so that acorns must have been an important part of their food.

For all wild animals it seems to apply that the density increases as the landscape opens (Tschermak 1950). If we may assume that the LBK occupation created clearings we may also assume that the density of the wild animals increased during that occupation.

At Hienheim the conditions for the conservation of bones are somewhat more favourable than in Southern Limburg. The loess is decalcified at Hienheim until approximately 80 cm beneath the surface, so that the deepest pits reach into the calcareous subsoil. As a result, some bone material has been found during the excavation. The material has been described by Clason (Clason in press). It comprises the following species: squirrel, beaver, bear, wild boar, red deer, roe deer, elk and unidentified remnants of fish. Among the cattle-bones there are some of which it cannot be determined whether they belonged to domesticated or to wild cattle. The animals, which Clason found in the material of the Stichband- and Rössen-settlement, can be added to the list. It is true that these animals lived some centuries after the LBK occupation, but we feel that we may assume that animals from e.g. the Rössen-period were already present in the area during the LBK occupation. We can then add fox, badger, two bones identified as aurochs and one as a Cyprinide, but not carp, to the list.

A further addition can be obtained from the find material of the settlements Regensburg-Pürkelgut and

Regensburg-Kumpfmühl. The first has been dated as LBK/Stichband/Rössen, the second dates from the period of the so-called Bayerisch Rössen. The identifications are by Boesneck (Boesneck 1958). Regensburg lies in a similar surrounding as Hienheim, 30 km to the north-east. Boessneck's list mentions, in addition to the beaver, bear, wild boar, red deer, roe deer, aurochs and fish remains which were also found at Hienheim, a bird of the size of a duck, and a hare. With respect to the latter, Boessneck states that the bone looked as if it did not date from the Neolithic, but from a later period. Therefore it is not sure whether the hare belongs to the list.

Concerning the biotopes of the species found at Hienheim Clason remarks: "The squirrel lives in needle woods as well as foliage tree woods, but favours young, dark forests. The beaver lived in light woods with undergrowth along the river. The fox can live in a variety of biotopes, but likes dry terrain. In the last century it has become apparent that the species can adapt itself very well to the man-made landscape of present day Europe. The bear lives in mixed deciduous woods. The badger can be found in the same woods, but also needs clearings in the vegetation. Red deer can live in woods as well as in open plains. The roe deer lives at the edge of a wood, young woods with much undergrowth or in the open plain if there is enough shrub cover. The elk needs open woods with much undervegetation. In summer, the species likes marshy areas, but in winter it prefers higher and drier terrains (van den Brink 1968).* It seems quite possible that all those slightly differing biotopes could have been found within walking distance from the settlements. The Danube valley was inhabited the year round by the beaver and in summer by elk, the undisturbed woods by the squirrel, bear and red deer. The badger and roe deer can have profited from the opening of the forest by man, while the fox could have lived anywhere. The aurochs would have appreciated the open spaces created by man, with their tree succession."

We fully agree with Clason's remark that all biotopes mentioned by her could probably be found within walking distance around the settlement. It is impossible to give a more detailed description, as we know very little about the vegetation around Hienheim. Perhaps there was more open forest around Hienheim in the dry limestone area than there was in our area around Sittard, Stein and Elsloo. For the rest we could produce a description of the fauna around Hienheim similar to that for the fauna in Southern Limburg.

We shall not try to indicate the densities of the animals mentioned by Clason, as a sufficient detailed reconstruction of the vegetation is not available. The only thing to be said about numbers is that perhaps the red deer was more numerous than the roe deer, because far more bones were excavated of the red deer (29 bone fragments) than of the roe deer (7 bone fragments). In saying this, we assume that man shows the same behaviour as the animals to which the following quotation relates: "Lukas Tinbergen, Harvey Croze, John Allen, Ian D. Soane, David T. Horsley and I have found that frequency-dependent selection is often encountered in the behavior of hunting animals. Not only fish but also predatory birds and mammals seem to concentrate on common types of prey and to overlook rarer types." (Clarke 1975 p. 58). Such a behaviour implies that abundant animals will be found relatively more often in waste material than rarer animals. Of course, comparisons should only be made when the respective animals and their remains are more or less comparable. It is, for example, not justified to say that the squirrel was much rarer than the red deer, because only one squirrel-fragment has been excavated. However, we are not capable of judging whether the assumption that hunting men react in the same way as hunting animals is allowed; therefore we make the remark concerning the frequency of red deer and roe deer with great reserve.

* See our reference van den Brink 1972.

III. 6 HUMAN POPULATIONS

After the environmental factors climate, substrate, vegetation and fauna have been studied, one environmental factor remains to be discussed: the presence or absence of people who do not belong to the settlement. These may be people from the same "culture" or people with a quite different "culture". As far as we know, there are two population groups in our case which will have to be considered. The one group consists of people who lived in nearby LBK settlements. The other group is formed by a population with a Mesolithic tradition which might have been present.

Several LBK settlements are known in the surroundings of Sittard, Stein and Elsloo, which themselves are located less than 10 km from each other and are therefore neighbours in this respect. Besides, a rather large number of other sites have been found within a distance of 10 km. The sites shown in figure 2 are taken from a distribution map published in 1970 (Modderman 1970). It is true that some more sites have been found since then, but this does not change the distribution pattern. We were able, however, to incorporate these recent observations in figure 16. One of the sites shown in figure 2, the dot on the west bank of the Maas, lies just outside the 10 km zone. This settlement, Caberg, is linked to a concentration of settlements in Belgium.

The question is whether the settlements which are shown on the distribution map existed simultaneously. They are all Linearbandkeramik, it is true, but this culture lasted circa 400 ± 50 years (Modderman 1970 p. 201). It is very well possible that some settlements were already abandoned while others were yet to be founded. C14 dates are of no use in answering this question, because their rather great inaccuracy makes them useless to demonstrate simultaneous presence in a case like this. The decorated pottery and the typology of the houses offer more possibilities for a division into time phases (Modderman 1970). The phases distinguished, Ib through IId, of which mention has been made in chapter II, would each have lasted 3 to 4 generations at the most (Modderman 1970 p. 201). We assume that settlements, which belong to the same phase, really existed simultaneously, although we are unable to prove this at the moment.

In agreement with Modderman, we do not think it probable that the settlement was rebuilt on a completely new terrain each generation, or even within a generation. Probably the population displaced itself within a limited area in the course of time. This displacement would explain the large surface over which traces of occupation have been found. The traces of Sittard cover circa 10 ha. Traces at Stein have been found over a surface of 6 ha, and Elsloo covered at least 10 ha. Several phases, as these are recognized in the pottery decoration and in the typology of the houses, are represented in these large areas. At a certain time, only a part of the area which shows traces of occupation nowadays, was really inhabited. This phenomenon implies that a small test (a small excavation) can never answer the question during which phases of the LBK a settlement was occupied. Those sites which are known only by the investigation of some waste-filled pits, cannot be dated satisfactorily by means of the contents of those pits. Best dated are those settlement areas of which a considerable part has been excavated. In Southern Limburg there are four of them: Sittard, Stein, Elsloo and Geleen-Kluis.

The dates of all settlement areas known to us are mentioned in table 3. It appears from the excavated material of Sittard, Stein and Elsloo, that these three places existed simultaneously during a number of phases. We think that the discontinuity in the material of Stein is due to the fact that only a part (not even one third) of the area has been excavated. The absence of phase Id at Stein can be explained more simply by assuming that the LBK houses of this phase are located under recent buildings, than by assuming that the area was not occupied in the phase in question. In the present publication, we start from the assumption that all three settlements were occupied continuously. They were each other's neighbours. Moreover, there were still other settlements within a radius of 10 km. We shall discuss this matter again in chapter V.

Table 3. The LBK settlement areas between Maas and Geleen and the phases during which they were occupied; phases according to Modderman 1970.

	Ib	*Ic*	*Id*	*I*	*IIa*	*IIb*	*IIc*	*IId*	*II*	*unknown*	*references*
1 Beek-Kerkeveld (= Hoolstraat)	—	—	—	—	—	—	×	—	—	—	Archives ROB
2 Beek-Molenstraat	—	—	—	—	—	—	×	—	—	—	Beckers & Beckers 1940
3 Beek-Proosdijveld (= O.L.V. Plein)	—	—	—	—	—	—	—	×	—	—	Archives ROB
4 Berg-Dorpskom	—	—	—	—	—	—	—	—	—	×	Beckers & Beckers 1940
5 Elsloo	×	×	×	—	×	×	×	×	—	—	Modderman 1970
6 Elsloo-Geulle	—	—	—	—	—	—	—	—	—	×	Beckers & Beckers 1940
7 Elsloo-Heide	—	—	—	—	—	—	×	×	—	—	Archives ROB
8 Elsloo-Julianastraat	—	—	—	—	—	—	—	×	—	—	Beckers & Beckers 1940
9 Elsloo-Spoorlijn	—	—	—	—	×	×	×	×	—	—	Archives R.M.v.O.
10 Geleen-Daalstraat	—	—	—	—	—	—	—	—	—	×	Beckers & Beckers 1940
11 Geleen-Kluis	×	—	—	—	—	—	—	—	—	—	Waterbolk 1958/1959
12 Geleen-Noord	—	—	—	—	—	—	×	—	—	—	Archives ROB
13 Geleen-Rijksweg (= Kermisplein)	—	—	—	—	—	—	×	×	—	—	Archives ROB
14 Geleen-Station	—	—	—	—	—	—	×	×	—	—	Bursch 1937, Bloemers 1971/1972, Archives ROB
15 Geleen-Zuid	—	—	—	—	—	—	—	—	—	×	Archives ROB
16 Sittard	×	×	×	—	×	×	×	×	—	—	Modderman 1958/1959d
17 Sittard-Philips	—	—	—	—	—	—	—	—	—	×	Archives ROB
18 Sittard-Zuid (= Ophoven)	—	—	—	—	—	—	—	—	—	×	Archives ROB
19 Stein	×	×	—	—	×	×	×	×	—	—	Modderman 1970
20 Stein-Haven	—	—	—	—	—	—	—	—	—	×	Holwerda 1928
21 Stein-Heideveldweg	—	—	—	×	—	—	—	—	—	—	Beckers & Beckers 1940
22 Stein-Huis 50	—	—	—	—	—	—	—	—	×	—	Modderman 1970
23 Urmond-Graetheide	—	—	—	—	—	—	×	—	—	—	Beckers & Beckers 1940
24 Urmond-Hennekens	—	—	—	—	—	—	×	—	—	—	Beckers & Beckers 1940

As explained in section 1 of this chapter, the possibility exists that a region with a radius of 10 km is too small when we want to show with which other people the inhabitants of the settlements in question could keep in daily contact. A region with a radius of 30 km would be the maximum, within which daily visits and the like could be made. When we check if there were LBK settlements beyond the 10 km radius around Sittard, Stein and Elsloo, we can point first at the already-mentioned settlement at Caberg. Caberg is the eastern most of a group of settlement areas to which, among others, Rosmeer belongs. Rosmeer would have existed both during the old and the young LBK, as house-plans have been found from periods I and II (Modderman 1970 p. 113). Further to the south-west, along the river Jeker or Geer, a large number of settlements have been found which, in as far as is known, seem to belong to the younger LBK (de Laet 1972). North of Sittard are the seemingly isolated settlements of Montfort and Horn, of

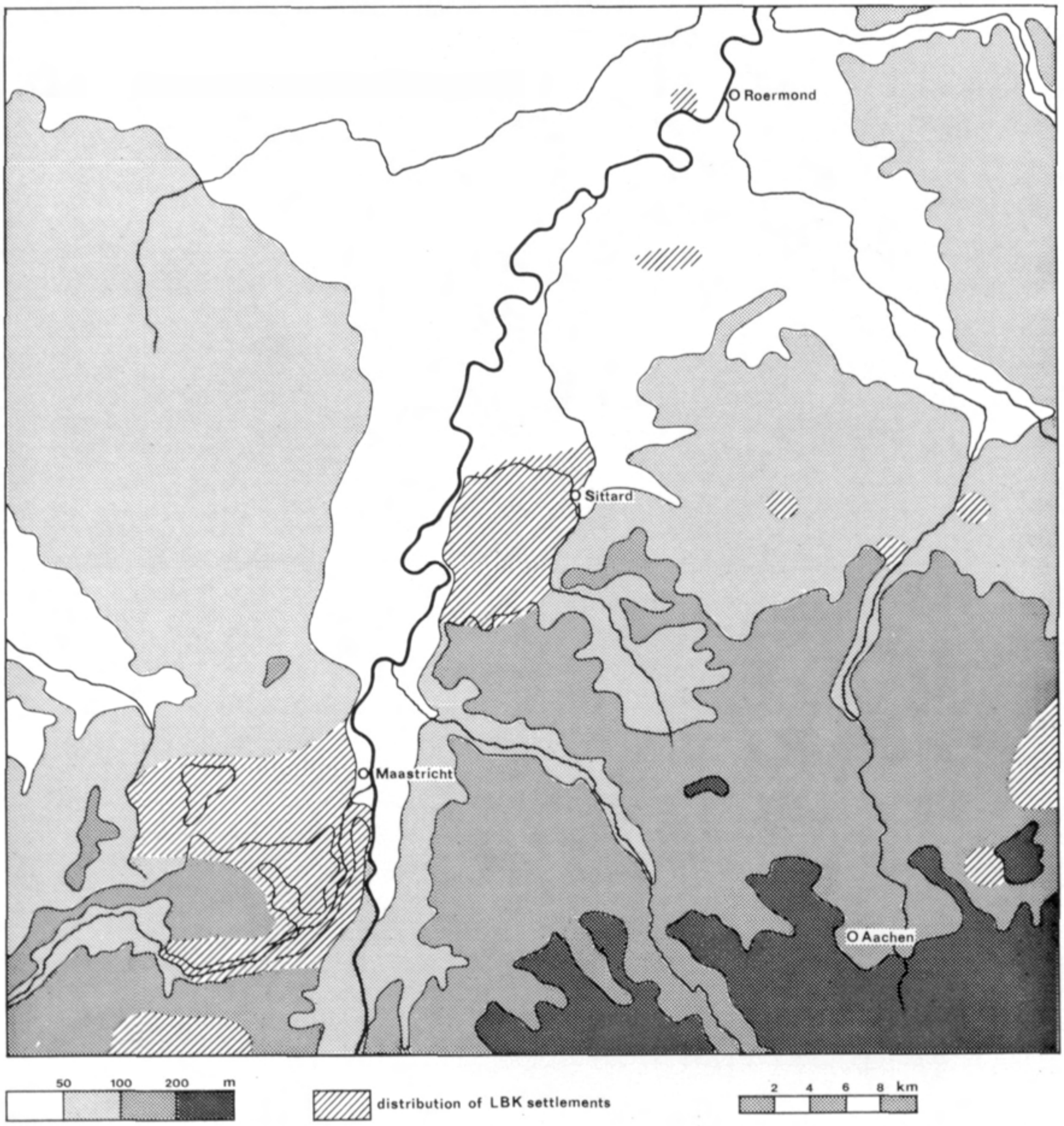


Fig. 8. Generalised distribution of LBK settlements within a 30 km distance of Sittard, Stein and Elsloo. Scale 1:400 000.

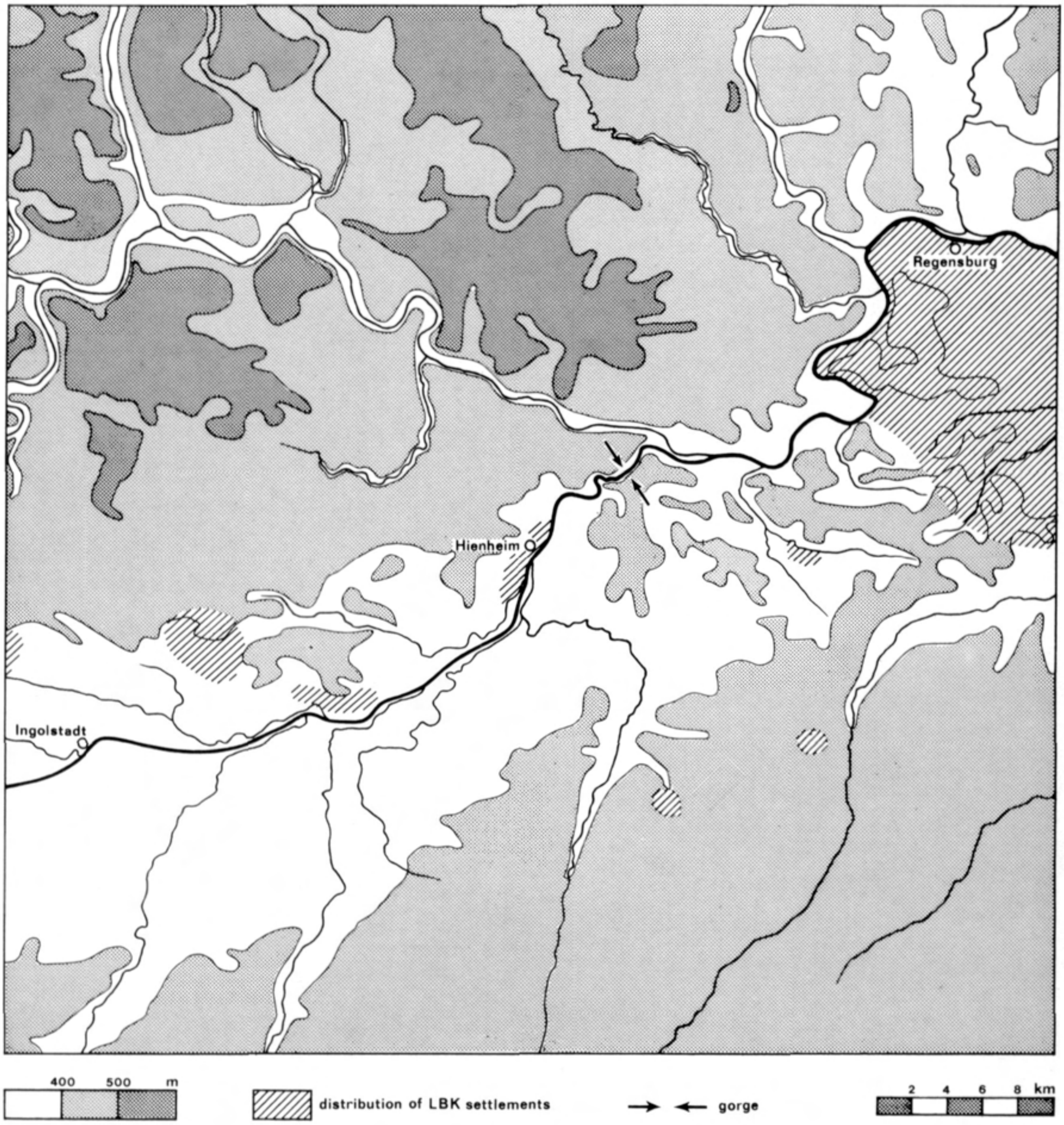


Fig. 9. Generalised distribution of LBK settlements within a 30 km distance of Hienheim. Scale 1:400 000.

which little is known. They existed at least during period II. East of Sittard, Stein and Elsloo there are large concentrations of traces of occupation, among which those of the Aldenhovener Platte are the best-known. These areas were inhabited during all the periods which were found in Southern Limburg (Dohrn-Ihmig 1974).

These places, where bearers of the Linearbandkeramik culture lived, are shown in figure 8. When contacts with other LBK people outside the own living area between the rivers Maas and Geleen existed, these were directed to the south-west and particularly to the east. In as far as the physical condition of the terrain is concerned, the contact should not have been difficult to establish. Figure 8 also shows the relief and the large water-courses. Neither water, nor important differences of altitude obstructed contacts. Whether contacts really took place is of course a different matter.

The LBK settlements from an area extending with a radius of 10 km around Hienheim, have become known in the first place by surface-collections made during surveys. They are located in the territories of the municipalities Hienheim Ldkr. Kelheim and Irnsing Ldkr. Kelheim, and have been called Hienheim-Fuchsloch, Irnsing-Schanze and Irnsing 1. In Autumn 1975, Modderman carried out excavations at Hienheim-Fuchsloch and at Irnsing-Schanze, among other things in order to obtain a more accurate date for these settlement areas. The soil traces at Irnsing-Schanze turned out to have disappeared almost completely by erosion. Hienheim-Fuchsloch provided more data. These are still being studied. It is obvious, however, that Hienheim-Fuchsloch existed simultaneously with Hienheim (van de Velde 1976 verbal information). The scanty data concerning Irnsing-Schanze and Irnsing 1 make any such statement impossible. During our surveys we could discover no other settlement areas with LBK material. The places are shown in figure 3 as well as in figure 17.

In figure 3 there is, be it beyond the 10 km radius, one more site: Herrnwahlthann Ldkr. Kelheim. This is a first indication that the group of settlements at Hienheim is not isolated, but that there are more LBK settlements within a radius of 30 km. The respective areas, where LBK occupation has been proved, are shown in figure 9. There are settlements near Ingolstadt and a very large concentration has been found south of Regensburg. In both areas traces of occupation have been found, which date from the same period as Hienheim. It follows from the distribution map that Hienheim might have maintained most contact with areas in the east and in the west. There is clearly an axis along the river Donau. Linearbandkeramik has never been found north of Hienheim; it appears that LBK settlements are represented rarely in the south. Obstacles in the terrain should not have hampered possible contacts. The main obstacle is on the way between Hienheim and Regensburg. If one travels along or on the Donau, a place must be passed where the Donau streams through the Jurassic reef limestone via a gorge: the Weltenburger Schlucht. The current is very fast at this place and the sides of the valley are high and steep. But one can easily travel overland south of the gorge.

The LBK occupation around Sittard, Stein and Elsloo on the one hand and around Hienheim on the other hand is concentrated in certain areas, as show figures 8 and 9. Between these concentrations no traces of the Linearbandkeramik culture are found, apart from some isolated objects. Especially as far as Southern Limburg is concerned, this is certainly not a hiatus due to lack of investigation. There are two possibilities with regard to the occupation of the "empty" areas: 1) nobody lived there, 2) another population group lived there. The latter could then have been a group with a Mesolithic way of life. From both regions Late-Mesolithic sites are known. For Southern Limburg mention may be made of the place Sweykhuizen, which is located 5 km south of Sittard, on the east bank of the river Geleen (Wouters 1952/1953, Bohmers & Wouters 1956). Moreover, finds have been made north of Sittard (Newell 1970, van Haaren & Modderman 1973). For Hienheim, we remind the reader of sites along the Altmühl (Naber 1973) and of traces of occupation near Sarching Ldkr. Regensburg (Schönweiss & Werner 1974). An absolute date of these places is unfortunately not available yet. It seems, however, that the inhabitants of LBK settlements had something to do with a Mesolithic tradition, as influences of this tradition can be found in the typology of the flint artefacts (Newell 1970, Taute 1973/1974b). For Newell the simultaneous presence of LBK and Late-Mesolithic in Southern Limburg is therefore certain: "The Mesolithic microliths, recovered from Bandkeramik contexts . . . are unmistakable indications of the contemporaneity of the Mesolithic and Linearbandkeramik populations and also that contact and acculturation took place". (Newell 1970 p. 167, see also Newell 1973 p. 408). Taute, however, could hardly prove such contacts for Southern Germany. He remarks that only very few indisputable indigenous artefacts have been found in a LBK-context. Neither does he wish to make a connection between ground stone adzes in Mesolithic context (e.g. at Sarching) and a Neolithic influence. Yet, the periods in which the Late-Mesolithic and the Early-Neolithic were present in Southern Germany, overlapped each other at least partially, so that contact is not excluded. The difficulties experienced in trying to prove such contacts are attributed by Taute to the low density of the Late-Mesolithic population and/or a rapid acculturation (Taute 1973/1974 a and b). All in all it is probable, in our opinion, that the areas which were not occupied by the Linearbandkeramik culture, were used by people with a Mesolithic tradition. We consider a contact between both population groups not excluded.

III.7 FINAL REMARKS

In the above sections we have tried as far as possible to reconstruct the environment of the settlements chosen for our investigation. In doing so, we followed the ideas developed in section 1. The only factor which we have not taken into account, is the presence of raw materials within the home range. We think it better to discuss this aspect in chapter IV, in which the raw materials will be studied.

We have tried to make the reconstruction as detailed as possible. At the moment we fail to see how the accuracy can be increased. Only at an occasional point could more investigation bring improvements at short notice. A more detailed description of the vegetation around Hienheim will become available when more palynological research has been carried out.

The environment in the area which we have called "Southern Limburg" for convenience' sake, appears to show both differences and similarities with the environment of Hienheim. A factor in which a difference can be distinguished, is the climate, which at Hienheim had a somewhat more continental character than in Southern Limburg. Also the substrate is different. The terrain around Hienheim is characterized by landscape units in part differring from those in Southern Limburg. The distribution of the landscape units over the Hienheim region has a very disjointed appearance, this in contrast to Southern Limburg where the major landscape units cover coherent surfaces. Similarities are found in the presence of a loess landscape and a river-valley landscape, which are both present in the immediate vicinity of all four settlements. Another shared characteristic is present in the vegetation. Both areas were covered with deciduous forests, although less is known about the forests near Hienheim than about those in Southern Limburg. The respective faunas had perhaps many animal species in common: at least it is certain that deer, roe deer, boar and aurochs were present near Hienheim, as well as in the surroundings of Sittard, Stein and Elsloo.

The question is to what extent the similarities and differences had a recoverable influence on daily life in the four settlements. Connected thereto is the question to what extent the reconstruction of the environment answers the purpose, whether it is insufficiently detailed or, on the contrary, offers superfluous information. These questions can be answered only when the relation between the settlement and its environment has been subjected to a closer study. Only at the end of our study shall we be able to say how relevant our reconstructions are.

IV

THE RELATIONS BETWEEN THE INHABITANTS OF THE SETTLEMENTS AND THEIR ENVIRONMENT

IV.1 INTRODUCTION

The presence of settlements in the environment described in chapter III implies that the inhabitants of the settlements were able to survive in that environment. In particular, it means that they were able to derive both food and drinking water from it, either directly by the local presence of both vital necessities, or indirectly by the presence of a factor by which these could be obtained. The main relations between man and environment are thus established and food and water are therefore the first subjects to be discussed.

Food and water, however, are not the only factors that can be placed in the framework of relations between man and his environment. Man without tools is inconceivable and man usually possesses many other items. A number of these objects are retrieved during excavations. Further, traces of buildings have been revealed in the settlements. The raw materials for objects and constructions must have been taken from the environment. Hence the origin of the different raw materials is the third object to be discussed.

The fourth subject relates to another universal aspect, namely fire and the fuel rẹquired.

As we have explicitly included in the environment the presence of groups of people other than those who inhabited the settlements under examination, the fifth subject of our study should deal with the relations between the settlement and the neighbouring populations. Such a description, however, requires an insight into the nature of contacts between groups of people in general. Since we do not have the necessary knowledge, we shall forgo this study and restrict ourselves to the four material aspects listed.

In our opinion, the description of material things should in principle provide three kinds of data: a qualitative description, a statement about the origin and an indication of the quantities used. In practice, the emphasis will be on a different kind of data for each subject.

Where food is concerned, a description must be given of the plants and animals which were eaten; it must also be stated whether or not the food was gathered or produced by the inhabitants of the settlements themselves. If the inhabitants provided their own food, the origin of the foodstuffs, or at least the size of the area around the settlement where it came from, can be worked out. As said in III.1, people seldom travel further than 1 or 2 hours' walking distance from their settlement to get food. Gathered or produced foodstuffs must have come from the site territory defined in III.1, that is in an area with a radius of 10 km at the most around the settlement. One can try of course to indicate whether some parts of the site territory were more important than other parts for the origin of a certain type of edibles. One may try e.g. to determine the location of fields. A quantitative consideration of the food supply must of course not be excluded, since the quantity of food available for consumption is of great importance for the life in the settlements.

With respect to the water supply, the quality of the water and the quantity available in each season play a part. In our areas of Southern Limburg and Niederbayern the presence of freshwater throughout the year is nothing special, so that this aspect will hardly be mentioned. However, a quantity to be established is the distance between the water and the settlements.

A central point in the description of each kind of raw material is its origin. By comparing the materials from the settlement with the materials present in the environment, an attempt may be made to determine the possible origin. The underlying thought in this investigation is that people tried to avoid the transportation of materials as much as possible. Starting from the assumption that raw materials from the vicinity of the settlement were preferred over raw materials that had to be brought some distance,* we first compare the raw materials of artefacts and the like with their nearest sources. When a good similarity is found, it is very probable that the raw materials in question indeed came from the investigated places. When no satisfactory parallel can be found among the materials in the direct surroundings of the settlement, locations further away may be taken into account. Thus, three types of provenance may be distinguished here. The first one is the "site territory" as defined in III.1: materials from this area may be said to be locally present, since they could be fetched daily by the inhabitants of the settlements. The second is a source in the "home range" as defined in III.1, that is from the area which can be visited within one day and which theoretically covers a circle with a radius of 6 hours' walking distance or 30 km. This material too could be obtained daily. The distinction is made because the area qualified as "site territory" was indeed visited daily according to statements from the ethnographic literature, whereas our "home range" is largely a theorethical area (see III.1). Raw materials which must have come from outside the home range, could not have been obtained within one day's travelling. If the inhabitants of the settlements went themselves to get these materials, they had to spend the night elsewhere. This implies the organization of smaller or larger expeditions. The alternative is that the inhabitants got the materials or the objects made thereof through others. In both cases we should like to speak of imports and we call the raw materials or goods in question imported raw materials or goods.

In the framework of relations between the settlements and their environment, the quantitative aspect of the investigation of raw materials is relevant only, in our opinion, there where such quantities are needed that demand exceeds the supply. In our investigation we see a reason to speak of quantities only where building materials are concerned. The raw materials of smaller objects are of such a nature, that we cannot believe that the sources were exhausted by the exploitation.

Finally the qualitative and quantitative aspects of the fuel as well as its origin are investigated in as far as possible.

Food, water, raw materials and fuel were taken from the environment by the inhabitants of the settlements and one may ask whether the environment changed as a result of these activities. The influence which the inhabitants of the settlements exerted on their environment is certainly a subject that belongs in the framework of relations between man and environment. Therefore we discuss as last subject the possible changes which occurred in the environment because of the presence of settlements.

* "Luxury articles" can be an exception. We think of small, light objects such as ornaments.

IV.2 FOOD AND FOOD PRODUCTION

The organic remains, relevant to the food consumed by the inhabitants of the settlements can be subdivided into remains of plants and remains of animals. These will be discussed separately, followed by a recapitulation.

FOOD OBTAINED FROM PLANTS

In a climate like that of Western and Central Europe remains of plants, unless they are preserved in an anaerobic or saline environment, are preserved only when they are in a carbonized state. Uncarbonized vegetal tissue rots and disappears. There is one exception to this rule: the opal-phytoliths, which are formed in the cells of certain species of plants such as the grasses, consist entirely of silica and therefore stay intact. The original species can sometimes be recognized by these silica bodies. A third source of information, besides the carbonized remains and the opal-phytoliths, are the impressions left by plants in loam that has been fired afterwards.

As the settlements of the LBK under study are located neither on wet nor on salt terrain, we depend on carbonized material, on impressions and possibly on opal-phytoliths for information concerning vegetable foods. Opal-phytoliths were not investigated since the data which they might provide are of limited importance and the material is, moreover, difficult to interpret (Peters 1968).

The carbonized material consists almost entirely of charcoal, which will not be discussed yet, and of carbonized seeds and fruits.* Roots, stems and leaves are absent, apart from a few exceptions. Apparently they do not leave identifiable remains when carbonized. In addition to carbonized seeds, we also find carbonized remains which are visible as crusts on pottery fragments. The examination of these crusts has not yet provided anything recognizable. Similar carbonized remains are found frequently on LBK pottery. We are aware of two settlements where these remains have been identified, namely Herkheim Ldkr. Nördlingen and Nähermemmingen Ldkr. Nördlingen. In the carbon, Grüss found remains of emmer wheat (among other things starch grains), of the horsebean (Vicia faba) and of beer-yeast (Grüss in Frickinger 1932, 1934). Grüss' identifications are, however, open to criticism.

Carbonized seeds are present everywhere in LBK settlements in the rubbish filling the pits. But the seeds are rarely together in large concentrations, so that they are easily overlooked in excavations. Besides, not all pit-fillings contain remains. The low density of the seeds is probably the reason that no attention was paid to them during the excavations of Sittard, Stein and Elsloo. In an attempt to gather more information, all the charcoal samples which were not used for C14 dates were examined for possible seeds. This post-examination was succesful in two cases. Moreover, we recently had the opportunity to examine a pit-filling from the LBK settlement Beek-Kerkeveld-Hoolstraat. The seeds found are enumerated in table 4.

* In the following we often use the word "seeds" when also fruits and the like are meant.

Table 4. Carbonized seeds from Southern Limburg.

	Sittard 81	*Sittard 250*	*Beek*
Sample size, dm^3	0.2	0.1	7
Triticum dicoccum (emmer)	—	12	2
Triticum monococcum (einkorn)	—	—	2
Triticum sp.	2	—	15
Spikelet forks of Tr. monococcum or Tr. dicoccum	—	4	9
Papaver somniferum var. setigerum (poppy seed)	—	—	1
Chenopodium album	26	—	10
Lapsana communis	—	—	12
Bromus secalinus	—	—	33
Echinochloa crus-galli	—	—	1
Polygonum convolvulus	2	—	20
Polygonum persicaria	—	—	6
Rumex sp. (non R. sanguineus)	—	—	1
Galium spurium	1	—	—
Corylus avellana	—	—	1
unidentifiable	—	—	4

During the exacavation at Hienheim soil-samples from the pit-fillings were sieved, which led to the frequent appearance of seeds. The results of the sieving are mentioned in Appendix II. The list of species comprises 5 cultivated plants and 23 wild plants.

The information obtained from carbonized material could in principle be supplemented with data gathered from the impressions on pottery and on daub. From a summary by Willerding it appears, however, that the number of plants which manifest themselves as impressions is limited (Willerding 1970). The species with large seeds, and particularly the cereals, are predominant, whereas other plants are found extremely rarely. Willerding's findings are confirmed by an investigation of Bandkeramik potsherds from Nerkewitz Kr. Jena (Tempír & Gall 1972). It is not surprizing therefore that our examination of the impressions from Stein and Hienheim has added no new plants to the list. The loam now found as lumps of daub, in as far as it contained any plant material, was always mixed with chaff fragments of emmer and einkorn. Sometimes chopped cereal- or grass-stalks occur, whereas at Hienheim we once found the impression of a pea and once the impression of Polygonum convolvulus. By the way, the examination of the daub from Stein was started already in 1938 by Helbaek (Beckers & Beckers 1940). He too found only emmer and einkorn. The pottery from Stein and Hienheim appears to show very few impressions. At Hienheim all potsherds from 25 pit-fillings were examined: only four of them showed identifiable impressions, of which two were caused by emmer and two by einkorn. Two emmer impressions were observed at Stein. Because of the low efficiency, the study of impressions at Sittard and Elsloo was not undertaken.

It results from the above that in an attempt to describe the food from plants of the LBK, we shall be occupied exclusively with the interpretation of carbonized seeds and in particular with the interpretation of carbonized seeds from Hienheim.

In the investigation of food-plants, the domesticated plants must be considered in the first place. Although not all plants which were domesticated in the course of time were meant as human food, it may be accepted that the cultivated plants found were all consumed. These are: two species of cereals, namely the wheat species emmer and einkorn, two species of pulses, namely pea and lentil, and two oil-bearing seeds, namely linseed and poppy seed. Among the non cultivated plants there are also edible species. This applies certainly to the hazel-nut which, by the way, is much rarer than would have been expected. Hazel-nuts must have been abundant in the surroundings of the settlement. The pollen of hazel indicates that this plant was generally present. In the Late-Mesolithic settlement Sarching Ldkr. Regensburg, the presence of hazel-nuts was already observed during the excavation (Schönweiss & Werner 1974). But both at Hienheim and Beek only a single fragment was found.

Another wild plant that could have been part of the menu is Bromus secalinus. The fruits of this plant form a conspicuously large part of the find from Beek, so that in this respect it is very similar to the finds from the Rheinland, which Knörzer studied thoroughly. Knörzer assumes that the fruits of Bromus secalinus were consumed (Knörzer 1967b). He presents a series of arguments for this point, the main ones being: 1) Bromus secalinus is present in relatively very large quantities in the examined sites. 2) The grains of Bromus secalinus always occur together with grains of cereals and have been carbonized in the same way. The grains were not thrown away as weeds with the chaff of the domesticated cereals. 3) The grains are of the same size as the Neolithic cereal species. Therefore they are not inferior, in this respect, to the cultivated plants. 4) The grains were always found without their glumes. These had been removed (Knörzer 1967b p. 35 and 37). The lighter grains of the other Bromus species are considered by Knörzer as true weeds. So far very little Bromus secalinus has been found at Hienheim, as opposed to the Rheinland. There is only one find-number with a rather large number of Bromus grains, but there appears to be no Bromus secalinus in this find. Considering the evidence, we cannot, therefore, say that the inhabitants of Hienheim consumed Bromus regularly.

A third wild plant which could have been eaten is Chenopodium album. This plant was eaten as a leaf vegetable in historic times (Singer et al. 1954). The few seeds which we found could have come from plants gathered as leaf vegetables. Population groups are known, however, which also used the small seeds as food (Dembińska 1976, Helbaek 1960). Until concentrations of seeds, for example in vessels, have been found, proof for the consumption of the seeds in the LBK is absent. Large numbers of Chenopodium album seeds have so far only been found in the Rheinland. Knörzer considers these seeds as waste, which was thrown away when the vegetables were cleaned (Knörzer 1973 p. 149).

Similar problems of judgement arise in the interpretation of other small seeds. It is quite possible that the seeds of Polygonum convolvulus or Echinochloa crus-galli, which seeds are rich in starch, were consumed, but as long as no clear concentrations are found, this can not be considered as proved. Moreover, some species of plants are more likely to have been consumed than others. It is improbable that, for example, Solanum nigrum was eaten, as this plant is poisonous.

Subsequently, the relative composition of the vegetable foods should be established. This question is difficult to answer. At Hienheim the carbonized cultivated plants are in the majority as to number of specimens and certainly in weight. This fact does not tell much, as it is certain that not all the plants used originally are represented by the carbonized seeds. The lack of evidence as to roots and leaves has already been mentioned. Besides, it is known that some seeds and fruits stand a greater chance of becoming carbonized than others. This becomes clear when the plant material from settlements on wet terrain is studied. In such settlements both carbonized and non carbonized seeds occur, but the composition of the former always differs strongly from that of the latter with respect to the individual species as well as to the ratio between their numbers (e.g. Körber-Grohne 1967, Hopf 1968). The cause of this phenomenon could be that the seeds were not carbonized arbitrarily, as would be the case in a fire in the settlement, but that the carbonization is the result of specific, human actions, so that a selection took place. In settlements where only the carbonized material is still present, it is this selection exclusively which is found during the excavations. In our opinion, this also applies to the seeds which originate from LBK settlements. The very regular occurrence of small quantities of seeds, scattered over the entire settlement area, may be considered as an argument in favour of the thesis, that carbonized seeds are not the remains of a catastrophic fire, but the results of the normal course of events. Concentrations of carbonized seeds which would represent carbonized stocks (results of a fire) are extremely rare in LBK settlements. At Hienheim not a single find qualifies for such an interpretation since the number of seeds per dm^3 is nowhere large enough. All seeds give the impression of having been thrown away in a carbonized state as waste.

The carbonized waste would be the result of small mistakes committed in certain activities. Willerding, Knörzer and Gall, among others, have suggested a number of processes in which carbonizing could occur (Willerding 1970, Knörzer 1973, Gall 1975). These processes can be divided into three categories. The first category relates to the preservation of the crop. It comprises the drying and kiln-drying of the harvested plants. The second category refers to the burning of waste, for example, of the chaff and the agricultural weeds gathered with the crop. The third and last category relates to the preparation of the food itself. Each of these activities probably results in a different composition of the now excavated assemblages.

As the assemblages provide no true picture of the seeds used in the settlement, it is impossible to reconstruct the food composition exactly. On the other hand, it is possible in certain cases to distinguish the results of the above three categories of activities. This implies that we can try to subdivide the seed assemblages into assemblages which were not yet suitable for direct consumption, such as unthreshed cereals (carbonized during the drying or kiln-drying), assemblages which were not meant for consumption, such as threshing waste, and assemblages which were directly suitable for consumption, such as stocks (carbonized during the roasting?) and burnt food remains. Assemblages in which cereals occur with quantities of chaff were unlikely to have been meant for direct consumption. The chaff remains which we have observed so far consist of the fork-shaped bases of the spikelets of emmer and einkorn. In the case of einkorn usually one grain develops per spikelet, whereas emmer spikelets are two-grained in most cases. In an unthreshed and non-winnowed quantity of wheat there are therefore at least half as many bases as there are grains. Even more spikelets will be found in threshing waste. The numbers of grains and spikelets are mentioned in table 5. We have listed only finds with 50 or more grains; we consider finds with less too small to justify a judgement. For the bases a maximum and a minimum number are given, because most bases have been broken lengthwise and it is then halves which are being counted. The maximum number equals the number of whole + half bases, the minimum number is the number that would be present if all halves would fit together. The quantity which was originally present is probably situated between the two values.

Table 5. The ratio grains: spikelet bases in the wheat finds from Hienheim.

Find number	*grains*	*spikelet bases*		*grains:spikelet bases*	
		max.	*min.*	*min.*	*max.*
325	284	272	238	1:1	1:1
414	250	0	0	—	—
701	75	37	24	2:1	3:1
764	131	60	37	2:1	4:1
1140	155	149	76	1:1	2:1
1420	81	42	22	2:1	4:1

In our opinion, only number 414 could be considered as an assemblage which was directly meant for consumption. All others contain too much chaff. On account of the ratio grains: spikelet bases it can be assumed that these wheat assemblages had not yet been threshed.

Find no. 414, it must be noted, contains relatively little wheat; the main components are peas. It could be observed during the excavation that the wheat grains lay scattered among the peas. At least in the discarded material, the wheat constituted an admixture to the peas. This does not necessarily mean that both were eaten as a mixture. The find might originate from a pit similar to the one that has been found at Westeregeln, Kr. Wanzleben (DDR) where two small piles of carbonized seeds were found on the bottom, one consisting of peas and one of a mixture of emmer and einkorn (Rothmaler & Natho 1957). When such a pit is emptied, seeds which were originally separated become mixed. We think that the peas and the wheat were kept apart at Hienheim. Like 414, the finds 701 and 1089 comprise mainly peas, whereas 325, 764, 1140 and 1420 consist almost entirely of wheat. The composition of these finds is shown in fig. 10.

The meaning of the separation can only be surmised. It could be that peas and wheat were cultivated separately, but it is also possible that they were grown on the same field, but harvested separately. Finally, it is possible that they underwent different treatments after being harvested, for example being used in different dishes. Since no pea straw was found, there is no hint as to which phase of the crop treatment the pea finds were in.

In our opinion, einkorn and emmer were not distinguished strictly by the inhabitants of the LBK settlements, which is why we always speak of "wheat". At Hienheim both wheat species are invariably mixed, as was also the case at Westeregeln. Earlier, Knörzer and Tempir arrived at the same conclusion (Knörzer 1973 p. 148, Tempir 1966, p. 1327).

The assemblages mentioned so far comprise few weeds. It appears, however, that at Hienheim, besides cereals with chaff and few weeds (type 1) and peas with few weeds (type 2), there is a third type of pit-filling, consisting of weeds with some wheat (type 3). This type is represented by only one find number: 1211. In addition to weeds, there are many spikelet bases in this assemblage. The carbonized waste of 1211 may therefore perhaps be considered as waste from threshing, since it is conceivable that tall weeds were harvested with the wheat-ears, and burnt later with the chaff. Knörzer has repeatedly applied this interpretation to such remains (Knörzer 1967a, 1974). Indeed the seeds of weeds from 1211 belong to climbers (Polygonum convolvulus, Galium spurium) or to plants with long stems (Bromus species, Lapsana communis, Solanum nigrum; even Silne ducubalus can reach a height of up to 60 cm).

Summarizing it may be that among the seed assemblages which we found at Hienheim, there are five which could come from a still unthreshed crop (325, 701, 764, 1140, 1420), one which represents either an unthreshed crop or a thrown-away remnant of a stock (1089), one that could be the carbonized remnant of a stock (414) and one assemblage which could pass for threshing waste (1211). Carbonized remains of food preparation (if present at all) could not be recognized in the material from the rubbish-pits. This would have been the case if ground cereals and the like had been found. All carbonized seeds, however, had originally been intact. If unground seeds were used in the kitchen and were carbonized there in that state, then it is impossible to distinguish these carbonized remains from the threshed seeds from a carbonized stock. It is therefore possible that our carbonized stocks are in reality carbonized food. The crusts, which are found on the pottery, are probably real food remains, but they could not be identified, as was stated on page 58. It is therefore impossible to judge by the excavated material the quantitative composition of the food from plants consumed at Hienheim.

We know even less about the sites in Southern Limburg. It may be assumed that seed assemblages from the waste-pits in this area will show strong similarities with the assemblages from the Rheinland published by Knörzer (Knörzer 1967a, 1972, 1973, 1974), since both areas are connected in respect of their geography. The one substantial find made so far in Southern Limburg, the find from Beek, confirms this assumption. We have shown in figure 10 the composition of two of the nine settlements published by Knörzer, namely Langweiler–2 Ldkr. Jülich, and Garsdorf Ldkr. Bergheim, together with the assemblage from Beek. The picture is different from Hienheim. Our types 1 and 2, assemblages with comparatively large quantities of grain and assemblages with peas, are completely absent in the Rheinland. Even if Bromus secalinus is considered as a cereal, the pit-fillings with "cereals" are completely different from our type 1. The assemblages with weeds correspond to our type 3, but they do not always contain many spikelet bases. Knörzer distinguished assemblages which were meant for consumption (e.g. Garsdorf 44), and assemblages which represent threshing waste (Garsdorf 28, Langweiler–2 89 and 306).

The difference between Hienhein and the Rheinland is too great to be attributed to coincidence. It is quite possible that the difference is a regional one. The fact that the samples from nine settlements in the Rheinland always show the same type of composition may be viewed as a strong indication that the composition of the carbonized material within one region may well be constant. More settlements in Bayern would have to be examined in order to prove that, for example, peas are a characteristic of that area, as could well be the case.

The cause of the differences can only be guessed at, though several explanations are possible. One of them is that the different cultivated plants were grown in different quantities. Another possibility is that the way of preserving the crop was not the same everywhere. If peas, for example, were kiln-dried at Hienheim, but not in the Rheinland (and Southern Limburg?), the chance of finding carbonized peas will be greater at Hienheim.

We have tried to establish whether more of such regional differences can be found within the European area where LBK settlements are found. For that purpose all the finds known from the literature and containing 50 or more seeds have been gathered in figure 10. These are the finds from Göttingen-Hagenberg Stkr. Göttingen (BRD), Rosdorf Ldkr. Göttingen (BRD), Dresden-Nickern (DDR), Zwenkau Kr. Leipzig (DDR), Dneboh near Mnichovo Hradiště (ČSSR) and Opava-Katerinky (ČSSR). The data have been taken from Meyer & Willerding 1961, Willerding 1965, Baumann & Schulze-Motel 1968, Rothmaler & Natho 1957, and Tempír 1968. We have.also shown the earlier.mentioned find from Westeregeln. The name "Westeregeln" has been placed between parentheses to indicate that these assemblages are not completely comparable to the rest, because they do not originate from a pit.

There are clearly differences. In Opava-Kateřinky the peas (type 2) are absent in all cases, as are perhaps also the large quantities of weeds (type 3), although the latter could be the result of the method of taking the samples. The scarcity of the pea in the Czechoslovakian finds could be a characteristic of this area (see the tables in Hajnalová 1977).

The regions west and north of the Harz (with Rosdorf and Göttingen) are so far the only ones which have provided carbonized barley. In addition to Rosdorf and at Göttingen-Hagenberg, barley has also been found at Eitzum Ldkr. Wolfenbüttel (BRD), 75 km north-east of Göttingen (Hopf in Niquet 1963). The species is absent at Hienheim and, apart from a few impressions at Müddersheim Ldkr. Düren (Hopf 1965), also in the Rheinland. We think that this cereal was not cultivated at Hienheim, unless in very small quantities. The same applies to the settlements in the Rheinland (Knörzer 1976, verbal information).*

* The presence of barley at Köln-Lindenthal is not certain. The finds of barley at Böckingen, Eisenberg, Ettersburg, Hundisburg and Nähermemmingen have not, in our opinion, been dated sufficiently. The presence of impressions in material from Müddersheim, Nerkewitz, Mohelnice, Strzelce, Chelmza and Kotovane is an indication that barley was more widely known than the carbonized finds would suggest.

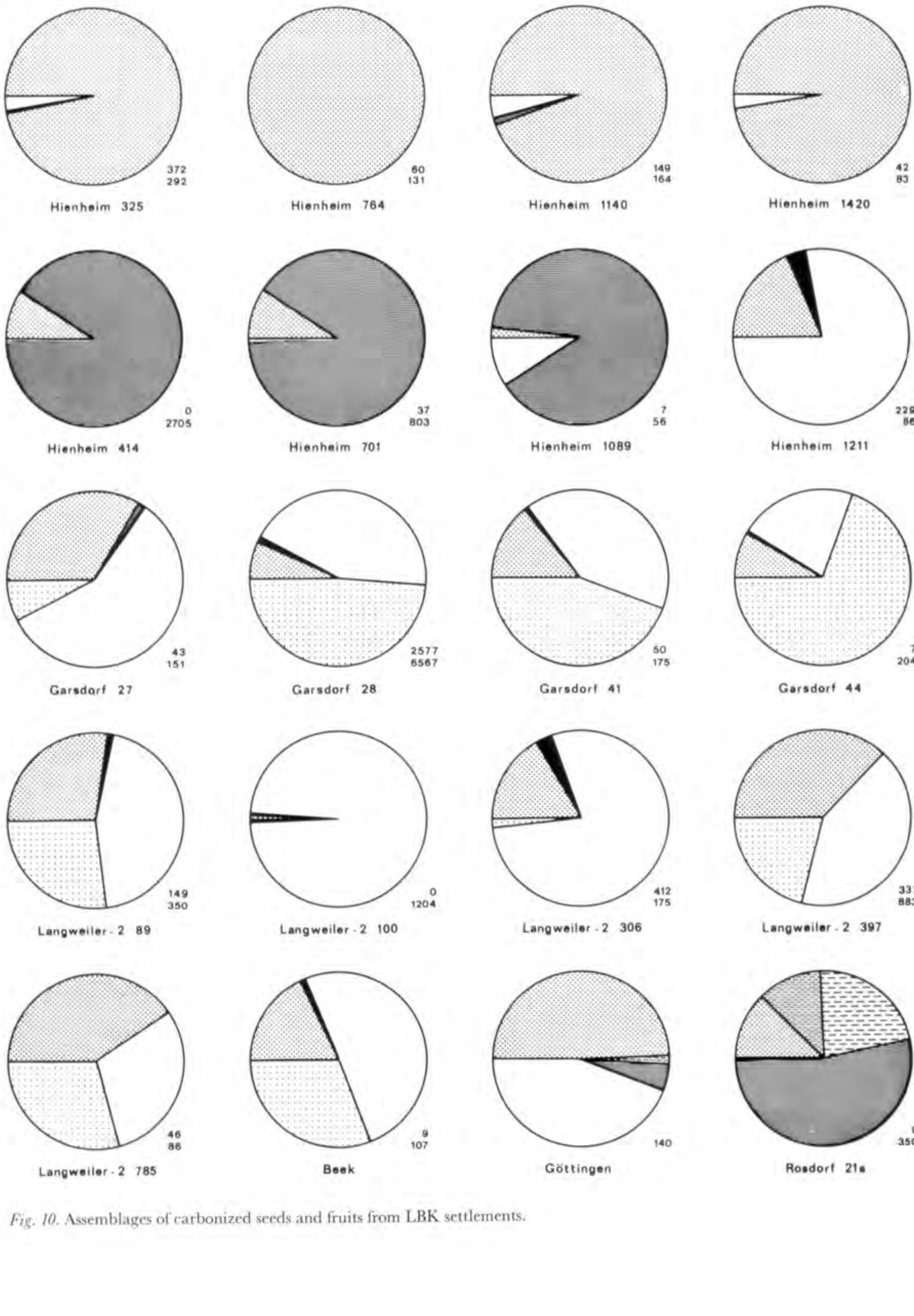
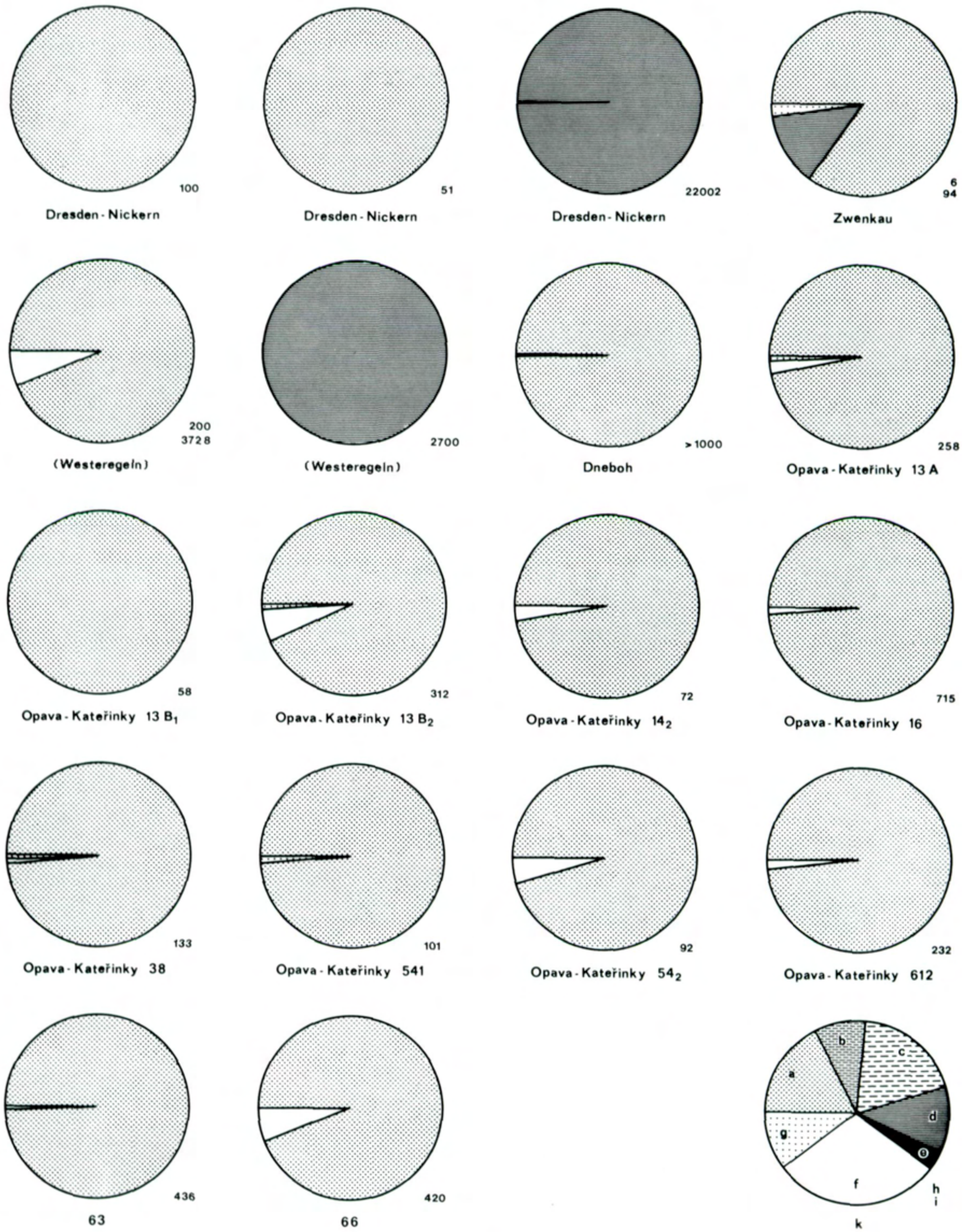


Fig. 10. Assemblages of carbonized seeds and fruits from LBK settlements.



a: wheat
b: barley
c: unidentifiable cereals
d: pea
e: remaining cultivated plants
f: wild herbs
g: Bromus secalinus
h: *total amount of chaff remains* (not included in the calculations)
i: total amount of fruits and seeds
k: site and find-number

Of course not enough settlements have been examined systematically so far to allow a division of the entire range with traces of LBK occupation into areas according to the seed assemblages. We feel, however, that at least the Rheinland and possibly the entire region between Rhein and Maas can already be described as a separate region.

It may be questioned when regional differences within the agricultural tradition of the LBK could first have occurred. It might be expected that the first farmers would apply uniform methods, at least shortly after the introduction of agriculture. Moreover it is known that the oldest phases of the LBK show the same picture everywhere in Europe with respect to the pottery and the construction of houses (see chapter II). Regionalization occurs in the later phases. A regionalization of the farming methods could have taken place parallel to this. We have tried to test this hypothesis. It appeared, however, that almost all settlements of which carbonized seeds have been described, belong to those phases in which there is already regionalization. Of the 35 sites which we know from the literature and which can be considered with certainty as LBK, only three date from the oldest phase of the LBK, namely Dresden-Nickern (Stelle 4), Eitzum (Stelle 5) and Ammerbuch-Pfäffingen Ldkr. Tübingen (BRD) (no. 15). 21 emmer-grains are known from Dresden-Nickern (Baumann & Schulze-Motel 1968). Eitzum provided a few specimens of emmer and the already-mentioned barley (less than five specimens) (Hopf in Niquet 1963) and Ammerbuch-Pfäffingen showed a single grain of a wheat-species, probably emmer (Dr. P. Schröter 1974 written information, identification by Dr. M. Hopf). From the next phase, Modderman Ib and equivalent periods, we know the above mentioned settlements of Rosdorf and Göttingen-Hagenberg, and a find from Mohelnice, near Zábřeh (ČSSR) (Kohl & Quitta 1963). Emmer is reported from the latter. It is obvious that the small number of observations disclose nothing about the agricultural tradition during the first two uniform phases of the LBK.

If something like a regionalization indeed took place, this would imply that the relative abundance of the different plants or the treatment of the food-plants in the settlements under consideration was different per period and per region. Sittard, Stein and Elsloo already existed in phase Ib (see table 3 on p. 50) and ended rather late in the young LBK. The settlements may have passed through the entire regionalization process. Hienheim existed only during the time in which regional differences had already developed. It is therefore quite possible that the inhabitants of Hienheim used methods slightly different from those of the contemporary inhabitants of Sittard, Stein and Elsloo. For the time being it is impossible to specify the nature of the differences.

We have tried in the above to describe the composition of the food derived from plants. It appears to comprise cultivated and possibly also wild plants. At least five species of cultivated plants were used at Hienheim: emmer, einkorn, pea, lentil and linseed. For the other sites we have direct information only about the presence of emmer and einkorn at Sittard and at Stein. We assume, however, that the inhabitants knew more species of cultivated plants. In the nearby Rheinland, for example, in the settlements of the Aldenhovener Platte, at a distance of 30 km, carbonized seeds of pea, lentil and linseed are found frequently in addition to the wheat species. Besides, the finds, like our find at Beek, sometimes contain poppy seed (Knörzer 1971a). It is probable that all these plants were also known at Sittard, Stein and Elsloo. In our opinion, the inhabitants of the settlements grew all the species themselves. In as far as is known, it were probably the bearers of the Linearbandkeramik culture who introduced these particular cultivated plants in Central and Western Europe. None of these species was originally indigenous so that it is impossible that the seeds were obtained from any local Mesolithic population. It also seems rather improbable agriculture was already so specialized that, for instance, one settlement produced only emmer and another only peas. We assume that each settlement grew its own food-plants.

The ratio cultivated plants/wild plants in the composition of the food is unknown, as explained above, and will probably remain so. We may assume, however, that the cultivation of food-plants was a major activity, as in each LBK settlement and, in as far as is known, over the entire settlement area, remains of cultivated plants have been found. Cultivated plants were most probably very common and perhaps the main components of the menu. The sedentary character of the settlement would plead in favour of the latter thesis. It is at least generally assumed that the settlements with their solidly constructed houses and partly fragile household-effects were inhabited around the year. In the vegetations around the LBK settlements as reconstructed here, there were few wild plants which were suitable to be stored as winter-stock. Hazel-nuts and acorns could be used for that purpose, but precisely these are found rarely if at all. Fruits of certain wild grasses can also serve as stocks, but then the suitable species must be present in very large quantities. This could have been the case of Glyceria fluitans, but grains of this plant have not yet been found. The storage of dried fruits (apples) and dried mushrooms could also be a possibility, just like the gathering of roots of, for example, marsh-plants. However, these alternatives were probably insufficient and the consumption of wild plants may be viewed rather as a complement than as the main component of the menu. Another possibility is that much meat or fish was eaten in winter, so that it was not necessary to store much in the way of plant material. Unfortunately the proportion of meat in the diet is an unknown quantity, so that we cannot evaluate this factor. Yet, it may be presumed that plants had a greater share in the food than animals.

On account of these considerations, we assume that the greater part of the vegetable food was agricultural in origin, and that agriculture was an important element in the existence of the inhabitants of the LBK settlements.

Another question is: where were the fields, what did they look like and how were they farmed? It is generally stated in the literature that the fields were laid out on loess or possibly on other fertile, not too heavy soils (e.g. Piggott 1965 p. 50). This is deduced from the preference with which the LBK founded its settlements on loess and equivalent substrates. It is indeed probable that the settlements were built at places where the fields could be laid out. In all population groups which were studied to provide the information contained in table 1 (see p. 8), there is a marked tendency to situate settlements as close to the fields as possible. We shall return to this in chapter V.

The settlements Sittard, Stein, Elsloo and Hienheim are located in a loess landscape which adjoins a river valley landscape. The loess landscape is very suitable for agriculture. A few higher parts of the river valley can also be used, but only in the summer season when there is no risk of flooding. If the summers were indeed drier (see III.2) and if the rivers had in summer the same discharge or carried perhaps even slightly less water (see III.3), we may not exclude the presence of some fields with spring-sown crop in the valleys. Nevertheless we consider the loess soil the most reliable and most important for agriculture. In both cases the fields were on fertile loam soils, the loess being perhaps somewhat easier to work than the river loams.

Real evidence that the fields were on loess or on river loam might be found in the composition of the weed flora. We agree with Knörzer that most of the carbonized seeds found their way to the settlement with the crop (Knörzer 1971b p. 100). His arguments are: 1) Carbonized seeds of weeds occur only together with remains of cultivated plants. They are absent in pits with charcoal but without cultivated plants. 2) In pits with many spikelet bases, many seeds of weeds are found. 3) Most of the weeds are also present nowadays as field-weeds. Knörzer's first argument also applies to Hienheim where no assemblages of carbonized seeds of wild plants without remains of cultivated plants have yet been found. Charcoal concentrations often contain no carbonized seeds and certainly no seeds of exclusively wild plants. A correlation between the numbers of spikelet bases and seeds of weeds, however, cannot be established at Hienheim. This is probably the result of the scarcity of pits with threshing-waste, no. 1211 being the only example. The third argument does apply to Hienheim, since the species found are all present nowadays as field-weeds. We also consider Solanum nigrum as a field-weed, although Knörzer names precisely this species as an exception. Solanum nigrum, however, is abundant on fields, though not often on cereal fields.

It was investigated whether the field-weeds found comprise species which are characteristic for loess- and/or loam-soils. Of the four species which could be identified and which occur in 5 or more of the 31 finds, Polygonum convolvulus (present in 22 of the 31 finds), Galium spurium (in 6 of the 31) and Solanum nigrum (in 5 of the 31) grow preferably on loam-soils and light clay-soils, which are rich in nutrients (Oberdorfer 1970). The fourth species, Chenopodium album, (in 9 of the 31 finds) is present on all types of substrate, provided these are rich in nutrients. Among the Bromus species, fragments of which are found frequently (in 19 of the 31 samples), there are species which prefer loam (Br. secalinus, Br. arvensis) and species which prefer sand (Br. tectorum, Br. sterilis). The last two, however, are also present on loam. Of the remaining plants, only Lathyrus tuberosus belongs specifically to loam and light clay. The other plants are either indifferent or the identification has not been carried out sufficiently to allow a judgement of their preferences. Setaria viridis for example occurs more on sand and Setaria verticillata more on loam and loess. The plant remains therefore provide no evidence contrary to the assumption that the fields around Hienheim lay on loess- and riverloam-soils. However, the finds provide no conclusive proof that the fields were laid out on loess: the plants found are not bound specifically enough to a single environment. Knörzer arrives at a similar conclusion for the Rheinland (Knörzer 1967a p. 26).

Most weeds are plants of the open terrain, but at Hienheim one or two species are represented which need some shadow, namely Lapsana communis and Bromus sterilis, if our Br. tectorum/sterilis would belong to the latter species. Both plants often occur, together with other shade demanding plants, in the weed assemblages of the Rheinland and made Knörzer assume that the fields were overshadowed by forest edges or hedges (Knörzer 1971b, 1974). It is also possible, that the shadow was cast by trees which were left standing in the fields. As the shade demanding plants occur frequently, there must have been many shaded spots, which implies that the fields were of small size.

The model developed by Knörzer of the LBK fields is based on a great number of observations. Far too little information is available to verify whether his model also applies to the fields of Hienheim and nearby settlements. For that purpose more data are necessary, also from sites other than Hienheim. The species of weeds which were observed at the site in Bayern differ to some extent from those found in the Rheinland. Chenopodium hybridum, Setaria sp. and Solanum nigrum, for example, have not yet been mentioned for the Rheinland, whereas they have been found more than once at Hienheim. On the other hand, 5 and probably a sixth of the 10 plant species which are characteristic for the community of field-weeds which Knörzer believes to recognize in the assemblages of the Rheinland and which he has described by the name "Bromo-Lapsanetum praehistoricum" were identified at Hienheim. These plants are: Chenopodium album, Lapsana communis, Polygonum convolvulus, Galium spurium, Bromus secalinus and Bromus sterilis. It is therefore possible that the weed-flora at Hienheim, may, in addition to certain differences, also have displayed great similarities with that of the Rheinland. This could imply that the growth conditions of Hienheim were more or less equivalent to those of the Rheinland.

It has already been repeatedly assumed that the area around Sittard, Stein and Elsloo must have looked very much like the Rheinland, which would imply that the fields were also alike. The find from Beek, with Lapsana communis, is in conformity with this assumption.

The invariable repetition of identical species assemblages in any given LBK settlement in the Rheinland, led Knörzer to conclude that the fields were used for years in succession. The uniform composition of the weed associations cannot occur when the use of the soil changes after one year or every few years. Using this and other material Groenman-van Waateringe also came to the conclusion that the fields were in use for a long time, even to such an extent that a hedge-like vegetation of thorny shrubs could develop around them (Groenman-van Waateringe 1970/1971). In as far as not taken from Knörzer's work, her evidence is, it is true, provided by research relating to the Early-Neolithic, but not specifically to the LBK. Therefore the existence of hedges or of a hedge-like, so-called mantle-vegetation along forest edges around the fields cannot be regarded as proved. In our opinion, Knörzer's material is also insufficient to give incontestable proof of a more or less permanent use of the fields. We think that a fixed system of clearing, tilling and sowing also results in a repetition of the weed-vegetation. The weed-communities cast with the sowing-seed perpetuate themselves, provided of course that the growth conditions remain the same. This implies that the tillage and also the preparation of the fields, i.e. the type of vegetation that had to be cleared for laying out the fields, was always more or less the same. Thus, the occurrence of only one type of assemblage can have two explanations: 1) the fields were used permanently. 2) the fields were always laid out in the same seral stage using the same methods. It is not at present possible to compare these considerations with real observations, or to make statements as to the length of the time during which the fields were in use.

The fields were not seen in the pollen diagrams of the two areas which we examined. Neither the diagrams by Janssen from Southern Limburg, nor our diagram of the Heiligenstädter Moos give any indication of the presence of fields and agriculture (Janssen 1960 p. 103). This was not probable either, as the LBK settlements are not sufficiently close to the sampled fens. Besides, we wonder if it will ever be possible to demonstrate the existence of small fields surrounded by tall vegetation. The pollen produced by the field flora will never settle further than a few meters from the field itself. The small clearings are relatively sheltered, so that the wind will have little chance to carry away the field pollen. Besides, pollen which is transported by air deplacement will be filtered by the surrounding tall vegetation. The chance of finding pollen from small fields is therefore extremely small. It is our opinion that only relatively large field complexes can be observed in pollen diagrams.

In the above it has been repeatedly assumed more or less implicitly, that the fields lay in forests. It is more than probable that this was indeed the case. As the surroundings of the settlements were covered originally with tall deciduous forest, the fields can have been laid out in the forest only, at least at the beginning of the occupation. Parts of the forest had to be cleared for that purpose. These clearing activities could not be observed in the pollen diagrams of the respective areas, since they probably took place on too small a scale. Just how the forest was cleared and how the soil was prepared for sowing cannot be established but we share existing opinions about the way in which the fields would have been laid out in forests (e.g. Iversen 1973). The method subsequently comprises the removal of trees (as much as possible), the burning of the cleared vegetation and the sowing of the clearance thus obtained. Big tree-stumps were probably left in the ground and tall trees not removed. It is possible that the latter were ringed or lopped in order to reduce the quantity of foliage, so that more light could penetrate through the canopy.

Clearings in primeval forest seem to need a minimum of tillage. Schott mentions that the farmers in Canada needed no plough during the first 2 to 4 years after the clearing of the original forest. The land was only harrowed superficially and the ashes of the burnt trees were spread over the land. Afterwards the cereals were sown and the top of a young tree was dragged over the land (Schott 1936 p. 169). The sowing-seed need not be cast, but can also be put into holes. According to Steensberg, the latter method has several advantages: 1) Grain is better protected against birds when put into holes. 2) It comes up more equally distributed when put in holes. 3) Triticum monococcum (and Tr. dicoccum) is difficult to cover when sown broadcast. 4) Grain sown in holes has an advantage in the beginning. 5) Weeding as well as harvesting is a little easier, when the grain has been sown in holes, because the stalks are then growing in bundles. 6) One will save at least half the amount of seed by putting it into holes (Steensberg 1955).

Nothing is known about the yield of fields farmed thus on loess. The plants grown by the inhabitants of the LBK settlements are species which are known nowadays as risky since their yield is subject to many variations. The weather plays an important part. In the temperate climate zone, in which the areas under study are located, crops suffer especially from too much precipitation and a too low summer temperature (Slicher van Bath 1970, Le Roy Ladurie 1971). We have assumed in III.2 that the summers were rather warm with much sunshine and that the precipitation in winter could have been slightly more than it is nowadays. The former circumstance would have a positive influence, the latter a negative. Much precipitation in the autumn and winter months would lower the pH of the fields and the potassium-, phosphorus- and nitrogen-content of the soil. Especially the reduction of the nitrogen-content would be disadvantageous (Slicher van Bath 1970 p. 121). It is possible that the use of wood-ash and the cultivation of nitrogen-fixing plants, such as peas and lentils, countered this effect. Moreover, some manuring with animal dung could have been applied, be it only by allowing the domesticated animals to graze in the f(elds after the harvest. The effect of the climate is such a complicated process, that it is preferable to refrain from speculations as to the influence of the Atlantic climate on the yield of cultivated plants. Besides, these influences seem to differ per type of substrate. Within Europe, especially the loess soils would show the least variations in yield (Slicher van Bath 1970 p. 121).

There are still other factors which play a part, such as weeds and damage caused by animals. Knörzer thinks that the agriculture suffered greatly from the growth of weeds, especially from grasses (Knörzer 1971b p. 104). This would explain the large quantities of grass-seeds in the carbonized remains from the Rheinland. We feel, however, that from carbonized seeds of weeds in settlements no conclusions can be drawn with respect to the quantity of weeds on the fields, because it is not known to how many plants the seeds found relate, how large the surface was where these seeds came from, etc. Still, an abundant growth of weeds should not be excluded, especially when the fields remained in use for a long time. The growth of weeds can never have caused much hindrance on fields laid out in newly cleared forest, because seeds or rhizomes of potential weeds were absent in this kind of substrate. They had yet to be introduced.

As for damage caused by animals, we presume that the fields were fenced to keep out game and free running cattle. This was of course of no use against birds and mice. It is impossible to estimate how much damage these animals caused.

When we have a look at the yield of similar fields from historic periods, it appears that it is very high. "We know from Scania, that the harvest of rye in old times was often 16–24 × the seed sown after burning, in comparison with 2–5 × in the normally tilled fields." (Steensberg 1955). Schott mentions that the crop in Canada was extremely good during the first years. The first crop of wheat produced 60–100 bushels (circa 1500–2700 kg) and on very good soil even 125 bushels (3400 kg) per ha. The fields were not fertilized here and the fertility dropped quickly to yields of 30–35 bushels (800–1000 kg) per ha. Yet, on good arable soil, wheat could be sown uninterruptedly for 25 years. But fields on sandy soils had to be abandoned after only three years (Schott 1936).

We assume on the basis of these parallells that the first crops of the LBK were very good. The yield per ha was perhaps not inferior to those of the good Canadian soils, but of course this is not certain. The climate is different and other wheat species were grown. How much sowing-seed was used and how it was sown are unknown factors. There may also have been a difference in yield between fields which were used for monoculture and fields on which a mixture of different plants was grown. It is at any rate certain that the yields of a given field decreased in the course of time. This process may have been slow on the loess. In Canada the very good soils were sometimes kept in use for 25 years. In agreement with Knörzer (see p. 69) we think it possible that in principle the fields belonging to the LBK settlements were also used for a long time. But the yield of a field which had been used for years, will not have been important.

Since the extent of time which elapsed before the fields were abandoned is unknown, the amount of agricultural land required by the settlement cannot be calculated. Neither is it known, if the fields were more or less impermanent, to what extent the forest was allowed to regenerate before it was taken into cultivation once more. A complete regeneration lasts many decades. Perhaps a complete regneration was not waited for, but a certain seral stage was chosen. The quantity of necessary agricultural land can vary much with the system used. We illustrate this with an example, in which we apply the Canadian production figures. In a situation where fields were kept in use for 25 years, always the same plot of 1 ha was necessary for an annual production of 1000 kg of wheat (1 ha yields 1000 kg). But when new fields were laid out every year in primeval forest or in completely regenerated forest, a total of $25 \times 0.4 = 10$ ha of land were necessary for the annual production of 1000 kg of wheat during an equally long period of 25 years (1 ha yields 2700 kg).

The quantity of necessary agricultural land is a factor which plays an important part in answering the question whether the settlements were abandoned after some time or whether they could remain inhabited for some centuries. It is therefore regrettable that we feel unable to calculate the area required for fields. Experiments with slash and burn agriculture could perhaps provide a little more information, but such experiments are hardly feasible, not in the least because almost all loess soils in Europe have for centuries been deforested. Moreover, it is not always certain that the experiments will provide clear results. The experiments in the Dravedskov (Denmark) were rather disappointing in this respect (Steensberg 1955).

Our conclusion is that the examination of the plant remains from settlements has not brought us any further as far as the size of the field area is concerned. In chapter V we shall try to approach this problem from a different angle.

FOOD DERIVED FROM ANIMALS

In chapter III.5 the faunal remains, found amongst the rubbish thrown into pits in the settlements were discussed; they were used in that chapter as a source of information regarding the wild fauna. The same remains provide now the factual material on which to base a description of the food derived from animals.

In the reconstruction of the fauna it has already been pointed out that the material found in the waste probably represents only a part of the animals which were eaten or otherwise used by man. Animals which provide no "waste" are of course not represented in waste assemblages, so that they cannot form part of the observation. It is also possible that animals, in particular large, heavy animals, were slaughtered far from the settlement, so that their skeletal remains will be found rarely, if at all, in the settlements. Within the settlements, remnants can be displaced and gnawed by dogs and other scavengers. Clason writes: "Especially the proximal epiphyses of the humerus, femur and tibia of the larger ruminants are often missing, also when the bones are well preserved, because dogs have gnawed them away. The dogs were not the only scavengers in those early villages and we have to reckon with other species too, such as foxes, wolves and vultures." (Clason in press). Finally, skeletal parts have disappeared by corrosion.

As was stated on page 44, the animal remains at Sittard, Stein and Elsloo are almost completely decayed. One bone remnant that could be identified, is a bovine radius from Elsloo. The size of this bone made Kortenbout van der Sluys presume that it was of a domesticated animal (Modderman 1970 p. 28). Furthermore the enamel of a bovine was found at Sittard (Modderman 1958/1959d p. 114). For data which might give some information about the situation in the settlements of Southern Limburg, we depend, as in the reconstruction of the wild fauna, on the material from Müddersheim, Ldkr. Düren (BRD) (see p. 44).

The animal remnants from Müddersheim were published originally by Stampfli, but as this author sets slightly different standards for the characteristics by which aurochs are distinguished from domesticated cattle, than authors such as Müller and Clason, who also studied LBK bone remains, we use the re-interpretation of Clason (Stampfli 1965, Clason 1972). This makes the data comparable to those of Hienheim, which will be discussed later.

According to Clason, the identifiable material of Müddersheim comprises 185 bones of domesticated mammals, 16 bones of wild mammals (not including the hamster, see p. 45), one bone of a bird and two fragments of a freshwater mussel. Within the category of the mammals, only 8% of the bones are therefore of wild animals. All these remnants originate from ungulates, namely horse (4 bones), boar (3 bones), red deer (1 bone + 1 antler fragment), roe deer (1 bone + 1 antler fragment), aurochs (2 bones) and probably aurochs (3 bones). In the category of domesticated animals, cattle predominate with 133 bones, which represent 72% of the number of domesticated animals. Second are the pigs with 32 bones or 17%, then come the sheep and/or goats with 19 bones or 10%, whereas a single bone of a dog has been found (0.5%). These apart, there are 15 bones of cattle, of which it could not be determined whether they were wild or domesticated.

As the boundary between the decalcified and the calcareous loess is situated much less deep at Hienheim than at Sittard, Stein and Elsloo (respectively 80 cm and 200 cm beneath the surface), bones were preserved at Hienheim. Clason was able to identify part of the material. It comprises 44 (+ 1) bones of domesticated cattle, 13 (+ 5) of goat and/or sheep, one horn-core of a sheep, 13 bones of domesticated pig and one bone of probably a dog. The figures between parentheses refer to identifications which are not certain. The wild ungulates comprise 5 bones of wild boar, 29 bones and 15 antler fragments of deer, 7 bones and 1 (+ 5) antler fragment of roe deer and 3 bone fragments of elk. Of 13 (+ 2) pig bones and 11 cattle bones could not be determined whether they belonged to wild or to domesticated animals and furthermore it was impossible in 20 cases to ascertain whether particular bones belonged to cattle or to deer. Besides ungulates, rodents and carnivora are also represented, namely a radius of a squirrel, 4 fragments of beaver and one fragment of a bear. In addition to remains of mammals, remnants of fish have been found. No percentages were calculated on account of the small numbers.

We start from the assumption that all these species were eaten. Although some species were perhaps not kept or hunted in the first place for the meat, we may agree with Clason that any dead or slaughtered animal could have been consumed (Clason 1973).

The bone material of Hienheim contains, according to Clason, a remarkable number of wild animals: "...the number of bones of wild species is relatively high for a Linear Bandceramic settlement.... The ratio of wild animal bones is usually under 10%" (Clason in press). This percentage was indeed under 10% at Müddersheim. Yet, the exact share of hunting in obtaining meat is not given by these percentages. Even if one restricts one's considerations to animals, the bones of which suffered to a comparable extent from corrosion, such as the ungulates, and even if one assumes that all hunted animals were boned in the settlement, the ratio wild-domesticated does not represent the real situation, because the calculated ratios are dependent on the standards which one sets in determining a certain skeleton remnant, especially when it belongs to cattle or to pig. Especially in as far as cattle, which is in the majority in the excavated material, is concerned, there are many transitions between domesticated and wild. Thus, a modification of the standards used in the identification will result in considerable differences in the percentage of wild animals. This is the reason why Stampfli gives 29% wild animals for Müddersheim and Clason only 8%. *The percentages can therefore not be used as absolute quantities. Of course it is possible to compare* settlements and periods with each other when the standards which are used are the same. Another reason for the problems encountered in the assessment of the ratio hunted animals – domestic animals, is the possibility that animals with the characteristics of wild animals might still have belonged to the stock. This is certainly the case with newly domesticated individuals (see further p. 74).

Notwithstanding the difficulties concerning the interpretation, the possibility remains that the inhabitants of Hienheim did indeed hunt more big game than those of Müddersheim, though the reason why can only be guessed at. It could be that there was more game to be hunted around Hienheim, because the game population was denser. This would be the case if the forests were lighter, a possibility mentioned in chapter III.5. It is to be observed, however, that the share of the wild animals in the material from Thüringen and Sachsen is also under 10%, although, according to Mania, stretches of open country and light forests were still present in this region at the time of the LBK (Müller 1964, Mania 1973b). Open landscapes are characterized usually by a dense game population (see p. 47). A second possibility could be that at Hienheim there was less pasture or food available for domesticated animals, so that fewer animals could be kept, but in view of our reconstruction of the vegetation this is not probable. On the contrary the terrain around Hienheim had rather more clearings which were suitable for tending stock. Numerous additional reasons may be offered for the possible differences, for example, that slaughtering methods were not everywhere the same.

Bones of cattle are in the majority in both the areas studied. By far the greater part of these bones originate from domesticated animals. Cattle are by far the heaviest animals of the identified species and provide most meat (van den Brink 1972, Clason 1973). In as far as we can and may judge by the excavated material, beef was the most common kind of meat. Of course we should like to know how many animals were eaten in a certain settlement in a given period of time. This question cannot be answered for Hienheim. The remains are preserved too badly and "It is... not of any use to establish minimum numbers of individuals, or to try to calculate the meat weight the bones represented." (Clason in press). Even for Müddersheim, where the bones are well preserved, the calculation cannot be carried out, because there are too many unknown factors. The first problem is that the percentage of the original quantity of bones retrieved by excavation is unknown. Modderman estimates that 10 to 25% of pottery and the like reappears in excavations (Modderman 1958/1959d p. 77). This percentage is certainly lower for bone material, because pottery is also found in decalcified loess, whereas the presence of skeletal remains is restricted to the calcareous loess. The decalcification level is at ca. 70 cm under the surface at

Müddersheim (Schietzel 1965 p. 111). Schietzel's publication does not mention the depth of the pits, but our own observations cause us to believe that the deeper pits with many finds reached a depth of 80 to 100 cm. Therefore the bones must all have been on the bottom of the pits. The pits become narrower towards the bottom and most pottery fragments are found usually in the top fillings. Therefore we estimate that the chance of finding bones is not more than 1/8 of the chance of finding potsherds. This would mean that the number of excavated bones represents only 1 to 3% of the originally present number. It is simply not permissible to calculate the number of slaughtered animals on the basis of such low percentages.

Although the finds suggest that the meat came mainly from ungulates, the diet was perhaps complemented with smaller creatures. Not only small mammals such as squirrels, but also birds, turtles, fish and crustacea may be considered here. Nor should eggs, snails and the like be excluded. It is impossible to estimate the share of these small animals in the daily menu since very few remains of birds, turtles and the like have been mentioned in the LBK settlements examined so far (Müller 1964, Clason 1968). Snail-shells have never been found yet, not even in settlements where find conditions are rather favourable, such as in Thüringen and Sachsen. Müller even concluded from the scarcity of the shells of freshwater mussels in the assemblages from Central Germany, that the molluscs were not eaten at all, but were gathered to serve as tools or as ornaments (Müller 1964 p. 56). As a matter of fact, Müller had to work with material from museum collections and it is possible that the smaller remains are greatly underrepresented in this kind of material. Furthermore, it is possible that the smaller remains were rarely mixed with the rubbish in pits, because they were crushed in the settlement or eaten entirely by scavengers. However, these possibilities offer no entirely satisfactory explanation for the scarcity of fish remains, snail-shells and the like. We think that the gathering of small animals was indeed only a supplement to the normal menu, one which, moreover, could have differred according to the region and the situation at hand. Taute found many fish remains in a LBK context in the cave "Felsdach Lautereck" (Taute 1966 p. 495) which could imply that quantities of fish were eaten in particular circumstances.

It may have become apparent from the above, that it is our opinion that the food derived from animals was, for the greater part, provided by domesticated animals and that hunting and gathering constituted only a complement to the diet. Perhaps there was not enough game in the surroundings of the settlements to feed the inhabitants around the year (see III.5). The situation could have been similar to that of the food derived from plants.

The inhabitants of Sittard, Stein, Elsloo and Hienheim were thus not only agriculturalists but also pastoralists. In the first place they kept cattle, besides some pigs, sheep and goats. For his material from Thüringen and Sachsen, Müller assumes that part of the cattle- and pig-stock could have consisted of locally domesticated wild cattle and pigs, a conclusion reached on account of the many transition stages between wild and domesticated animals. Cattle especially could have undergone a continuous domestication (Müller 1964 p. 66 and 67). The material from Müddersheim and Hienheim leads to the same conclusion. It is conceivable that very young animals were caught and raised in the settlement. Another possibility is that tame cows and sometimes also tame sows were served by wild congeners.

There seems to be no difference in the composition of the live-stock of the two areas under study, in as far as it is justified to form conclusions from a single observation per area. The question is where the animals were kept. One possibility is that the animals were kept in stables. Modderman suggests that the north-western part of the houses could be used as a stable (Modderman 1970 p. 110). This space is characterized by solid wooden walls which would resist the rubbing of the live-stock better than the wattle-and-daub walls used elsewhere in the construction of the house. In Southern Limburg the length of these reinforced parts varies from 1 m (Elsloo house 87) to 11.5 m (Geleen W3), and the width is usually between 5 and 7 m. If these N.W.-parts were indeed stables, the cattle must have been tied there, since there is no solid partition between the central part, which could have had a living function, and the possible stable. Cattle-boxes as known from later periods are absent, but the space between the end wall and the first row of three posts and also the space between the rows of three posts might well have been used as a cattle-box or as a double cattle-box. In a house-plan like house 32 from Elsloo (Modderman 1970 plate 18) 6 cattle-boxes or double cattle-boxes, three at each long side, could be drawn in this way. The cattle would then be stabled at right angles to the longitudinal axis of the house. However, the central path which belongs to this type of stables, is absent. The boxes are too narrow to accomodate two adult animals. The cattle of the LBK were big (Müller 1964, Boessneck 1958) and needed perhaps even more space than the cattle from the Bronze Age settlement Emmerhout where the boxes have a width of more than 1 m (Waterbolk 1975 p. 391). The space between the posts of a house like Elsloo 32 is approximately 2 m. The horned cattle of this household might, for instance, have comprised 2 grown cows, 2 calves, 2 yearlings, 2 heifers and 2 three-year old cattle. If the calves are allowed to stay with the cows and if the heifers and yearlings are stabled two by two in two boxes, exactly 6 boxes are filled. In this example we do not reckon with the possible presence of an ox (Müller obtained evidence for oxen in a LBK context). Moreover, we leave out barren cows and calf mortality. Of the mentioned stock hardly one or two grown animals could be slaughtered per year, whereas Müller had demonstrated that most animals were killed 3 to 7 years old. It is also hardly possible to keep animals other than cattle. The cattle must have been very docile too. Therefore we wonder whether the N.W.-part of the houses was large enough to serve as a stable at all, because even a large house as no 32 offers but minimal space. Anyhow we find it impossible to accept that the entire live-stock was stabled together. Therefore we agree with Waterbolk's opinion that stabling live-stock is the invention of a later period (Waterbolk 1975 p. 393).

It should be mentioned here that it was once attempted to demonstrate on basis of chemical analysis the differences in use of the three parts of a LBK house. Neither in Southern Limburg, nor at Hienheim, were the floor surfaces of the houses found in situ, but we assume that the dirt from the former floor did end up in the post-ghosts, i.e. in the holes left by the posts (not the pits in which the posts were erected). In one of the houses at Hienheim: no 8, the filling of the ghosts was clearly visible and samples could be taken from the holes of the central posts which would have supported the roof. Although the content of organic matter and of total-phosphate appears to be much higher in the ghosts than in the surrounding soil, the ghosts of the N.W.-, central and S.E.-parts of the house show no differences. Thus, a stable-part, with a high content of organic matter and phosphate to match, could not be distinguished. Milisauskas has carried out a similar investigation in a house-plan of Olszanica (Poland). He determined the nitrogen content: "There was no variability in the nitrogen content inside the house, even though a difference generally existed between the areas inside and outside." (Milisauskas 1976 p. 36).

The alternative is that domesticated animals were kept outside the settlement in the open air. In that case they grazed freely in the forest or in clearings. It may be questioned where the animals found their food. As was stated in III.5, very few wild ungulates could be found in the surroundings of the settlements, because the natural vegetation offered sparse food for this kind of animal. Therefore there cannot have been much food for the domesticated animals either, certainly not in the pioneering stage of the LBK occupation. The best pastures were probably in the river-valley where the forest was layered, and clearings were present along the river. We were able to demonstrate such clearings in the valley of the

Donau near Hienheim (see p. 161). Later, during the occupation, clearings occurred also in the higher forests as a result of agriculture, and stubble-fields and abandoned fields could be used as grazings.

We assume that the first inhabitants of a settlement had to cope with a lack of pasture. The same seems to have been the case when the Canadian forests were brought into culture in the 19th century. Schott writes that so little light penetrated through the dense forests that not even grass could grow underneath. Therefore the pioneering farmers had great difficulties in feeding their live-stock (Schott 1936 p. 29 and 30). Thus, at the outset the live-stock must have received much additional food. This additional feeding could later still have been of importance, for instance when the river-valley was flooded. For the additional feeding, plants which the animals could not reach themselves, could be used, in particular tree foliage. Such a practice would explain the rapid elm decline in the Donau valley near Hienheim. This decline, which is dated 4300 ± 110 B.C., coincides more or less with the beginning of LBK occupation in that area; the oldest C14 dates from Hienheim are 4205 ± 45 B.C. (GrN–7156), 4270 ± 45 B.C. (GrN –7558) and 4285 ± 45 B.C. (GrN –7557). Within the category of deciduous trees, elm and ash seem to provide the best fodder (Iversen 1973 p. 80). The ash, however, was hardly present in the Donau valley (see p. 43), so that only the elm remains as fodder-tree. That the elm did not recover might be attributed to the fact that the method of additional feeding never went out of use completely and though lopping may have occurred on a lesser scale, it might still have been severe enough to prevent a complete recovery of the elm vegetation. As explained in Appendix I, there are no reasons to attribute the elm decline near Hienheim to climatological or edaphic factors. (As another possibility for an anthropogenic origin of the decline the use of elm-bark for constructional purposes might be mentioned, see IV.4 p. 88).

In as far as we know, Hienheim is so far the only place where the elm decline is correlated through a C14 date to the beginning of LBK occupation. Whether there is a real link can of course only be established by repeated observations. Such an early elm decline has not yet been observed in Southern Limburg. The elm decline in the diagram of Meeswijk, if it is a real elm decline, has been C14-dated at 3260 ± 130 B.C. (Lv–284) (Paulissen 1966 p. 126 and 127). At Sittard there is an elm decline at a level which has been dated at 3130 ± 80 B.C. (GrN–1660) (van Zeist 1958/1959 p. 22). In the series of deposits of Meeswijk and Sittard, the deposits which would date from the period of ca.4000 B.C., are, in our opinion, absent, so that a possible earlier decline cannot be established. In the diagram of the Leiffenderven, which could have shown the influence of the LBK settlement "Staher Bruch", the percentages of elm pollen are far too low to demonstrate a decline (Janssen 1960). Finally, the diagram of Brommelen shows no decline at all in the Atlantic, but the sample point is very far away from the then inhabited world (Janssen 1960). It is also possible, that the sediments of the Leiffenderven and Brommelen date from the period after an elm decline. It will probably be very difficult to prove the relation between the LBK occupation and the elm decline as the required combination of pollen-bearing deposits from the Atlantic in the immediate vicinity of LBK settlements appears to be a very rare combination. Yet, there do seem to be opportunities for investigation. For instance, the former lakes in the so-called "Mitteldeutsche Trockengebiet" are situated in an area which was densely populated during the LBK. An elm decline can indeed be seen in one of the diagrams which Müller made of the former Gaterslebener See. Profile A5 may be mentioned. The elm decline is on the boundary of the pollen zones Firbas VI-Firbas VII, i.e. in the middle of the Atlantic. This decline could be an equivalent of the phenomenon at Hienheim. Unfortunately, the level is not provided with an absolute date (Müller 1953/1954). Lange's diagrams from the same area show a similar elm decline (Lange 1965). The first clear decline in her diagrams already takes place during the "older Atlantic" (period VIb). This decline usually occurs slightly earlier than the first, infrequent occurrence of herb pollen, which could point to human influence (Lange 1965 p. 20). Lange sees a relation between the decline and the earliest Neolithic occupation, which, in this area, is a LBK occupation. We see in Lange's observations a clear parallel to our own near Hienheim. Unfortunately, here also, C14 dates, which could form an independent factor in linking the phenomena in period VIb of the pollen diagrams to the LBK occupation, are lacking.

FOOD: A SUMMARY

From the above survey it is apparent that information concerning the food consumed by the inhabitants of the Linearbandkeramik settlements is very incomplete. Yet, the conclusion that the greater part of the food was produced by the inhabitants of the settlements themselves, may be allowed. Hunting and gathering, it appears, played only a minor part. This is in complete agreement with existing opinion (e.g. Jankuhn 1969, Tringham 1971, Behrens 1973).

The activities comprised both plant cultivation and animal husbandry. The cultivated plants which could be identified are: emmer, einkorn, pea, lentil and linseed. Besides, poppy-seed was found in Southern Limburg. Barley was absent or almost absent. Emmer and einkorn were probably cultivated together. It is possible that other plants, especially peas, were cultivated separately. Anyhow, they were stored separately in the settlements.* The fields on which the plants were grown, were of small size and lay between tall vegetation. It is not clear whether they were used for a short time or for a long period. The fields were probably laid out on loess or on dry parts of the river valley, but this could not be proved.

The seed assemblages from Sittard, Stein and Elsloo on the one hand and from Hienheim on the other hand show similarities, but also differences. The latter are mainly of a quantitative nature. They might be attributed to differences in the quantities which were cultivated of each plant species. It is possible that many peas were cultivated of each plant species. It is possible that many peas were cultivated at Hienheim, whereas Bromus secalinus can be considered almost as a cultivated plant in Southern Limburg. It also seems that many more weeds grew on the fields in Southern Limburg than at Hienheim. However, the possibility exists that all these deductions are false. The established differences in seed assemblages might be the result of different methods of harvesting and drying the cultivated plants.

The live-stock comprised mainly cattle. In addition there were pigs, sheep and goats. The cattle and, to a lesser extent, the pigs display characteristics which point to interbreeding with wild congeners. We assume that the animals were tended outside the settlement. Probably it was necessary to give additional food to the live-stock: tree leaves could have been used for that purpose. Perhaps the live-stock at Hienheim was somewhat smaller than that of the settlements in Southern Limburg. A reason for this phenomenon cannot be given.

So far we have spoken only indirectly of the share of plants in proportion to meat in the menu (see p. 67). The excavated material does not allow to establish this ratio. We return to this subject in chapter V.

As pointed out in IV.1, obtaining food is a vital component in the total set of relations which exist between the inhabitants of settlements in general and their environment. In the case of the settlements studied here, it appears that this relation consists in the environment being used for the local production of food, i.e. for plant cultivation and animal husbandry. Using the environment as a direct source of food was of secondary importance.

* So far, linseed was rare in our finds, but there are indications that this plant too was cultivated or stored separately, at least in the Rheinland. We refer to the linseed assemblages from Köln-Lindenthal and Morken-Harff (Buttler & Haberey 1936, Hinz 1969).

Undoubtedly the environment must have had certain properties to meet the requirements made by the methods used for food production. These requirements comprised good conditions for the cultivation of the desired plants, sufficient possibilities for animal husbandry and perhaps also a wild fauna from which the live-stock could be supplemented.

The activities relating to food production must have changed the original environment. We mentioned the creation of fields by removing forest and the possible gathering of elm-leaves by which stands of elm were damaged. These are rigorous interventions in the natural vegetation. Changes in the vegetation, however, also influence all other aspects of the environment described in III.1. These aspects of food production will be discussed in IV.6, where a survey of the influences which the settlements might have exerted on their surroundings will be attempted.

IV.3 WATER

The inhabitants of Elsloo, Stein, Sittard *and* Hienheim *did not dig wells. It is unlikely that any of the pits* in the settlements can be interpreted as a well. We may recall that the settlements were built on loess plateaus, areas characterized by a very deep water table (III.3). An exact indication is impossible, because the water table is not measured in loess areas at present, since it is so far beneath the surface that the measuring of its depth has no economic use. Anyhow, digging wells on loess plateaus is a time-consuming work.

The alternative for wells is the use of rain-water or of surface water. We know nothing of catching rain-water. If the summers were indeed rather dry, as was assumed in III.2, receptacles would have been needed to bridge the period of drought. However, we cannot now identify structures or vessels with such a reservoir function. Therefore we fail to see how storing rain-water could fulfil the daily demand for water. The inhabitants of the four LBK settlements most probably got their water from the nearest natural open water.

In Southern Limburg the nearest surface water is running water. For Elsloo, the upper course of the stream Ur answers the necessary requirements. The valley of this small stream had perennial flow up to a distance of 750 m from the settlement until recently. More inland, the valley has the aspect of a dry valley. In III.3 it was argued that there is no reason to assume that the dry valleys had a permanent, perennial flow at the time of the LBK occupation. In the same chapter it is stated that the water courses must have been about the same during the Atlantic as nowadays, at least if the very recent village developments, draining works and canalizations are left out of consideration. This leads to the conclusion that the inhabitants of Elsloo had to walk some 750 m to reach water. In winter and early spring the dry valley might also have carried water: in that case the distance to the water would have been shorter in these seasons, namely about 450 m.

Stein was further down the same water course. The distance to the water was 250 to 500 m, depending on the place of the settlement within the settlement area. Sittard was situated on the left bank of the Geleen, a stream in a rather wide valley and much bigger than the Ur. Depending on the course of the Geleen in its valley, the distance to the water was 250 m at the least and 600 m at the most. The exact course of the stream cannot be reconstructed. The same goes for the Ur, but the valley of the latter is so narrow, that the stream could only displace itself over short distances.

The inhabitants of Hienheim must have taken their water from the Donau, since it must be assumed that the small dry valley, which seems to form the boundary of the settlement at the south-west side, did not carry water at the time of the LBK (see III.3). At Hienheim, the Donau flows through a wide valley, which is why we cannot indicate the distance between the settlement and the river accurately. Besides, it is also possible that the inhabitants did not obtain their water from the river itself, but from a cut-off river-channel. Anyhow, the distances that had to be walked were not long. The minimum is circa 125 m and the maximum about 600 m.

It is obvious that the four settlements were not situated near the water. Apparently the inhabitants were prepared to walk some hundreds of meters to fetch it. It must be stressed that water was not only used as drinking water, but was also needed for mixing clay and loam and for grinding stone, to name some examples. We cannot say how much water was needed daily.

The position of the settlements with respect to the water is far from unusual. Everywhere in Europe the LBK settlements discovered so far appear to be situated in a similar way. They are located in the vicinity of a water-course but seldom on the bank itself (for the rareness of settlements in river valleys, however, see Quitta 1969). Long distances between settlements and water, that is distances of over 1 km, are unusual (see Sielmann 1971 p. 99, among others).

IV.4 RAW MATERIALS

BUILDING MATERIALS

The first category of raw materials which we shall discuss is the building materials which the inhabitants of a LBK settlement needed for construction. We think then in the first place of houses. As we mentioned in chapter II, the occurrence of large buildings, which are interpreted as houses, is one of the best-known characteristics of the LBK culture. Today the houses exist as house-plans only. As far as Sittard, Stein, Elsloo and Hienheim are concerned, they have been described extensively by Modderman (Modderman 1958/1959 and 1970, Modderman in press). Several authors have written articles about the types of construction that would have left the traces found. Fairly recent reconstructions are those of Zippelius, Soudský and Modderman (Zippelius 1957, Soudský 1969, Modderman 1973).*

In addition to houses, there were other kinds of constructions in the settlement. We mention here the trenches of Sittard, which might have been dug for palisades (Modderman 1958/1959d p. 75).

The above-mentioned authors are convinced that wood was the main building material. Long, thick poles supported the roofs of the houses; the walls were erected mainly of timber or wattle; the frame for the roofing was also of wood. The wood manifests itself in the first place by discolorations in the soil, which indicate that poles had been sunk into the ground. Most of the traces are of round poles, but there are also traces of split timber. In Stein, in particular, it could be seen very clearly that thick tree trunks had been made into posts with a semicircular cross-section, posts with a triangular cross-section and even planks (Modderman 1970).

A second indication of the use of timber is provided by the impressions of wood in the so-called loam plaster. These impressions too are of round wood as well as split timber. For a discussion of the type of construction requiring this wood, we refer to the section on "loam" further on.

* The article by Meyer-Christian was published after this section was written. His conclusions, however, do not significantly alter our line of reasoning (Meyer-Christian 1976).

A third proof of the use of wood is the presence of charcoal in the settlements. The charcoal, however, need not necessarily have originated from building elements: the wood in question may also have served as firewood. Charcoal can be found in pits as well as in ghosts of posts. We believe that there is no difference between the fillings of the two. The charcoal remains are usually found in the form of small fragments mixed with soil; this applies for both the ghosts and the pits. That is why we do not accept as an established fact that the charcoal in ghosts originates from burnt posts. We think it highly likely that the presence of charcoal in the ghosts is secondary. According to Schweingruber's findings, the origin of the charcoal could be indicated by the number of wood species represented. Firewood would presumably contain a mixture of many species, whereas construction wood could be recognized by the limited number of species (Schweingruber 1973 p. 156). It will appear later that unfortunately this criterion cannot be applied to the charcoal finds from the settlements described here.

It is assumed that in addition to timber, loam was also used. Only a certain type of house would have had walls that consisted entirely of wood (house type la in Southern Limburg). In the other houses only a part, i.e. the N.W. part, was erected of massive timber. Wattle would have been used for the remaining walls. These wattle walls would have been filled with loam. No direct proof is available for the existence of such walls. However, lumps of burnt loam with impressions of branches, the so-called loam plaster, are often presented as evidence (Trier 1969 and other authors). The loam from the walls must have been burned in a fire. This view, however, is not generally shared. Schietzel points out that the loam plaster is fired so well that it must have been in intense contact with fire for a long period of time. He considers the loam plaster to be the remains of fireplaces (Schietzel 1965 p. 13). Soudský also believes that the loam is fired too hard to have originated from a burnt house. He mentions an oven as the original construction (Soudský 1969 p. 16). These ovens would have had a domed roof consisting of loam-covered branches (Soudský 1969 p. 57). Modderman also considers the burnt loam to be the remains of a fireplace (Modderman 1973 p. 133). However, a fire is certainly able to produce "burnt loam plaster", although to a limited extent. Hansen writes of a burned down experimental house in Allerslev (Denmark): "It was only at the top, and at places that had been especially severely exposed to the heat, that the clay was practically baked through, and large pieces of mud-plastering similar to those originally discovered on the "genuine" site, could be broken off" (Hansen 1961 p. 144). Nevertheless, we too do not believe that the loam comes from walls. At the least, it cannot have come exclusively from walls. Our argument for this view is that no concentrations of burnt loam have been found around ground-plans. The loam appears to be distributed arbitrarily over the settlement area. It is a normal component of pit-fillings. Unless fires were very common, this could indicate that the "loam plaster" was burned under conditions which were more frequent than fires.

When we say that we do not consider the presence of loam plaster to be proof of the existence of wattle walls, this does not necessarily mean that we wish to exclude wattle for the walls of these houses. On the contrary, we even find it a very attractive idea. In addition to walls, the loam might also have been used for floors. However, remains of floors have never been found.

Given the composition of the plaster, the loam used was often tempered with chaff and chopped plants (see p. 59); this raw material is therefore also considered a construction material.

How the different wooden parts of the roof frame were held together is completely unknown. We can imagine that, besides possible true joints, rope was also used. This rope may have been made from tree-bast fibres. Some bast species are very suitable for this purpose. The roof covering was probably still another building material, unless planks or faggots were used. It is often assumed that the roof was covered with reeds (Zippelius 1957 p. 21 and other authors). Alternatives are straw (Soudský 1969 p. 15), sods and skins (Modderman 1973 p. 138). Bark is also possible.

Summarizing we can say that there are three kinds of construction material which we know for certain were used, namely wood, loam and fine plant material. Then there are at least five materials that could have been used: bark or bast, reed, straw, sod and skin. We shall consider in the following where they may have come from and whether they were sufficiently abundant. We look for the origin in the first place in the neighbourhood of the settlement, since we start from the assumption that man did not transport building materials over long distances when he could obtain equivalent material nearby.

Wood was certainly available in the immediate surroundings. In III.4 we arrived at the conclusion that the areas we are studying were forested. That was certainly so when the settlements were founded (see p. 38). Whether the local wood was actually used for building is a second question. To prove this, one should be able to demonstrate that the local kinds of wood were indeed incorporated in the buildings.

The only witnesses of the kinds of wood used in the settlements are the previously mentioned charcoal fragments. As stated, building wood is difficult to distinguish from firewood in this material. According to Schweingruber, construction material might be recognized by the fact that it contains few species. This criterion, however, can only be applied when it may be assumed that the small number of species in the charcoal assemblages is not the result of selective corrosion. Unfortunately such corrosion may well have occurred in our settlements. Sediments in which clay is displaced are unfavourable for the conservation of charcoal. The clay infiltrates the charcoal fragments and destroys their structure by swelling and shrinking. As clay displacement was an important phenomenon in the pit fillings (van de Wetering 1975a), we must assume that the process of destruction certainly took place in our settlements. Certain woods may therefore have become unrecognizable. We see in the dominance of oak in the material from Hienheim no proof whatsoever for the exclusive use of oak-wood; the dominance is rather the result of the fact that oak-charcoal disintegrates slowly and remains recognizable for a long time (see also Appendix II).

During the excavations at Sittard, Stein and Elsloo no charcoal was gathered for identification purposes. However, we may compare these settlements with Langweiler-2 Ldkr. Düren (BRD), which lies 30 km east of Sittard. In Langweiler-2 a relatively extensive investigation was conducted by Schweingruber (Schweingruber 1973). In this publication Schweingruber remarks that the absence of the charcoal of soft wood species can be the result of corrosion. The charcoal which he did find probably originates predominantly from firewood, since the material contains many fragments of shrubs, young branches and mouldered wood. The only samples that Schweingruber indicates as possible remains of construction are the charcoal remains from three postholes in Langweiler-2 house 21; the posts would have been of oak (Schweingruber 1973 p. 156). We wonder, however, whether the charcoal found is indeed part of the original posts, because some carbonized seeds were found in the same samples (Knörzer 1973 p. 147); therefore we assume that the charcoal was secondary.

Apparently charcoal can offer us no adequate information about the kinds of wood used as construction timber. So there is no proof for the thesis that the wood for the houses came from the immediate surroundings of the settlement. It is true, however, that all wood species represented in the charcoal occur in the local forests, so that there is no proof of import either. An exception is perhaps the spruce from Langweiler-2; unfortunately the possibility exists that the samples containing spruce-charcoal are contaminated (Schweingruber 1973 p. 153).

Another approach lies in the question of whether the wood from the local forests was suitable as building timber and whether a different and better timber could be found farther away.

All reconstructions known to us of LBK houses indicate that many long boles were needed. Short stakes were almost never used. Both Zippelius and Soudský assume walls circa 2 m high (Zippelius 1957, Soudský 1969). For this height, the roof-supports would have had to have a length of 4.5 to 5 m, according to Soudský (Soudský 1969 p. 12). Very long pieces of wood were required for the ridge-poles. The rafters too were long, heavy pieces of wood (Modderman 1973). This implies that only trees with a well-developed trunk were suitable. It should have been no problem to find trees of this type in the vicinity of the settlement. We wrote on p. 35 that trees in a dense forest develop long, column-shaped trunks of regular thickness. Therefore a number of indigenous trees met the requirement of a sufficiently long bole. These are: birch, alder, oak, ash, maple, elm, cherry, lime, poplar, willow and in Hienheim also pine (the pine did not occur in Southern Limburg during the Atlantic). The trunks of these trees have no branches up to considerable heights; the length of the branch-free trunk varies from 6 m (cherry) to 20 m (pine); the average lenght is 12 to 18 m. Thus all tree species have been mentioned that occurred in Central and Western Europe, with the exception of the mountainous areas, at the time of the LBK. No other tree species could be found for kilometres around the settlement. Therefore the choice was not enlarged by the import of wood from remote areas. As said, one species was absent in the local vegetation of Southern Limburg: the pine. It is theoretically possible that pine-wood was in demand in Sittard, Stein and Elsloo. It would then have been transported over distances of more than 100 km, which we find highly unlikely. Besides, pine-wood has no special properties that would make such an import plausible.

The question of whether local timber was used seems to have been answered adequately since there are no alternatives. Yet we may wonder whether there was enough local wood to build houses. This is related to the question of how large must a forest be to provide wood for one single house or an entire settlement. To answer these questions, we need to know first which tree species were preferred. In addition to the trunk length, other criteria probably played a role in the choice of the timber. One of them will have been the durability of the woods.

Nowadays timber is usually divided into five classes of durability on the basis of practical experience. In table 6 we have listed the classes of the above-mentioned tree species, together with some relevant properties. The classification applies for heartwood. Sapwood has a very poor durability. The data have been taken from circulars of the Houtinstituut TNO in Delft and apply for temperate climates. Durability

Table 6. the durability of the heartwood of a number of indigenous woods.

	Class	*Durability 1 (years)*	*Durability 2 (years)*	*Attack by insects (dry wood borers)*
oak	II–III	10–25	25–50	almost nil
cherry*	III	10–15	25–40	moderate
maple elm pine	IV	5–10	12–25	moderate
birch alder ash lime poplar willow	V	< 5	6–12	severe

* the classification of cherry-wood is based on only a few observations; perhaps this wood has been classed too high.

1 is the number of years that the heartwood remains intact when in continuous contact with humid soil. Durability 2 indicates the life of heartwood which is not in contact with humid soil but is exposed to weather and wind. The durability of dry wood inside a house is determined mainly by the susceptibility to attack by the larvae of insects.

It appears from the table that birch, alder, ash, lime, poplar and willow are not suitable in the present climate as construction wood for buildings above the water table. Outdoors they rot away very quickly and under dry conditions the risk is great that the immobile pieces of wood will be attacked by insects. Nowadays woods from classes II through IV would be selected for building houses (class I is absent in Europe). Although the Atlantic climate differed from the present one (see III.2) the differences are not great enough to invalidate the classification. At the most, the number of years listed should be taken with reserve. We suspect that the woods that would be selected nowadays for certain kinds of construction were preferred in former times as well. Thus we believe that oak-wood was probably chosen for the most vulnerable part of the house: the gable-wall. These short walls were insufficiently protected by the gable-roofs against rain and wind; furthermore the soil in which the posts were sunk was always moist. The long walls and the posts within the house were far less vulnerable, because they were placed sufficiently far under the roof to stay dry; moreover, the soil in which these parts were placed was relatively dry. We think that wood from class IV is also suitable for these parts. Furthermore, we can imagine that when the construction elements were not embedded in the ground and also when they could be replaced easily if attacked by insects, no particular attention was paid to durability. We return to the life-span of the wooden houses in chapter V.

For the supports a third criterion was perhaps of importance, namely the strength of the wood. For wall posts and roof-supports this means the stiffness and the compressive strength, for ridge-poles and the like the bending strength. It would take us beyond the scope of this publication to calculate the load on the different posts in the different reconstructions. This load, by the way, is closely related to the type of roofing. As will appear later, the type of roofing is unknown. The woods from durability classes II–III through IV, however, are nearly all strong woods. Only some elm species are considered moderately strong.

Wall-posts and roof-supports were in a number of cases made of split wood. In Stein, heavy trunks were split lengthwise into at least 12 pieces. Moreover, planks were sometimes used for the walls. The ease with which the wood is cloven may therefore have been a fourth criterion. Among the wood species which we consider suitable, pine and oak are split the easiest.

On the grounds of the above we think that the conclusion is justified that oak was the most sought after timber for building houses, followed by maple, elm and cherry and in Hienheim perhaps also pine. This wood must have been obtained from dry or at least periodically dry ground. We exclude the carrs of the wet soils because oak, maple, elm, cherry and pine do not grow here, at least not in the areas under study. In Southern Limburg the forests of the two loess landscapes, the eolian sand, the area with loess on gravel and parts of the Lower Terrace must therefore be considered as potential suppliers of timber. The loess plateau and the higher parts of the river and stream valleys come first, because the settlements were located in or adjacent to these units and the distance to be covered was therefore the shortest. In the case of Hienheim, the vegetation of the loess landscape, the limestone area, the area with eolian sand and the higher part of the river valley will have contained suitable trees. We should like to exclude the steep slopes within the limestone area, because here the trunks of the trees undoubtedly were insufficiently developed. The loess landscape and the river valley landscape come first in Hienheim too.

Of course the composition of the forests was different in all landscapes, and not all wood species occurred everywhere in the same quantities. Our reconstruction of the vegetation of the units in question shows that oak was the most common of the suitable tree species (see III.4). The cherry was probably the rarest tree. It is not clear at the moment where the inhabitants of Hienheim obtained the pines they used.* Our knowledge of the vegetation is insufficient here. It is improbable, however, that pine grew on the loess or in the Donau valley.

The necessary quantity of timber is related of course to the size of the house to be built. Modderman distinguishes "Kleinbauten", "Bauten" and "Grossbauten", that is small, medium and large houses. In the table below we give an estimate of the minimum number of trunks required for the different houses. We had to make a few assumptions for our estimates, one being that the walls of the houses were 1.5 m high and not 2 m as Zippelius and Soudský assume (Zippelius 1957, Soudský 1969). A wall 1.5 m high is sufficient, certainly in a house with a roof construction without cross beams (Soudský 1969, Modderman 1973). We do not consider Soudský's observation concerning the wall of house 41 in Bylany to be adequate proof of the existence of walls 2 m high (Soudský 1969 p. 12). Furthermore we have taken into account the fact that the wall-posts were embedded in 50 cm of soil, which means that they must have been circa 2 m long. Whenever the wall sections between the posts consisted of wood, we assume planks were used. These would have come from one single bole per space between two posts. In our calculations this piece of wood has the same length as a wall-post. For a wall height of 1.5 m, a roof angled at 45° and a house 6 m wide, the supports of the ridge-pole must have been 4.5 m long. Since they were sunk at least 1 m, trunks 5.5 m long were required for the roof-supports. The other supports would be shorter. With the same basic dimensions, they reached a height of 3 m above the floor. They too, however, were deeply embedded, so that the trunks used had to have a total length of circa 4 m. The five extra supports in the S.E.-part of house Elsloo 58 are considered to be real supports, although this may be incorrect as their function is not clear. The roof frame contained at least 5 longitudinal connections, that is one along each wall and three over the supports. It is possible to use one single trunk for each of these beams, but branch-free trunks are then not long enough for long houses. The top part must be included in the roof construction, so that the branches must be removed. It seems to us that it is easier to work with trunks without branches. Therefore we assume two trunks per longitudinal connection for long houses. We include no transverse connections, with the exception of rafters, in our calculations. The rafters probably extended over the walls. Trier assumes in similar cases that the roof, projected on the ground, reached 50 cm beyond the wall (Trier 1969). For a roof angled at 45° and a house 6 m wide, the rafters must have been nearly 5 m long.

When we "translated" the above-mentioned post lengths into the number of tree trunks, as we did for the longitudinal connections, we took into account the fact that relatively thin trunks were used for the construction of the houses. The discolorations of the soil indicate that the round posts were 45 cm thick at the most; this maximum is found for the supports of the ridge-poles. Diameters of 20–40 cm are normal.* Thin trees have relatively short trunks. That is why we chose 12 m as the average length of the trunks that were used. We must also consider the fact that the LBK builders did not have wood saws and had to cut the trunks with stone adzes. This involved a considerable loss of wood, which we estimate at 30 cm per cut.

* Pine was used in Hienheim, as is demonstrated by the presence of pine charcoal.

* We assume that the diameter of the ghosts indicates the real thickness of the post. We think that the posts rotted in the soil and the ghosts are the filling of the resulting holes. It has never been demonstrated during excavations that a post had been dug out to be used again. Nor can they have been pulled out of the ground. If this were possible at all with the very long roof-supports, a conical hole would have been made. The ghosts, however, are truly cylindrical (see Modderman 1970 plate 5a for instance).

These considerations lead us to assume that five wall-posts or two roof-supports or two rafters could be made out of one tree trunk.

Table 7. The minimum number of trees used in the construction of a LBK house.

			wall-posts	*long walls (planks)*	*short walls (planks)*	*roof-supports*	*longitudinal connections*	*rafters*	*total*
Kleinbau	Elsloo	28	4	–	–	8	5	5	22
Bau	Elsloo	57	6	2	2	9	5	6	30
Grossbau	Elsloo	58	9	3	2	19	10	11	54
Grossbau	Elsloo	27	10	10	4	15	10	9	58
Kleinbau	Hienheim	35	7	–	–	6	5	4	22
Bau	Hienheim	8	15	4	4	17	10	11	61
Grossbau	Hienheim	2	16	3	5	17*	10	11	62

* The plan of Hienheim 2 is incomplete, only 25 roof-supports were observed in the field; 33 is an estimate.

It depends on the type of roof whether more trees were used. If the roof consisted of planks or shingles, certainly more trunks were needed. If the roof consisted of faggots or another material that only needed to be supported, then perhaps the tops and branches of the trees used were sufficient.

As previously mentioned, the discolorations of the soil indicate that the boles had a maximum thickness of 45 cm. If thicker trunks were used, these were split. The use of split wood reduces the number of trees required drastically. It could be observed in the plans of some of the houses in Stein that trunks 75 cm thick were split into approximately 12 pieces. One thick trunk of oak at least 18 m long and 75 cm across would in this way provide at least 84 wall-posts 2 m long. We do not know how often split wood was used. Although ghosts of roof-supports are seen relatively often, we know little about wall-posts. The use of split trunks has been observed so far only in Southern Limburg alone: in Hienheim only pieces of round wood have been found. However, the loam plaster of Hienheim does contain traces of split wood, so the technique was known.

When we assume only round wood, the main parts of small houses required, according to table 7, some 20 tree trunks; for large houses about 60 were used.

The lack of detailed knowledge of the vegetation makes it impossible for us to calculate exactly per type of vegetation how large an area is required to provide the necessary number of trunks. The frequency of the tree species depends amongst other things upon the importance one wishes to attribute to lime trees. As far as Southern Limburg is concerned, both Van Zeist and Janssen have demonstrated that lime was predominant in the forests which bordered the streams within the loess landscape (van Zeist 1958/1959, Janssen 1960). Munaut writes that the lime, and not the oak as is generally assumed, dominated the vegetation of the eolian sands (Munaut 1967). This view is shared by Iversen (Iversen 1973). In III.4 we arrived at the conclusion that if Munaut's interpretation is correct, the loess plateaus must also have been covered with lime forests instead of mixed oak forests. It makes a great difference in the calculations whether, in a forest containing both lime and oak, one out of every ten or one out of every five trees is an oak. Lime is totally unfit for building purposes. In a recent dense deciduous forest on a substrate rich in nutrients, such as loess or river-loam, there are circa 300 trees per hectare (data from the Stichting Bosbouw Proefstation "De Dorschkamp" in Wageningen, and own observations). The maximum seems to us to be 1000 trees per hectare; then there would be a tree every three metres. If 10% of these trees are of a wood species suitable for construction, then only 30 to 100 trees of the desired species could be found per hectare. If, however, 50% of the forest contained the right kinds of wood, then 150 to 500 suitable trees were available per hectare. The trees will not always have the right thickness. When we assume that about half the trees had a suitable thickness, then this means that in the most favourable case the wood for one house was obtained from a forest covering one-quarter of a hectare or less. In the most unfavourable case this area would be 4 hectares.

In the case of Hienheim we know even less about the local forests. If we have to estimate the size of forest required to have enough trees to build an average house in Hienheim, we would say one-quarter to one-half of a hectare. We assume then that lime was not predominant over oak since our two pollen diagrams, in contrast to those of Southern Limburg, do not show high percentages of lime pollen. When the suitable trees have been cut down, it takes a long time for new trees of the same species to reach the size necessary for being used in building. Even in the event of patchcutting* it will be almost 100 years before oak trees with a diameter of 30 cm or more will be found. The other tree species grow slightly faster. In principle a certain plot of forest could thus again provide construction wood in about 100 years or slightly less. Of course the forests must then be left alone. Since we do not know whether the young trees could grow into trees with trunks that were suitable for building houses, we must take the possibility into account that a new piece of primeval forest was exploited for each new LBK house. A village such as Elsloo where, according to Modderman, 200 to 250 houses were built over a period of circa four centuries (Modderman 1970 p. 204) would, if new wood was used for each house, have extracted construction wood from a forest with a maximum area of 50 ha in the most favourable case and 1000 ha in the most unfavourable case. We shall come back to these figures in chapter V.

We have counted so far only the number of posts that were needed for building houses. However, other posts were also in use in the settlements, i.e. as part of the previously mentioned palisades in Sittard. Nothing indicates, however, that much heavy wood was required for such constructions. One type of construction outside the settlement, namely the fences around the fields, may have consisted of many poles. We know nothing about these fences; certainly they need not have been of durable wood. We assume for the time being that the wood for palisades and the like was obtained from the same forest area as the wood for the houses.

The inhabitants of the settlements probably needed not only posts but also wood in other forms. Wattle walls require quite a different kind of wood, namely long withes. Most suitable are hazel or willow branches and the shoots of several trees including lime. Furthermore, saplings are a possibility. If the walls of the LBK houses were indeed made of wattle-work, numerous branches must have been available. As the hazel was very common, the gathering of flexible hazel withes should not have been a major problem. Young trees occur in large groups in primeval forests. Shoots occur when trees fall or are damaged. The tree stumps left in the ground when the forest was cut to create fields could have produced large quantities of shoots in a short time. Furthermore in river and stream valleys beavers bring about a vegetation that looks very much like an osier bed (Lebret 1976). In contrast to trees, branches regenerate quickly after cutting. Therefore we are convinced that sufficient quantities of withes were always available.

It appears from the above that the LBK settlements used large quantities of the raw material "wood", and we have not even included firewood. Nothing indicates that there was ever a shortage of this important raw material, not even in the later phase of occupation. Even in Southern Limburg, which was more densely populated than the region around Hienheim, more houses were build during the later phases than in the earlier period (see III.6). An argument in favour of this view is the fact that settlement traces

* Patchcutting is the method of forest exploitation most favourable for forest regeneration.

from the younger LBK (Modderman period II) are more numerous in Southern Limburg than traces from period I (see table 3), whereas the periods do not differ much in length. Also, a settlement like Elsloo would have grown in the course of time (Modderman 1970 p. 205). Another point is that the quantity of wood necessary for the construction of houses in period II was not less than that which was used in the older LBK, at least insofar as this can be seen from the soil traces. There is no indication whatsoever that the houses became smaller. It is true that Modderman points out that the number of Grossbauten of type 1b decreases percentage-wise in period II with respect to the number in period I (Modderman 1970 p. 112), but this difference is not significant (χ^2 (5) = 7.4, the cirtical value is 11.1 at $\alpha = 0.05$). The ghosts of the ridge-supports of the later houses do not have a noticeably smaller diameter compared with to those of the older houses. We think that we may conclude from these facts that there was always sufficient timber available.

The origin of the l o a m is obvious. The houses of the four settlements were built on loess. This substrate is highly suitable for plastering and the like. The clay illuviation zone, the so-called textural B, has the best adhesive properties. This textural B was already developed to some extent (see p. 21 and 27). The use of local loess, however, need not have been restricted to textural B loam; material from the other zones was also useful. Thin sections of loam plaster show that the loess was indeed used as construction material; the loam component of loam plaster appears to be highly similar to loess (Jongmans 1976 verbal information).

It is generally assumed since Paret that it was the digging for loam that caused the many pits usually found in a LBK settlement (Paret 1942). It is thought that in particular the oblong pits beside the long walls of the houses provided the loam for the houses, i.e. the material for the walls (Modderman 1973, among others). Scheys observed during the excavation of the LBK settlement in Rosmeer (Belgium) that the pits were restricted mainly to the clay illuviation zone which, as stated, contains the best material (Scheys 1962 p. 61). He concludes from this that the inhabitants of the settlement used mainly loam from the textural B. In our four settlements too the loam used will have been predominantly loam from the textural B. We wonder, however, whether this was intentional. The pits have an irregular bottom and certainly they have not been dug systematically to the same depth. There are pits that extend just into the textural B and pits that pass through this zone. Moreover, thin sections of loam plaster by no means always show signs of clay illuvation (Jongmans 1976 verbal information). We do not consider Scheys' conclusions generally applicable. The depth of the loam pits can be the result of quite different factors; we do no wish to exclude chance.

At the settlement Olszanica B 1 (Poland) Milisauskas investigated whether the contents of the pits along the walls were indeed enough to construct an entire wall. He started with the volume of the pits as they manifested themselves upon excavation. So Milisauskas does not take into account the possibility that the original surface may have been higher. Even with this unfavourable starting-point the result of his calculations is that the contents of the pit were enough to cover the entire wall with a loam layer up to 10 cm thick (Milisauskas 1972). Furthermore, the loam need not have come exclusively from the deep pits which were discovered during excavation. We think it quite likely that there were also shallow pits which have disappeared due to changes in the relief at the settlement area (see fig. 4). Furthermore the excavated loam need not have been used exclusively for walls. Both considerations were reason enough not to repeat the calculations of Milisauskas for our settlements. We are convinced that there was always enough loam. The supply of this building material was inexhaustible.

The third raw material known to us is small plant remains which apparently were added to the loam. They manifest themselves as impressions in the plaster. Sometimes not only impressions but also carbon or plant remains that are completely reduced to ash are visible. The loam was not always mixed with plants; sand was also used; in addition there are lumps of burnt loam that show no visible temper at all. Still, the majority of the pieces show traces of plant remains.

The plant remains are seldom longer than 1 cm. Insofar as they can be identified, they are remains of gramineae: stems, leaves and chaff, including chaff remains of emmer and einkorn. It is possible, however, that other plants are also represented. The material as a whole is highly suggestive of chopped straw. We have made no attempt to prove that the most common temper material was indeed straw. This is perhaps possible through the analysis of opal phytoliths. In some cases it is clear that the loam was tempered with chaff only.

The chaff and the straw used must have been gathered especially for this purpose. It is assumed that the straw was usually left behind on the fields. The inhabitants of the LBK settlements would have harvested only the ears. This is concluded from the fact that the weed species found in the settlements belong exclusively to tall or climbing plant species. Low plants are rare, which would mean that the stalks were cut or picked just below the ear and not just above the ground (Knörzer 1967a, see also p. 62). Furthermore, there are indications that the chaff that found its way into the settlement was not always kept but was sometimes also burnt (see Appendix II).

The question is how much temper material derived from plants the inhabitants needed. If both the loam for the possible ovens and the loam for the wattle walls was mixed with this material, considerable quantities will have been necessary. We have no idea how much chaff and straw was produced yearly. We do not consider them as a raw material that was automatically available in large quantities.

It is possible of course that hay was used instead of straw, but hay could not have been easily available either since grassland was not common (see p. 75).

Another question is whether the plant stems were always chopped, also when used in wall plaster. Chopping or crushing straw or hay seems to us to have been a difficult task, especially large quantities. At present we have no idea what instrument could have been used to chop the straw.

We wanted to illustrate by the above the fact that the use of plants as temper material is not as obvious as it may seem. Perhaps an extensive study of loam plaster, however unattractive this may be, would provide more data. Other cultures could also be included in such an investigation.

For wood, loam and small plant remains, it has been demonstrated that these materials were actually used for construction purposes. This is not true for the materials which we shall discuss in the following. These are the materials which may have been used for the construction of the roof. Remains of the frame and of the roofing have never been found. That is why it is assumed that the roof consisted of perishable, organic material.

One of the materials postulated is bark (in the broad sense of the word) which could have been used for two purposes, namely as rope and as roofing.

In a vegetation of the type found in Central and Western Europe during the Atlantic, bast fibres are the most general natural source of rope. Lime- and yew-bast in particular were used for binding up to historic times (Vedel and Lange 1964). Willow- and elm-bast are also suitable. The latter was used successfully in the experimental construction of a "Neolithic" house in Allerslev (Denmark) (Hansen 1961).

We think that there was a frequent need for rope in the settlement but that it was not excessive. Given the abundance of trees with a suitable bast, we feel that there was always sufficient raw material for rope in the vicinity of the settlement.

We are not familiar with the potential supply of bark for roofing. From historic times we know only of the use of birch-bark in Europe, and then in combination with wood and sod. The birch is a tree which can not have been very common in the forests around the settlement or in the vegetation at larger distances. This tree requires much light and since the vegetations reconstructed by us include many shadow-casting tree species, it could only have stood in clearings. Under the influence of man, the birch certainly has increased in number in the course of time, but it seems improbable to us that birch-bark was used as roofing material on a large scale. It is possible, however, that other kinds of bark were suitable for this purpose, e.g. lime-bark or elm-bark which was used frequently in North America. We do not know enough about the properties of the different kinds of bark to pronounce a judgement in this respect.

Many authors concerned with the reconstruction of prehistoric houses choose reed for the roofing. This material is also mentioned as a possible roofing for the LBK houses (Zippelius 1957).

The reed plant is a cosmopolitan plant which occurs in a large number of habitats (van der Voo and Westhoff 1961 p. 238-239). The different habitats have in common, among other things, that they are humid-to-wet; the water table must lie at least just under the surface. This environmental requirement implies that most of the landscapes within a 10 km radius around the LBK settlements were too dry for the growth of reed. In our opinion the wet spots that occurred within the "dry" units, such as small marshes in stream valleys and hollows with stagnating rain-water, were covered with forest or at least were overshadowed by trees. Reed may have grown in the carrs, but it was probably fairly sparse because of the lack of light.

The only unit in which we think that reed could have grown in larger quantities is a river valley. As this unit too was forested for the most part, the areas with a potentially dense reed growth were restricted to the edges of open, stagnant or slowly running water, that is to the banks of ox-bow lakes and some inner bends of the big rivers. Ox-bow lakes, by the way, do not always have a zone with dense reed vegetation. A reed zone is absent when the concentration of nutrients is too low for one reason or another. We assume, however, that the majority of the ox-bow lakes in the Maas valley and the Donau valley were flooded often enough by river-water to enable reeds to grow.

We think that the chance is small that additional reed fields were present outside the 10 km radius and beyond the river valley. It is true that open water could be found outside the ox-bow lakes, but the question is how much reed grew here. In Southern Limburg there was a little lake near Cortenbach-Voerendaal; Janssen could indeed demonstrate reed in the peat deposits of this former lake. Such lakes, however, are very rare (Janssen 1960). As for the region of Hienheim, there is a vast marsh, the Donaumoos, 55 km west of Hienheim. However, the peat deposit in this area showed no reed remains at the point where the sample for the pollen diagram published in Appendix I was taken.

We are of the opinion that the construction material "reed" was present in the vicinity of the settlements Sittard, Stein, Elsloo and Hienheim, but that the source of this material was of limited size. On the other hand, the LBK houses were big and thus had large roofs. The quantity of reed that would be needed to thatch the houses is given in table 8. The calculations relate to the same house plans used for the calculation of the quantity of wood (see table 7). The measurements have been taken from publications by Modderman. The data for Hienheim are more detailed than those for Elsloo. We have copied them without modification. The roof surface was calculated for a gable-roof with an angle of 45°, which corresponds to the minimum slope that a reed roof must have to be waterproof. Moreover, we have taken into account the possibility, c.q. the probability, that the roof extended beyond the walls. The eaves are 50 cm long when projected on the ground; this corresponds with the calculations of Trier (Trier 1969). The quantity of reed is expressed in bundles. This is the unit in which reed is sold nowadays. A bundle has a circumference of 55 cm. For a waterproof roof 9 bundles of reed per m² are necessary. The last column indicates the area of cultivated reed land which today would yield the necessary number of bundles. The yield of reed beds may vary markedly, namely from 200 to 1200 bundles per hectare. A cautious estimate sets the average at 400 bundles per hectare (according to a number of reed cultivators, including the Rijksdienst voor de IJsselmeerpolders and the Vereniging tot Behoud van Natuurmonumenten). We have assumed 400 bundles per ha. For the habitats under consideration around the oxbow lakes, this estimate is probably too high.

Table 8. The quantity of reed necessary for the roof of a LBK house.

		length of house m	*width of house m*	*roof surface m²*	*reed bundles (number)*	*reed belts (hectares)*
Elsloo	28	10	5.5	101	909	2.3
Elsloo	57	14	5.75	144	1296	3.2
Elsloo	58	26	6.5	286	2574	6.4
Elsloo	27	27	6.5	297	2673	6.7
Hienheim	35	8.8	5.4	88	792	2.0
Hienheim	8	24.5	5.25	224	2016	5.0
Hienheim	2	17.8	4.8	154	1386	3.5

When we want to relate the required area of reed beds to the available area, we are faced with the problem that we do not know the number and the size of the main source, that is the ox-bow lakes. It is impossible to reconstruct the situation at the time of the LBK settlements. For lack of better, we will try to procede from the sub-recent situation.

The first dikes were constructed in the alluvial plain of the Maas in 1880, whereas the Donau was not restricted by dikes until the middle of the 20th century. Before those dates the two rivers could migrate freely within the river plain. It is known that the beds of these rivers shifted frequently in historic times. Paulissen has demonstrated that the Maas showed the same behaviour during the Atlantic (Paulissen 1973). We can imagine, however, that the number of displacements of the main channel was not as great in the Atlantic as in the sub-recent period. In the valley of the Maas, the bed shifted as a result of major floodings. The chance that the bed will shift is greatest when the summer bed is obstructed, e.g. by drift-ice. Paulissen writes: "The hypothesis can be made that in the alluvial plain of the Maas, where lower lying areas are absent, the most important shifts of bed would usually be the result of natural obstructions of the summer bed by icefloes" (Paulissen 1973 p. 70 our translation). Since there was perhaps less drift-ice during the Atlantic because the winters were not as cold (see III.2), it is possible that there was less shifting of the bed during the Atlantic and that therefore fewer ox-bow lakes would be created. On the other hand, the ox-bow lakes that were present could have stayed open for a longer time. Abandoned channels often fill with the sediment of the main stream. The speed of this filling is not constant but depends not only on the distance to the new bed but also on the load of the stream. This was smaller in the Atlantic than in historic periods (see III.3, p. 16). Therefore we think it possible that on the one hand the valley of the

Maas had fewer abandoned channels during the LBK occupation than it does today, but that on the other hand the abandoned beds that were present stayed open longer. We assume the same for the Donau.

On the basis of this consideration we feel that we may use, though with great reserve, the sub-recent situation to calculate how much open water was present in the river valleys. For the valley of the Maas, we use the situation in 1806, mapped under the direction of Tranchot (Tranchot Map, reissued 1967–1971, 1:25 000), and for the valley of the Donau the recent situation as shown on the topographical map 1:25 000. Within a radius of 10 km around the settlements there is a total of 13 km of abandoned channels in the valley of the Maas that still contain more or less open water. Around Hienheim there are 30 km of stagnant or slowly running water.

A last unknown factor is the average width of the reed belts. This width is not constant. Factors that play a role in the development of the belts are, among others, the concentration of nutrients in the water, the movement and the depth of the water, the slope of the bank and the composition of the subsoil (van Donselaar 1961). Therefore it is difficult to indicate exactly how wide the reed belt around the former ox-bow lakes will have been. Moreover, for Southern Limburg, it is impossible to borrow such data from the recent situation since all still existing ox-bow lakes, such as the abandoned channels at Stokkum and Dilsen, have been influenced rigorously by man. There is hardly any reed here anymore. The situation in the vicinity of Hienheim is more favourable. The reed plant is still common in the Donau valley; in the abandoned river channels it forms belts which vary in width from 0 to 5 m (the belt is absent where the bank is overshadowed by overhanging trees). If we had to estimate the possible width of the reed zones along the banks of the Atlantic ox-bow lakes, we would choose a figure between 1 and 5 m. Of course, this is an average; there were undoubtedly lakes without reed and lakes with wide riparian zones.

If we assume that the reed belts had an average width of 1 m, then a house with a roof surface of 267 m^2 (slightly smaller than Elsloo 58) required 60 km of river bank, that is a narrow water such as an ox-bow lake 30 km long, to thatch the roof of the house with reed. If the width of the reed belt is 3 m or 5 m, the requirement is 20 and 12 km of bank, thus an ox-bow lake 10 and 6 km long, respectively. It is true that reed can be harvested every year, but it is obvious that with a total of 13 km of channels only a few houses per year could have a new reed roof. The number increases slightly when not only the ox-bow lakes but also the inner bends of the active waterways are included in the calculations. Reed, however, is not always present here and the growth is not at an optimum. Moreover, the calculation of the number of hectares of reed required per roof is on the low side. According to Modderman, the inhabitants of Elsloo alone built one house in two years (Modderman 1970 p. 204); at the same time houses were also being built in other settlements. Not only for Elsloo, Stein and Sittard, but for all simultaneous settlements in Southern Limburg, the necessary reed had to come from the Maas valley. We feel that this is hardly possible, assuming of course that the settlements listed in table 3 (III.6) were indeed built simultaneously and assuming that our calculations for the reed beds are correct. In Hienheim the situation was more favourable. On the one hand the area producing reed was larger, and on the other hand it seems that there were fewer settlements. We think that the supply of reed, if important, was not a problem for Hienheim.

In this connection we wish to draw attention to the fact that all four settlements under study were located near a wide river valley. This is certainly not the rule for LBK settlements. Many sites, such as most of the sites along the small Méhaigne River in Belgium, are located far from the vast river valleys with their supply of reed. The inhabitants of these settlements would have had to go a long way for their reed. Although we have not made a special study of the growth of reed in Europe, we consider it likely that during the Atlantic the valleys did not contain enough reed to thatch all houses in all LBK settlements.

Therefore we wonder whether the houses of the LBK were thatched with reed at all. For the time being we should like to doubt it.

When one starts looking for alternatives, one may think in the first place of other types of thatch. Water plants, such as reedmace, offer of course no real solution because they require the same banks as reed. Plants of drier soils, however, might be the answer. Soudský mentions straw (Soudský 1969). But straw, like reed, is needed in large quantities. In the discussion of the possible use of straw for the temper of the loam for walls, we already questioned whether enough straw could be produced. The same considerations are valid now. Straw does not seem to us to be an obvious alternative for reed as thatching.

In addition to bark, reed and straw, sod, skins and planks have also been named as possible roofing materials. Sod must have a dense structure to function well on a roof. The plants which together with the adhering soil form the sod must grow close together and have a dense network of small roots. The types of vegetation that provide good sod are those of open ground such as grassland and moors. These types seldom or never existed in the period and area under consideration. Therefore we wish to exclude sod as a possible roofing material.

Regarding the possible use of skins, as suggested by Modderman (Modderman 1973), we should like to remark that the material was indeed present but that we wonder whether enough skins were available. The largest feasible skin, cowhide, averages 150 × 100 cm nowadays and thus has a surface of 1.5 m². This implies that for a house like Elsloo 28, with a roof angled at 45°, at least 67 present-day cattle skins would be needed. Elsloo 27 would have required 198 skins. These figures are perhaps on the high side, because the angle of the roof may have been smaller. Furthermore the skins may have been slightly larger; on the other hand we have not included the necessary overlap in the calculations. We wonder, however, whether the supply of skins would have been sufficient to provide all houses with a roof. This opinion has nothing to do with the question of whether skins were suitable for roofing large, permanent houses. We know of no examples. That is why we do not consider skins to have been used as roofing.

We have already discussed wood. Wood could have been used in the form of planks, shingles or faggots. The number of tree trunks required for an entirely wooden roof depends greatly on the way in which the wood was used. We think that the amount of wood required, even when planks were used, will not have exceeded 1 trunk per running meter. Assuming a split trunk would provide 8 to 10 planks 5 m long, then for the construction of a house such as Elsloo 28 a total of 33 trunks instead of 22 would have been needed (one trunk extra for the eaves of the roof) and for a house such as Elsloo 27 not 58 but 86 trunks. Of course, the corresponding forest area is also increased considerably. For shingles, less wood is needed; whereas the use of small branches need not involve new cutting activities at all. We consider wood to be the obvious choice as material for roofing. In the forested areas of Europe wood was used frequently for roofing until recently.

RAW MATERIALS FOR MOVABLE GOODS

The excavations at Elsloo, Stein, Sittard and Hienheim provided a large number of objects and remains of objects which were made mainly of mineral raw materials. Organic material is absent, except for a few bone fragments and some traces of pitch. The reason is undoubtedly that organic materials had little chance of surviving in our settlement areas, which are poor in lime and relatively dry. However, it is possible that minerals too have dissolved or fallen apart. It is quite likely that the objects which we have found represent only a very small part of the assortment originally present.

For the sake of convenience, we have divided the objects into seven groups mainly according to the raw material used. They are: 1) pottery and other objects of fired clay, 2) chert artefacts, 3) adzes, 4) artefacts that apparently served to grind or pulverize something, 5) stones that cannot be considered artefacts but which sometimes show traces of being used, 6) fragments of paint, 7) miscellaneous.

We have encountered vessels only in the form of pottery. It is usual to distinguish two kinds of LBK pottery, namely coarse and fine ware. The distinction is based mainly on the surface texture. Coarse pottery has a rather rough surface, whereas fine pottery is smooth and may even be polished. The difference in surface texture is determined not only by the finishing, but also by differences in the coarseness of the temper used. Other points of distinction are the average thickness of the sherd and the colour and shape of the pottery. Coarse pottery has a relatively thick sherd and is browner that fine pottery, where grey and black predominate. The fine pottery is often decorated with grooves.

The pottery from the settlements Elsloo, Stein and Sittard can be divided according to the above criteria into coarse and fine ware (Modderman 1958/1959d, Modderman 1970). The material from Hienheim, however, contains transitions so that it is not always possible to make the distinction (Modderman in press). As in all known LBK sites, the sherds of coarse pottery are by far in the majority.

Within the framework of our investigation into the use of the natural resources by the inhabitants of the settlements, asking whether their raw materials were local or not, we must of course take a closer look at the origin of the pottery. Two questions arise. The first one is whether the pottery was made locally or whether it was imported. The second question is whether the presumably local pottery was fashioned from local raw materials and, if so, which ones.

A generally accepted model presumes that most of the LBK pottery, like all prehistoric pottery, by the way, was made locally. The arguments in favour of this theory are borrowed mainly from ethnography. The excavated material has not yet provided real evidence. Archaeological analysis of shape and decoration has so far appeared to be insufficient to establish local production. However, the method can indicate regional differences. The pottery from Elsloo, Stein and Sittard is indistinguishable, but there is a clear difference with respect to Hienheim. Through very accurate registration, some investigators hope in the future to be able to identify certain potters or workshops, so that discrimination would indeed be possible at the local level (Stehli 1973 p. 59).

In another approach, attempts are made to borrow evidence from the analysis of the raw materials used. If the same raw materials were used for the majority of the excavated ceramics, and these raw materials, moreover, were present locally, then this pottery must have been manufactured in the settlement. Imports might be distinguished, in favourable cases, by a different composition. For this approach the assumption is made that the principal raw materials for pottery, clay and temper, were obtained locally. Transportation of clay over distances of more than 10 km seems to be improbable, given the required quantities of this material. Also in historic times, the pottery was usually manufactured fairly close to the clay source. The ready product was traded, not the clay itself. "Clays are widely distributed; only infrequently would it be necessary for potters to go far for body clay. Although clays differ greatly in their properties and although it is conceivable that either high standards or tradition would lead potters to import clay long distances, such instances in historic times are the exception rather than the rule." (Shepard 1963 p. 337). The same applies to temper (the nonplastic material that is added to clay in order to prevent excessive shrinkage, etc.). "Temper, of all ceramic materials, is the least exacting in its requirements; consequently, nonplastic materials are the least likely to be obtained in trade or from a great distance." (Shepard 1963 p. 337). That is why one can try to relate the composition of the pottery to local clays and temper. The many mistakes that can be made in the interpretation of the results of such an investigation are discussed by Shepard (Shepard 1963 p. 336–341).

As far as we know, the first search for the raw materials of LBK pottery was conducted by Obenauer. He examined sherds from Köln-Lindenthal by means of thin sections (Obenauer in: Buttler & Haberey 1936

Table 9. Description of sherds used for analysis.

number	*temper*							*thick-ness*	*colour*			*other remarks*
	sand grains size in mm			*pottery fragments size in mm*			*vanished material*					
	< 1	1–2	2–4	< 1	1–2	2–4		mm	*exterior surface*	*core*	*interior surface*	
Elsloo												
149–1	–	–	–	x	X	X	–	7	1	1	1	–
149–2	–	x	–	X	X	X	–	7–10	3	1	1	–
149–3	–	–	x	X	–	x	–	6–10	5	5	5	–
149–4	–	–	–	X	x	–	plant mat.	7–8	1	2	1	–
107–1	–	–	–	X	–	–	–	4–5	1	1	1	decorated
107–2	–	X	X	x	–	–	–	7–8	1	1	1	decorated
107–3	–	–	–	x	–	x	–	6	3	1	3	decorated
107–4	–	–	–	X	x	x	–	7	2	1	2	decorated
107–5	–	–	–	x	–	–	angular holes	12–13	3	1	1	–
107–6	–	–	–	x	–	–	–	12	4	4	4	–
107–7	–	–	–	x	–	–	angular holes	10	2	2	2	–
Hienheim												
*325–1	x	–	–	X	–	–	–	4	2	1	2	decorated
325–2	x	–	–	–	–	–	–	4–5	3	2	2	decorated
*325–6	X	x	–	–	–	–	–	6–7	2	2	2	decorated
325–10	X	–	–	x	–	–	–	9–11	3	3	2	–
*325–11	x	–	–	x	–	–	–	10	3	2	2	–
325–12	X	x	x	X	x	–	–	7–8	4	4	2	–
*325–14	X	X	–	x	X	–	–	8	2	4	2	–
921–1	x	–	–	–	–	–	–	3	1	2	2	decorated
921–6	–	–	–	X	–	–	–	6–7	3	–	4	decorated
921–7	–	–	–	–	–	–	–	11	3	2	3	–
921–10	X	X	X	–	–	–	–	11	2	4	2	–
921–11	X	x	x	–	x	–	–	6–8	4	2	4	–

temper : X = main component
x = accessory material
*: analysis by Slager, Van der Plas and Van Doesburg

colour : 1 = light non oxidized
2 = dark non oxidized
3 = light uncertain
4 = dark uncertain
5 = light buff fired

(colours based on the Munsell system

light = values 6–8
dark = values 2–5
non oxidized = chroma 1
uncertain = chroma 2–5, hue yellower than 2.5 YR
buff fired = chroma 6–8, hue yellower than 2.5 YR)

p. 123-129). With this technique only the temper and the natural impureties can be determined; he therefore restricted himself to a description of the tempers used. The results of the investigation supported the findings of the archaeological-morphological investigation. Some sherds were qualified in the latter investigation as different or even intrusive and appeared to differ from the rest which was called local; this difference was apparent in the thin sections as well (Buttler & Haberey 1936). For one group, "Importgruppe II", Obenauer showed that import was plausible and he even indicated the possible provenance. These sherds contained minerals that belong in a volcanic area. The pottery might therefore have originated in a region south of Köln, and more precisely in the Neuwieder Becken. Sources of raw material were not included in the investigation. Probably the import was of minor significance; "Importgruppe II" contains only 19 sherds.

Another thin section investigation which should be mentioned concerned LBK pottery from Müddersheim (Frechen in: Schietzel 1965). Frechen examined 12 sherds: six were coarse and six were fine pottery. He compared the minerals which were identifiable in the thin sections with the mineral composition of two local clays, namely the local loess loam and the underlying clay. Only three of the twelve sherds might possibly have been made of local material; the mineral composition of two of the fine sherds is similar to that of loess loam and one fragment of coarse pottery resembles the clay. Of the other nine sherds, six might have been made from river clay: Frechen suggests clay from the Rhein valley. Finally three fragments of the coarse ware should have originated near a volcanic area, which could be the Siebengebirge. Müddersheim lies 25 km from the Rhein valley and 40 km from the Siebengebirge. If Frechen's test series is representative for all Müddersheim pottery, his results would imply that most of the pottery was not made of local material and therefore was not manufactured locally. Unfortunately the sample is far too small to justify such a conclusion. In addition, the publication does not clearly define the composition of the sample.

The examination of our own material also started on a small scale, too small admittedly, with the analysis of 11 sherds from Elsloo; the analysis was carried out by Dr. C.J. Overweel. A more extensive examination was impossible at the time. For the sample, sherds were selected from two pits, namely numbers 149 and 107. Pit 149 belongs to house 32 and is dated as phase Ib. Pit 107 belongs to house 27 and dates from phase IIc. The sample from 149 consisted of 4 sherds of coarse pottery. The 7 sherds taken from pit 107 comprised four fine and three undecorated, coarse pieces. The external aspects of the sherds selected differed as much as possible. The features that are visible with the naked eye are stated in table 9.

The questions were restricted to two points, namely whether the group of pottery could have been made of the same raw materials in spite of the inhomogeneous external aspect, and whether the clay used could have been the local loess. Loess is the nearest suitable raw material for the manufacture of pottery. To answer the second question, not only the sherds were analyzed but also two samples of loess loam from the clay illuviation zone on the excavation site.

The techniques used consisted of examination of thin sections and X-ray diffraction. The latter method allows the identification of clay minerals. The results of the thin section examination support what had already been seen with the naked eye. Overweel's report states the following about the X-ray diffraction: "In order to compare the substance of the sherds with one another and with the raw clays, an X-ray diffraction method was used. Powder diagrams of the mineral mixtures in the pottery and in the clays were obtained with a Guinier de Wolff focussing monochromatic camera and Cu Kα radiation using 35 kV, 20 mA and an exposure time of 3 hours. With the combined thermal and X-ray diffraction technique for identification of ceramic materials (Isphording 1974), the untreated powder sample was analyzed first. It was then heated to 1100° C for 4 hours and the resulting diffraction patterns of the high temperature minerals were compared with those of the untreated sample. The diffractograms of the sherds and of the loess showed, in addition to the pattern of quartz and feasible feldspar lines in the 3.25–3.19 Å region, lines at the locations of clay mineral reflections which are not shifted by heating at 4.50, 2.60–2.55 and 1.51–1.50 Å. Most of the few indeterminable lines occurred both in the diagram of the loess and in those of the pottery. After heating the samples at 1100° C for four hours the diffractograms showed the patterns of α Fe_2O_3 and mullite. It appears that the high temperature phases of loess and the sherds conform. Therefore the possibility is not excluded that the loess was used for the manufacture of Elsloo's LBK pottery. The external differences in the ceramics did not show up on the diffractogram."

Should the small sample be representative for the pottery of Elsloo, this would mean that this pottery was indeed made from one and the same raw material. This raw material might have been obtained from the nearest source of clay: the loess. However, before drawing conclusions about the origin of the clay, we shall have to make more observations, examine more clays and study analysis results obtained with other techniques. Thus, another obvious clay, namely the river loam from the Holocene valley of the Maas, has not been analyzed yet.

The temper which was used, mainly pottery fragments, shows no specific features. The broken sherds may very well have originated from within the settlement.

Should we arrive in the future at the conclusion that the pottery found in Elsloo was made from local raw materials, this does not mean that the pottery was fired by the inhabitants of Elsloo themselves. We think in fact that an analysis of pottery from e.g. Stein or Sittard would provide exactly the same results. The local raw materials belong to the same loess deposit and the same type of river loam. We believe that it will probably never be possible to conclude, on the basis of a material analysis, that the three settlements in Southern Limburg each made their own pottery. With respect to the manufacture of pottery we shall (for the time being?) have to consider the settlements Elsloo, Stein and Sittard as one complex.

Pottery that might be considered import was not found in our small sample. Perhaps an analysis of a larger series of sherds might reveal pottery of a different composition. It is true that Modderman found amongst the normal LBK pottery, no indications of the existence of imported pottery, but in theory it is possible that LBK pottery hides imports which have not been discovered because their manufacture and decoration are highly similar to the home-made pottery. Modderman does describe an exceptional piece of pottery which differs in shape, colour and temper from the rest, namely a "steilwändige Becher" which was found in Sittard (Modderman 1958/1959d p. 98–99, fig. 69). This piece could have been imported. Furthermore he describes a small collection of pottery which was not made according to the LBK tradition: we refer to the so-called Limburger Keramik (Modderman 1970 p. 141–143). Thus it is clear that pottery from elsewhere "entered" the settlements, at least if one assumes that the "strangers" who made this "exotic" pottery did not live in the LBK settlement as well.

The pottery from Hienheim was analyzed in the first instance in the same way and on the same small scale as the pottery from Elsloo. Again, sherds were taken from two pits. Very different specimens were selected. The external aspects are listed in table 9. The collection of local clays is somewhat more extensive than that for Elsloo. The clays are: 1) two samples of decalcified loess (loess loam) originating from the excavation site, 2) two residual loams from the Cretaceous originating from a location in the Hienheimer Forst (one is white, the other is light brown), 3) a Miocene loam from Arresting, a place 3 km north-west of Hienheim, and 4) a Subatlantic river loam from the Donau valley. The weathering loams, the Miocene loam and the river loam are calcareous.

We quote from Overweel's report on the X-ray diffraction analysis: "All the powder diagrams of the investigated LBK pottery fragments contain the pattern of quartz and lines of feldspar in the 3.1–3.21 Å region. Of the possible clay mineral reflections at 10.0, 4.48, 2.575 and 1.495 Å the lines at 2.575 and 1.495 are the broadest. They stretch from 2.60 to 2.55 Å and from 1.50 to 1.49 Å, respectively.

In addition to quartz and feldspar, the powder diagrams of the loess samples contain conceivable clay mineral reflections at 15.0, 10.0, 7.0, 5.0, 4.48, 2.60–2.55 and 1.50–1.49 Å. Not only the positions of the three lower reflections but also the relative intensities between these lines are identical for pottery and the loesses.

The same lines which may point to the presence of clay minerals in the loesses also appear on the diffractograms of the calcareous clays, where calcite and quartz are the main non-clay components. Feldspars in the 3.1–3.21 Å region also occur here.

In the powder diagrams of the heated samples of pottery and loess, α Fe_2O_3 or hematite and mullite are clearly present; in contrast not these minerals but wollastonite was observed in the fired samples of the calcareous clays.

Röntgenographically, no traces of calcite were found in the pottery, nor traces of wollastonite in their fired counterparts. For this reason we can assume that calcareous clays were not used as the raw material for the LBK ceramics in Hienheim. As hematite and mullite distinctly occur, both in the fired pottery and in loess samples, there is a good chance that uncalcareous loess was the raw clay used in the manufacture of the ceramics investigated. It is interesting to note that the applied technique revealed no differences between the clays of the two distinct groups of pottery (i.e. the fine and the coarse ware, C.B.)."

Thus the local loess qualifies as raw material for the pottery which was excavated at Hienheim. Here too there is no certainty. As in the case of Elsloo, it is for instance possible that the pottery was fired in an area containing similar loesses.

The co-operation which developed between the Institute of Prehistory at Leiden and the Department of Soil Science and Geology of the Agricultural University at Wageningen resulted in the creation of a project for the purpose of studying the pottery from Hienheim more intensively than before. The investigation is conducted by Dr. Ir. S. Slager, Dr. L. van der Plas and J.D.J. van Doesburg. The first results of a test investigation of four sherds are included in Appendix III. The four very different sherds were taken from the assemblage of pit 325, which was also used by Overweel. They are described in table 9. The sherds were compared with four different clay samples from the surroundings of Hienheim: 1) loess loam from the illuviation zone at the excavation site, 2) calcareous loess from the C–2 horizon at the excavation site, 3) river loam from the valley of the Donau and 4) a white residual loam from the Hienheimer Forst. The Miocene loam is missing from the list because there were no samples available at the time of investigation. It must be noted that the river loam is from a sub-recent deposit. As mentioned on p. 23, the river loam was perhaps slightly sandier during the Atlantic.

The first phase of the investigation including firing tests on the different clay samples in order to determine whether they are indeed suitable for making pottery. This led to the rejection of one clay type, namely the residual loam which showed too much shrinkage to be useful. The calcareous loess does not have optimum properties either; the two other loams appear to be suitable. Subsequently thin sections and powder preparations were made of the sherds. Part of the powder was used for chemical analysis, another part for X-ray diffraction and a third part for different thermal analyses. The same methods of analysis were applied to the three more or less useful clays. As the analysis results are described in Appendix III, we mention only the provisional conclusions here.

The investigation shows that the river loam and the loess differ as far as the composition of the felspar assemblage is concerned. The felspars in the sherds are highly similar to the felspars in the loess. This could be a first indication that the four sherds examined were not made of river loam. A second point is that the river loam was found to contain a smaller clay fraction than the two loess samples. Since the sediment that was deposited by the Donau during the Atlantic was probably even sandier than the present sediment, river loam might have been less attractive as raw material. The possibility exists, however, that a good clay was found in dead river channels. Overweel's argument that the river loam could not have been used, because X-ray diffraction of the sherds showed no traces of calcite and heating to 1100° C revealed no traces of wollastonite, is not generally valid according to the diffraction data of Slager, Van der Plas and Van Doesburg which showed traces of wollastonite. However, the original material could not have been rich in lime, according to the latter investigators. Therefore they wish to exclude the calcareous loess from the C–2 horizon of the soil profile. Their provisional conclusion is that a loess may have been used that was less calcareous than the unchanged loess, but more calcareous than the present loess loam from the illuviation zone. Since Van de Wetering assumes in the reconstruction of the Atlantic soil profile that the profile was already decalcified to the present depth (see p. 27), a mixture of decalcified loess and calcareous material could have been used for making pottery. Furthermore, it appears that the raw material is not completely identical for all four sherds. One of the sherds contains less felspar, less normative mullite and more quartz than the other sherds, a difference that cannot be attributed to the temper. The body clay of this sherd must have been poorer in felspars and kaoline and richer in quartz than the body clay which was used for the other three. Another sherd is very rich in micas 0.03 mm across, whereby it is not clear whether they belong to the clay or were added with the temper. The final conclusion is that on the basis of an analysis of four sherds not much can be said yet about the raw materials. The local loess may have been used, but then it must have undergone certain treatments, according to the investigators, to arrive at the given composition.

The above-mentioned investigation also provided data about the temper material. The results of the analysis make it plausible that the same type of sand was used for the four sherds, namely a quartz sand with a felspar content of circa 20%. For the coarse pottery a sand fraction with grains of up to 0.2 mm was used. The grain size in the fine material is between 0.02 and 0.04 mm. Besides the felspar content, the sand is characterized by a few chert fragments. It is striking that the grains of the temper are angular. That is why normal river sand is excluded: it is not clear to us at the moment which material was used. The pottery fragments which were also used as temper cannot be distinguished, at least in the thin sections, from the pottery in which they were incorporated. It is plausible therefore that they are of the same type of pottery.

A third aspect which the investigation showed is the high phosphorus content of the sherds. No satisfactory explanation of this phenomenon has been found so far.

The many questions encountered during the test investigation were sufficient reason to continue the investigation with more sherds. The results are not yet available.

So far we have spoken exclusively about the main components of the pottery, namely the body clay and the temper. However, other materials were used for finishing certain pieces. Specimens of fine pottery were sometimes coated with a slip. To our knowledge this slip has not yet been described, or examined. Within the framework of the investigation of the pottery from Hienheim, this mineral material will be studied as well. Furthermore, remains of a coloured paste have been found sometimes in the grooves of the decorative patterns. This paste contrasts in colour with the wall of the sherd. We have not yet seen such coloured fillings on the pottery of Hienheim, but the pottery from Southern Limburg does show traces of colouring matter. A white paste is seen most frequently (Modderman 1958/1959d p. 85), but we also know of fillings of red paste. The pastes have not been analyzed in our investigation. Meier-Arendt describes the composition of comparable paste remains in his work on the Untermaingebiet. The red paste consisted in one case of pulverized red-burnt clay and in another case iron oxide was certainly used. For black pastes he mentions once a resinous substance and once bone-black. White paste has not been analyzed (Meier-Arendt 1966 p. 50–51). Behrens mentions hematite, mixtures of hematite and clay, resin, manganese, lime and kaoline for incrustrations in Central Germany (Behrens 1960). As nothing is known about the colour pastes at the Dutch sites, not much can be said either about their origin. If hematite, a colouring matter than is found frequently in LBK settlements, was used for the red paste, then at least this matter is a raw material that had to be imported into Southern Limburg (see p. 118).

In our first category of objects we have included not only the pottery but all objects of fired clay, since not only sherds but also other ceramic objects were found in the settlements. These are very rare. They are described as "spindle-whorls" and fragments of "idols". The material of which they are made does not seem to differ from that of the pottery. The exceptional pieces have not been subjected to further analysis.

The second group of artefacts is the markedly heterogeneous group of objects made of c h e r t. By chert we mean all rocks consisting of microcrystalline or submicrocrystalline accumulations of silica. Cherts from the Cretaceous Chalk are often referred to as "flint".

In our settlements, chert artefacts and fragments are almost as frequent as pottery sherds. This type of rock was used in the manufacture of many different tools. We shall not discuss these tools here, but refer to the literature on the subject (Bohmers & Bruijn 1958/1959, Bruijn 1958/1959, Newell 1970 and de Grooth in press). The material excavated shows that the inhabitants of the settlements worked the cherts themselves, since considerable waste and rough-outs have been found. That is why the above-mentioned authors included the possible origin of the necessary raw material in their considerations. In the following we shall first have a closer look at the sites in Southern Limburg and then at Hienheim.

The inhabitants of Elsloo, Stein and Sittard used the same types of chert. The most common type varies in colour between light gray and grayish black (Munsell Rock Color Chart 1951: N7–N2). The colour is seldom uniform, even in small pieces; within the range of the greys there are larger and smaller blots and smears. In addition, the grey often contains many white dots. As the weathering of the pieces increases, the colour becomes lighter. The aspect of the fractures varies from smooth to slightly granular. A sample of this chert can be seen in fig. 11.

There are a few incidental pieces that are of another type. They form a highly heterogeneous group, which represents less than 5% of the find material. Some pieces belong to the type that Löhr has provisionally called "light grey Belgian chert" (Löhr 1975 p. 225). The use of different cherts is not limited to a certain period of the LBK occupation.

The grey chert closely resembles the chert found as horizons with nodules in the limestone deposits (chalks) of the Upper Cretaceous in Southern Limburg. Many of these limestone deposits belong to the geological period which is referred to as "Maastrichtian". Three formations can be distinguished nowadays within the limestone deposits: the Gulpen formation, the Maastricht formation and the Houthem formation, which is the youngest (Felder 1975). The Maastricht formation comprises two facies: the Maastricht Chalk and the Kunrade Chalk. Cherts occur in the upper deposits of the Gulpen formation, in the lower deposits of the Maastricht Chalk and in the Kunrade Chalk. The chert from the youngest part of the Gulpen formation is darker in colour and finer in texture than the other cherts (Felder

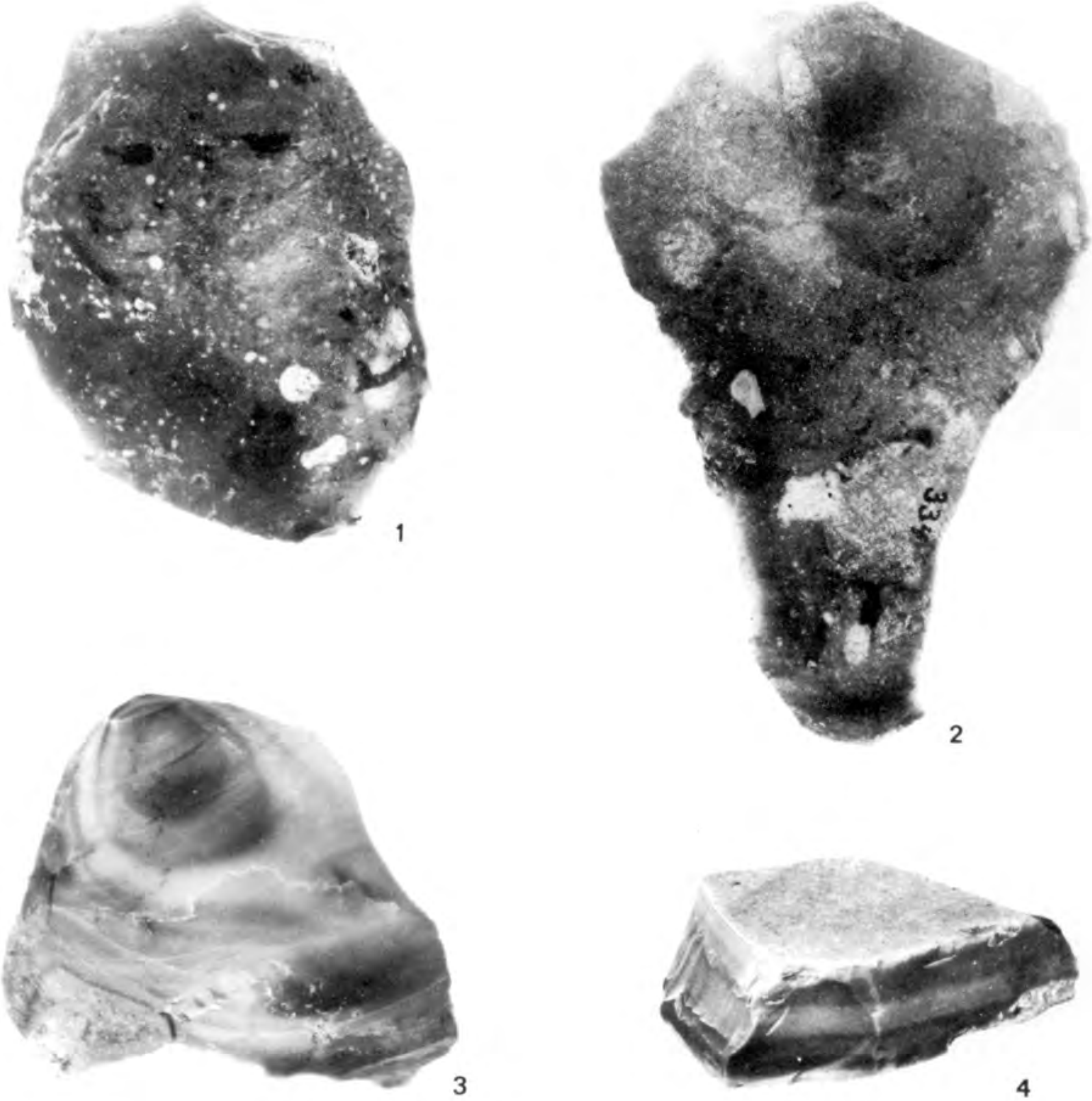


Fig. 11. Typical cherts. Scale 1:1.
nos. 1 and 2: chert from the Gulpen Formation, flakes excavated at Elsloo.
no. 3: chert from the Jurassic, flake from a nodule, excavated at Hienheim.
no 4: chert from the Jurassic, core from a plate, excavated at Hienheim.

& Rademakers 1971). It is this chert which the artefacts and waste from the LBK settlements resemble; the similarity is so striking that we, with many others, have no doubt that it was indeed used by the inhabitants of Elsloo, Stein and Sittard. That is why Newell writes of the "Gulpen flint", whereas Bruijn speaks more generally of "Maastricht flint", i.e. flint from the Maastrichtian (Newell 1970 p. 145, Bruijn 1958/1959 p. 213).

As mentioned on p. 15, the northern limit of the area where the limestone deposits of the Upper Cretaceous come close to the surface is just 10 km south of the LBK settlements. In this area the Gulpen formation crops out in valley slopes. The formation is cut by the valley of the Maas, among others. Not surprisingly chert from the Gulpen formation is a frequent component of the Maas deposits. Besides secondary chert in gravel deposits, there is also residual chert. The latter can be found in the eluvia to the south in Southern Limburg and in the adjacent Belgian territory.

The cortex of the chert, which was deposited as gravel, has undergone modifications as a result of transportation. These differences have been used by Newell to divide the artefacts and the waste of his "Gulpen flint" into two groups: one group which apparently was made of fresh chert and one group which must have been made of Maas gravel. "In most cases, the Bandkeramik flint knappers utilized fresh flint nodules taken from the chalk beds of the Rijckholt-Banholt-Rullen area. The freshness of the material is indicated by the presence of a thick, crumbly, white chalk cortex on some of the artifacts and a large number of the waste flakes." and "A second source of this Gulpen-formation silicate is the gravel beds of the middle Maas. There one finds blocks of flint heavily rolled and displaying a characteristic dark orange, weathered cortex which has been smoothened and abraded almost to the texture of a patina. Numerous blocks and flakes carrying this weathering have been found in the excavated Bandkeramik settlements. However, this source of raw material is secondary compared to the fresh flint." (Newell 1970 p. 145). Our counts indicate that the Maas gravel accounts for 10 to 20% of the total.* All phases of the LBK were taken together for the counts, which means that we did not verify whether the proportion of gravel varied per period. It is clear, however, that the blocks of gravel were used during all phases, which Newell confirms (Newell 1970 p. 145).

If the pieces with cortex represent the total amount of chert correctly, then 80 to 90% of the material consists of chert which was not transported by a river. Newell calls this chert "fresh flint", that is chert which came directly from the chalk. We wonder, however, whether cherts from eluvia should be excluded. A comparison of the cortex of residual chert and fresh chert indicated that the cortex of the former is usually thicker and harder. In addition, the colour of the residual chert is somewhat paler and yellower, although it certainly need not be as yellow as Löhr suggests (Löhr 1975 p. 95). The differences, however, are such that we could not always identify the individual pieces from the excavations. Therefore we do not wish to give percentages; our impression is that most cherts came directly from the chalk deposits.

We have tried to determine the origin of the grey chert in another way. The method followed is that of chemical analysis, namely neutron activation analysis. The concentration of certain elements is measured with this method. As the main components of chert are the same everywhere, possible chemical differences must be sought in the differences in the trace element content. The method of analysis chosen is very accurate. It measures concentrations expressed in ppm. We knew that the method was useful in distinguishing French chert (from the workshop La Chatière in Le Grand Pressigny), Danish chert (from the chert mine in Hov), and chert from the Gulpen formation (from the chert mine in Rijckholt) (de Bruin

* We observed during the counts that the cortex of the pieces from the gravel is not always as heavily worn and therefore is not always as dark orange as Newell indicated.

et al. 1972). Cherts from the different formations and facies of the Upper Cretaceous in Southern Limburg also appear to differ in their trace element content (Bakels 1975). The investigation of the chert used by the inhabitants of Elsloo, Stein and Sittard, however, must distinguish between the different chert sources within one single facies: the Gulpen Chalk. For the analysis we chose sources of chert which are known to have been used for the manufacture of prehistoric artefacts, though not necessarily during the LBK occupation. Samples were taken from the prehistoric chert quarries in Rijckholt, Mheer, Banholt and Rullen (for these sites, see Montagne 1971 p. 144). In Rijckholt pieces were taken from the band which was mined during the transition from the fourth to the third millennium B.C., as well as waste pieces that lay on the surface in the workshop. Probably the Rijckholt workshop made use of the chert from the mine, but it is also possible that some of the raw material came from one or two other bands. Of course the material from the mine and that being used in the workshop were kept separated. The workshops in Banholt, Mheer and Rullen obtained their chert from an eluvium and therefore worked derived cherts. Besides samples from the above-mentioned places, we took samples from gravel deposits of the Maas. Apart from differences in the cortex, the cherts are difficult to distinguish from one another with the naked eye. The only identifying feature is that the eluvium chert from Rullen is yellower than the rest. Between 40 and 50 pieces of rock from each site were examined. The results of the analysis were further processed by means of pattern recognition (see de Bruin et al. 1972 for the method of analysis and de Bruin et al. 1973 for the mathematical approach). The characteristics used in this case were the concentrations of Fe, Na, Co, Cr, Br and K. The results of pattern recognition are given in the following table.

Table 10. Neutron activation analysis of Southern Limburg cherts, summary of the results of pattern recognition, all samples used for training and testing.

right origin	*selected origin*					
	R.mine	R.workshop	Banholt	Mheer	Rullen	Gravel
Rijckholt mine	20	29	0	0	0	0
Rijckholt workshop	0	46	0	0	0	0
Banholt	1	36	1	2	2	2
Mheer	4	32	0	8	0	0
Rullen	3	36	0	5	3	0
Gravel	12	30	0	5	0	1

It appears from the results that only the material from Rijckholt has such well-defined characteristics that the individual pieces can be attributed to their own place of origin. The assumption that the chert from the mine can be attributed to the workshop is based on the probability that the mine supplied the chert to the workshop. The rest of the sampling sites have a more varied composition. The rocks obviously come from mixtures in which the Rijckholt type was predominant. The fact that so many samples were attributed to the Rijckholt workshop is the result of the mathematical approach, whereby samples are preferably attributed to groups with well-defined characteristics. Of course it is not surprising that the cherts from the eluvium and the gravel show the characteristics of a mixture. It might have been possible, however, that the trace element content of the derived cherts changed to such an extent with time that these locations could be also characterized. Unfortunately, this appears not to be the case. Even the samples from Rullen, which have a different colour, show no differences, at least no differences that can be demonstrated by our method of analysis. The result of the analysis is therefore that we have not succeeded in characterizing certain types of chert within the Gulpen formation. However, the analysis has not yet been completed; it is being continued with other chert outcrops within the Gulpen Chalk.

We have conducted one test to verify whether chert from a settlement could also be attributed to Rijckholt. For this purpose, 50 flakes from pit 334 of the Elsloo settlement were selected. The measurement of one sample had to be eliminated, so that the analysis data for 49 flakes are available. Analysis of the outer layers of the flakes was avoided in order to exclude insofar as possible the influence of patina, if present.

Table 11. Neutron activation analysis of Elsloo 334 flakes, pattern recognition, samples from table 10 used for training.

	selected origin					
	R. mine	R. workshop	Banholt	Mheer	Rullen	Gravel
Elsloo 334	8	34	0	4	0	3

Thus the chert from Elsloo 334 can indeed be attributed for the greater part to the "Rijckholt" type. The comparison with the Maas gravel was superfluous in this case, because the cortex of the flakes is clearly not a gravel cortex.

It appears from the above that at present no more can be said about the exact origin of the fresh grey chert than that it most probably came from the area of the Gulpen formation: from the Gulpen Chalk. This area, by the way, is larger than Newell suggests. Not only the Rijckholt-Banholt-Rullen area, i.e. an area south and south-east of Maastricht, must be considered but certainly also the region of the Jeker valley in Belgium.

It is not known how the chert was removed from the limestone deposit. The most obvious model, in our opinion, is modest open-cast mining where suitable bands reached the surface.

A third question that remains unanswered is who exploited the chert: the inhabitants of the LBK settlements themselves or others. We prefer a model whereby a few inhabitants undertook short expeditions to get the necessary chert, but of course other ideas are possible.

There is an indication that the rock arrived at the settlement in the form of whole chert nodules or large fragments of bands. A complete nodule measuring 23 × 16 × 15 cm was found in pit 45 of the Stein settlement. Furthermore the size of the waste suggests the large dimensions of the processed blocks.

We can be brief about the rest of the chert material. It is obvious that the grey chert which, given its cortex, must have come from gravel, was taken from the deposits of the Maas. The most probable sites are the gravel bars in the river bed. "The bed material which at low water levels can be observed over a long distance is mainly very coarse gravel with an average diameter of 15 to 20 cm. Blocks of up to 80 cm in diameter were observed." (Paulissen 1973 p. 86 our translation). Chert is one of the main components of this gravel. We assume that this situation also existed during the Atlantic (see p. 16). The same gravel bars could have been the source of the few cherts which do not belong to the "Gulpen flint". The cortex remains of the pieces from this group point in this direction. The only exception are two pieces of "light grey Belgian chert" with a cortex that indicates that they came from fresh blocks.

Summarizing we can say that a minority of the chert may have been found within 10 km of the settlements. The majority, however, did not come from the immediate vicinity. The area of origin does lie within a radius of 30 km and therefore within a travelling distance of one day. We think that there is no question of evident import.

The cherts found in Hienheim are completely different from the chert of Southern Limburg. Two types can be distinguished, although they look very much alike: a nodule-shaped and a plate-shaped chert. 75%

of the core pieces are made from nodules and 25% from plates (de Grooth in press).

The nodules are usually light grey to grey in colour; sometimes reddish colours are seen (Munsell Rock Color Chart 1951: light olive gray 5Y 6/1, olive gray 5Y 4/1, moderate reddish brown 10R 4/6 and moderate yellowish brown 10YR 5/4). The cortex is hard, white and 0.5–3 mm thick. The nodules often show a more or less concentric layered structure due to alternating light and dark zones. Upon fracturing the layers appear as rings and flames. The average diameter of the nodules lies between 5 and 10 cm. The chert plates are grey, light grey or yellowish in colour (Munsell Rock Color Chart 1951: light olive gray 5Y 6/1, olive gray 5Y 4/1 and grayish orange 10YR 7/4); these shades can occur within one piece in layers which extend parallel to the plate, so that upon fracturing the rock acquires a striped aspect. The plates have the same type of cortex as the nodules: the thickness of the plates averages 15 mm. The horizontal extension of the original plates cannot be determined from the fragments found in the settlement. The fractures of the nodules and plates are usually smooth, but shining and granular surfaces also occur. Examples of both cherts can be seen in fig. 11.

These two types are the only cherts that were used in Hienheim. According to De Grooth, the number of exceptions is about 10 out of a total of thousands of fragments: a negligible number (De Grooth 1976 verbal information).

Undoubtedly the cherts came directly or indirectly from the limestone deposits of the Jurassic, as found in the Frankische Alb. These cherts are referred to in German literature as "Hornstein." Material which is identical to the excavated material is found in the "Plattenkalk" facies (see also p. 22). Some "Plattenkalke" contain mainly nodules, others nodules and plates; there are also "Plattenkalke" without chert (Rutte 1962 p. 50–51). Deposits of the Jurassic are present in the vicinity of Hienheim, even within a distance of 10 km (see p. 22).

We think, in agreement with De Grooth, that the source of the cherts must lie in the first instance in the vicinity of the settlement since the raw material, in the shape of nodules as well as plates, must have been very easy to obtain. De Grooth writes in her publication: "cores were not used exhaustively and, even more important, many pieces were not examined until back in the settlement for their suitability as a core, given the frequent occurrence in the waste pits of pieces which apparently were discarded after one or two attempts at flaking." (de Grooth in press, our translation).

As in Southern Limburg, there are three possible origins, namely outcrops with chert in situ, residual loams with concentrations of residual cherts and cherts in river deposits, such as the Donau gravel. We can exclude the last possibility from the start, firstly because hardly any corresponding cherts can be found in the gravel (van de Wetering 1975b) and secondly because the cortex of the material used in Hienheim is that of either fresh or residual material. Sometimes it is very difficult to distinguish fresh chert from residual chert in the finds from the settlement. Chert fresh from the limestone was certainly used, but it has not (yet) been possible to determine the percentage. Therefore outcrops as well as concentrations of residual rock must be considered as sources of the cherts. Moreover, both types of source must lie in almost the same places, namely where the "Plattenkalke" reach or almost reach the surface, so that in the first instance the difference between chert in situ and chert from residual loams is not very important as far as the question of origin is concerned.

We have tried of course to find the chert sources which might have provided the material used in the settlement. In this attempt we were guided by the descriptions of two published map sheets of the Geological Map of Bayern 1:25 000 (sheet 7136 Neustadt a.d. Donau and 7037 Kelheim), as well as a map drawn by Davis (Schmidt-Kaler 1968, Rutte 1962, Davis 1975).

We have not succeeded so far in finding the chert within a radius of 10 km around Hienheim. In fact we only found one single occurrence near Schwabstetten, 7.5 km west of Hienheim. It is an outcrop of "Plattenkalk" with chert, as well as a concentration of residual chert. However, there were no pieces with a smooth or shining fracture like the good pieces from the settlement. Within a radius of 30 km there are more possibilities, certainly as far as nodule-shaped chert is concerned. Davis' map mentiones more occurrences with chert nodules than with chert plates for this area. We had a closer look at only one series of outcrops with plate-shaped cherts in Kelheimwinzer, 12.5 km north-east of Hienheim. The cherts gathered here appear to be coarse.

Although we cannot indicate (yet) a possible place of origin, we continue to consider the cherts as a local raw material. We are supported in this opinion by the findings of Davis. Davis studied the use of chert by Early- and Middle-Neolithic populations in the area between Neuburg a.d. Donau and Straubing, where Hienheim is also located. In his work he arrives at the conclusion that the cherts are of local origin. When there was a difference in the ratio of nodules versus plates per settlement, he could explain this by the difference in local availability (Davis 1975 p. 64). Possibly the present occurrences of cherts are only partly the same as those that could be seen at the time of the LBK occupation. Perhaps one day a very intensive search will reveal the latter.

Some quarries could have looked like the site described at Lengfeld Ldkr. Kelheim (Reisch 1972). The chert of Lengfeld is concentrated in a residual loam on Jurassic limestones. Nodule-shaped cherts are the most frequent; real plates are absent. The extraction took place by digging pits. Deer-antler picks were used for this work. It is possible that the chert concentration of Lengfeld had already been exploited at the time of the LBK, but there is no evidence of this. Most traces are from the Late-Neolithic. Of course, later traces may have wiped out the earlier ones. We think it possible that Lengfeld, a place 18 km east of Hienheim, supplied chert for Hienheim, but this certainly does not apply for all the material found in Hienheim, in any case not for the plates and nor for the nodules freshly hewn from the limestone.

In contrast to the preceding category of objects, which was a heterogeneous group of artefacts with a common raw material, the adzes can be described as a homogeneous group of artefacts made of different raw materials.

The adze is a very characteristic attribute of the LBK. Adzes are ordinary components of the settlement waste; they are also found in graves. The waste usually contains worn or broken specimens, whereas intact specimens were buried with the dead. The finds from Sittard, Stein and Elsloo have been described together in a publication by Modderman, which also includes a typological division (Modderman 1970 p. 184-191). Six types can be distinguished, and one type is subdivided into two subtypes. The criteria applied are the ratio of height to width, the ratio of width to length, and the absolute dimension of the width. Part of the adzes from Hienheim have been described by De Grooth (de Grooth in press).

The artefacts are made of a very dense, crystalline rock, which was ground in the last phase of manufacture. Chert was not used. The types of rock used in Elsloo, Stein and Sittard have been identified by the staff of the National Museum of Geology and Mineralogy in Leiden, where first Dr. C.J. Overweel and subsequently Dr. C.E.S. Arps conducted the investigation. Moreover, part of the material was studied by Prof. Dr. J. Frechen of Bonn. Arps also examined the adzes from Hienheim. Thin sections were made for the purpose of identifying the different types of rock. The description of the rock types has been included in Appendix IV, which contains Arp's findings. The rock types found in the Dutch settlements, as well as the corresponding number of specimens, are listed in table 12. The rock types can be divided into

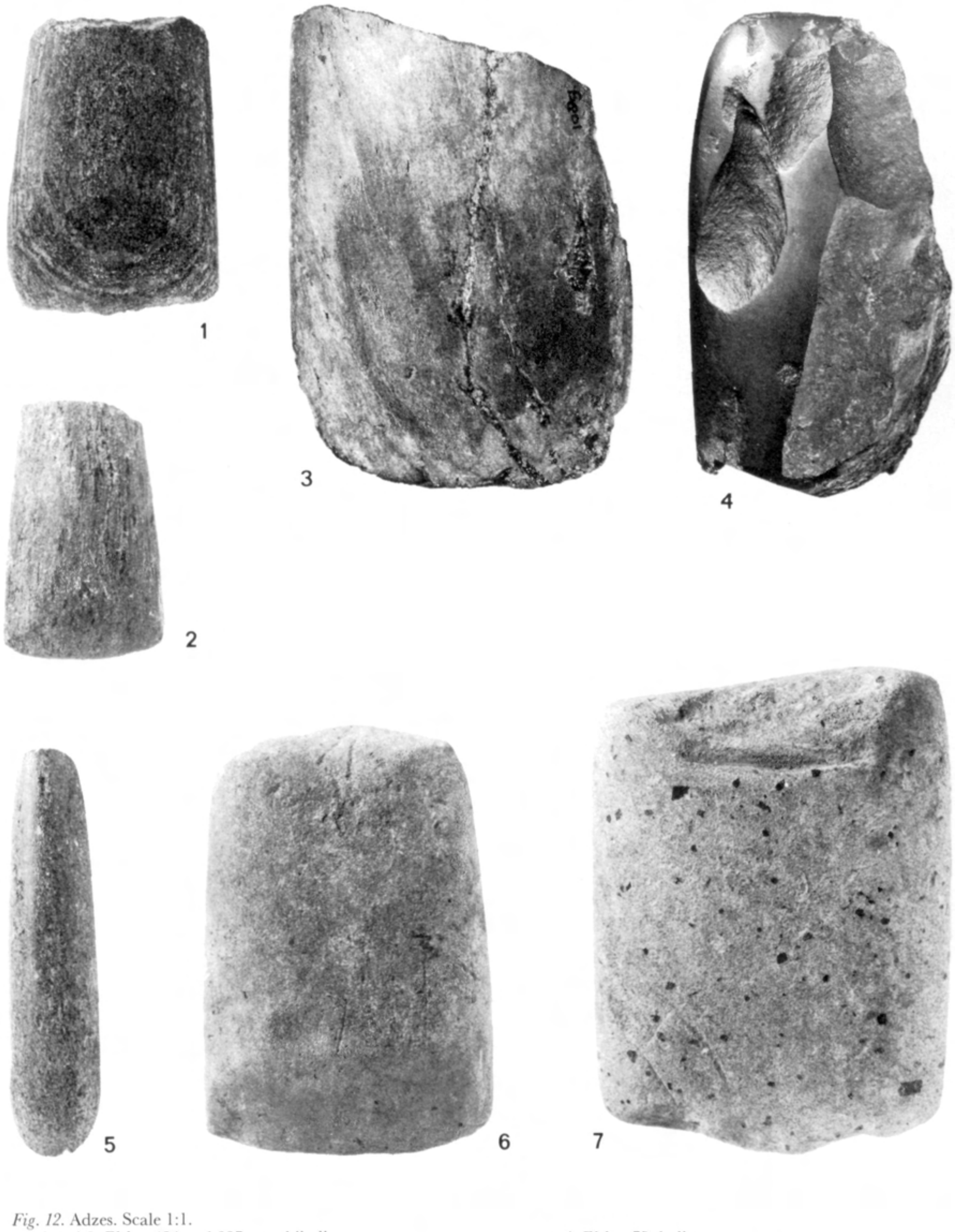


Fig. 12. Adzes. Scale 1:1.
nos 1 and 5: Elsloo 454 and 337, amphibolites.
no 2: Hienheim 703, "homogeneous" amphibolite.
no 3: Hienheim 1089, "fine inhomogeneous" amphibolite.
no 4: Elsloo 75, lydite.
no 6: Stein 129, basalt with small phenocrysts.
no 7: Sittard 66, basalt with relatively large phenocrysts.

Table 12. Adzes and adze fragments from Elsloo, Stein and Sittard.

		amphibolite	basalt	metaquartzite and lydite	dolerite	quartz arenite	quartzitic greenschist	quartzitic schist	biotite gneiss
Elsloo	period I	8	1	–	–	1	–	–	–
	period II	9	9	3	–	1	–	–	–
	un-dated	3	3	3 + 2*	–	–	–	–	–
Stein	period I	2	–	–	–	–	–	–	–
	period II	4	6	2	–	–	–	–	–
	un-dated	3	1	–	1	–	1	–	–
Sittard	period I	9	2	–	–	–	–	1	–
	period II	4	3	–	–	–	–	–	–
	un-dated	1	–	1	–	–	–	–	1

* = rough-out.

four groups, namely amphibolites, basalts, grey to black quartzites and a residual group. The last group consists of single pieces.

The amphibolites are often described in the excavation reports as greenish rocks. This colour is the result of weathering. It can be described as light olive gray 5Y 6/1 to dark greenish gray 5GY 4/1 (Munsell Rock Color Chart 1951). The weathering crust is ca. 0.5 mm thick. Darker and lighter stripes and bands contrast with the greenish colour. These stripes and bands are always oriented parallel or nearly parallel to the longitudinal axis of the adze (see the photographs in fig. 12). The rock further has a fine fibrous aspect, especially along fractures. This structure is most clearly visible on a cleavage in the longitudinal direction of the artefact. These observations are related to the fact that amphibolite is an oriented rock, that is a rock in which the rock-forming minerals are oriented in a certain direction. Apparently this direction was taken into consideration when the adzes were made. Two things may have played a role here. One of them is that it is easiest to cleave the rock parallel to the direction of orientation, so that the long sides of a rough-out develop more or less parallel to the direction of the rock. In the second place, following the direction of orientation is the best method to avoid cross fractures during the use of the adze, because the rock is strongest across its direction of orientation. It must be noted that the structure of the amphibolites is not the same in all pieces. There are coarse and fine rocks and some show more marked orientation than others. We refer to Appendix IV for a further description, but we do wish to remark here that the adzes certainly did not have a greenish colour at the time of the LBK. In the unweathered, fresh state they must have been black or almost black.

The basalts have a weathering crust, which is so soft that it feels sandy and leaves a light yellow to light brown streak on paper. The thickness of the crust is 0.5 to 1 mm. The colour of the weathering crust is light olive gray 5Y 6/1 to pale yellowish brown 10YR 6/2. It is speckled with dark grey and dark brown dots, many of which are regularly shaped. These dots are the relatively large crystals, the so-called phenocrysts, which become conspicuous as a result of the weathering of the rock. The size of the phenocrysts varies in the different adzes. In some specimens they are barely visible, whereas in others they are several mm across. Basalts with phenocrysts more than 5 mm in diameter are absent. A basalt with very small and one with relatively large phenocrysts are shown in fig. 12. The weathering crust developed after the adzes were buried in the soil. They were black when in use.

The quartzites are barely weathered; they are still medium gray N 5 to grayish black N 2. Most specimens have a layered structure: some fractures may be step-wise for that reason. Fractures can also be conchoidal. This characteristic is most pronounced for the rocks which look like lydite and can even be described more or less as such (e.g. Elsloo 75, see fig. 12). When there is a layered structure, it is parallel to the flat side of the adze.

The fourth group will not be discussed in detail here. It is a group of rock types which apparently were used incidentally for making an adze. We shall mention only one single piece: an adze of dolerite. This adze from Stein (Stein 218) is the only perforated adze among the finds studied.

We have investigated whether specific types of rock were used for the different types of adzes. One could imagine for instance that flat adzes were made exclusively of a layered rock. This appears not to be the case. There is no correlation between the height/width ratio of the adzes and the type of rock used. High as well as flat models were made of all rock types.

None of the rocks identified is present as a primary rock within a radius of 10 km around Stein, Elsloo and Sittard. When the area is enlarged to a radius of 30 km, outcrops still cannot be located. The only possibility of a local origin of the raw materials is therefore that they were brought in by the Maas and thus occurred as derived rock in the Maas gravel. The gravel analyses by Van Straaten, however, indicate no basalts at all in the Maas gravel* and the chance of finding amphibolites is negligible (van Straaten 1946). The latter were seldom found and then in the form of small pebbles. The grey quartzites may have originated from the gravel, as well as the rocks of the residual group. Van Straaten's observations imply that most of the material must have been imported.

As neither blocks nor rough-outs of amphibolite and basalt have been excavated, the rocks must have been brought to the settlement as finished or nearly finished adzes. A treatment such as grinding or polishing may possibly have taken place in the settlement. Traces of such proceedings cannot be demonstrated. Rough-outs of grey quartzite are present; since these rocks are local this could indicate that adzes were made on a modest scale in the settlements. However, not all adzes of quartzite and lydite need be of local origin. We wonder indeed whether the beautiful adzes of lydite-like material, as found in the Elsloo cemetery which is not discussed here, could have been made of local lydite (e.g. the adze from grave 83 = find number 776). The reason for our doubt is that large pieces of lydite are rare in the Maas gravel.

The next question to be asked is how the inhabitants of Elsloo, Stein and Sittard obtained their adzes. We believe that they could not possibly have imported the adzes from an area where Mesolithic traditions prevailed. Indeed, we would not expect a Mesolithic population to supply adzes of amphibolite and basalt, because the adze was not one of the normal tools of this population and amphibolite and basalt were not in vogue here either. The obvious assumption is that the adzes originated from settlements which used the same adzes, i.e. areas with LBK settlements.

Given the possibilities of contact with other LBK settlements, the imported adzes must have come either from the east, which means from the Rheinland, or from the south-west (see fig. 8). In the latter case it should be noted immediately that the settlements along the Geer or Jeker in Belgium were not occupied until the younger LBK (period II). During the older LBK (period I), Elsloo, Stein and Sittard were located more or less on the western boundary of the area with LBK occupation (see III.6). As the principal

* North of Sittard the gravels contain a component which was supplied by the Rhein. This component contains basalt blocks, although only rarely.

types of rock were already in use during period I (see table 12), we think it probable that most adzes reached our settlements via the settlements to the east. Furthermore, there are no outcrops of basalt or concentrations of amphibolite in Belgium either. The Belgian settlements may be considered as suppliers of quartzite and lydite during period II only. In this connection we wish to point out that an adze workshop is known to have existed in Belgium, in Horion-Hozémont (Dradon 1967). The raw material used was a dark grey quartzite. We have investigated whether there were pieces among our adzes that correspond to the material from Horion-Hozémont. The material for comparison was made available by Mr. M.G. Dradon. It appeared that there are indeed three adzes that might have come from Horizon-Hozémont (Elsloo 49, Elsloo 71 and Elsloo 644). It cannot be determined, of course, whether they were also made in Horizon-Hozémont; it is possible that the raw material just happens to be the same and that the three pieces from Elsloo came from the Maas gravel after all (we consider Elsloo 71 as a rough-out).

If the adzes of amphibolite and basalt in the Dutch settlement area came from settlements east of Elsloo, Stein and Sittard, then we may expect to find corresponding adzes at these sites. The settlements which must be investigated first are those of the Aldenhovener Platte. The adze assemblage of one of these settlements, Langweiler-2, has been published (Bakels 1973). The assemblage consists of amphibolite, basalt and dark grey quartzite and thus resembles that of the Dutch settlements very closely. Macroscopically the amphibolites and basalts are the same. At the time of the publication on Langweiler-2, we did not yet have thin sections at our disposal. These have since been prepared and show that microscopically the basalts and amphibolites are also of the same types as the Dutch material. The quartzites are different. Farther east is the settlement Müddersheim Ldkr. Düren; the adze assemblage of this settlement was examined by Frechen. Here too, comparable amphibolites and basalts have been found and again the quartzites are different (Frechen 1965, Frechen 1969 personal information). Among the basalts Frechen distinguishes several types which must have come from different sources. He could trace the basalts back to 9 outcrops in the Siebengebirge and the eastern edge of the Eifel. Frechen was kind enough to study a number of the basalts from Elsloo and Stein. The material appears to contain basalts from the Petersberg near Köningswinter, the Löwenburg, the Lyngsberg south of Godesberg, the Papelsberg-Jungfernberg east of Oberkassel am Rhein and the Gossberg near Walsdorf. The first four belong to the complex Siebengebirge-eastern edge of the Eifel and have also been demonstrated in Müddersheim. The last site belongs to the area of the Quaternary volcanism of the Eifel. In a later phase, when more adzes could be examined, the analysis of the basalt adzes was resumed by Arps, whose provisional conclusions can be found in Appendix IV. It must be noted, however, that the basalts of the adzes might show close similarities with basalts from the Eifel or the Siebengebirge, but that this does not prove that they also came from these areas. As the volcanos of Eifel and Siebengebirge are the nearest volcanos, it is feasible that they are the source of the basalts, but there is no certainty as long as the material of the adzes has not been compared with other occurrences of dense basalt in Central Europe, such as the Vogelsberg and the Westerwald. A comparative examination of source as well as adzes from other settlement areas could indicate (in the future) whether basalts were indeed always obtained from the nearest outcrops. In this connection it is interesting to note that the basalt of adzes from the Untermaingebiet is attributed without any reservation to the Vogelsberg and that for the basalt adze from Duderstadt near Hannover an outcrop on the western edge of the Leinetalgraben is mentioned (Meier-Arendt 1966, Ankel & Tackenberg 1961).

For the amphibolites of Müddersheim Frechen names an outcrop near Sobótka (formerly Zobten) in Poland. The same would apply to the amphibolites from Elsloo and Stein. We have always questioned this because we find the distance between Sobótka and the Dutch sites, some 750 km, very large indeed. Of course there are sufficient examples of the transportation of objects over long distances both in prehistoric times and in recent situations described in the ethnographic literature. We mention the transportation of obsidian in the Near East (Dixon, Cann & Renfrew 1968) and the distribution of stone axes in Australia (Sharp 1952, Binns & McBryde 1972). It is also known that within the area of the LBK Spondylus shells were transported over long distances (Clark 1952). So we do not want to exclude the possibility that the adzes did come from Sobótka. On the other hand, we refuse to accept this origin as established without further investigation, because Sobótka is not the only possible origin. Appendix IV gives a survey of the localizations of amphibolite in Central Europe. They are numerous, but at present we do not know exactly which sources contain amphibolites with a sufficiently fine structure to be used for adzes. Dipl.-Arch. Ing. geol. Ing. mont. G.F. Scholz (Schwarzenberg, DDR), to whom we sent photographs of thin sections of adzes from Elsloo and Stein, declared that the amphibolites might also have come from the Thüringer Wald or the Fichtelgebirge (Scholz 1976 written information).

The adzes from Hienheim are all made of amphibolite, without exception. The rocks show a greater variation in appearance than those of Southern Limburg. Conspicuous is a light gray to dark gray (N 6–5GY 6/1 to N 4) type, which is very fine-grained and shows many irregularities as a result of the presence of lighter bands and veinlets. The adzes made of this type were sometimes found to be completely splintered; the rock apparently splits very easily along the above-mentioned irregularities. The other amphibolites are of a more homogeneous structure. There are fine and coarse amphibolites which also differ as far as the degree of orientation is concerned. The colour of the adzes is an olive gray to greenish gray (5 Y 6/1 to 5 GY 4/1). These colours are likewise weathering colours. Examples can be seen in fig. 12.

Four pieces can be distinguished from the rest because of their characteristic appearance. Two are completely different: one rather large adze which is made of a dark brown amphibolite (find no. 343), and a rough-out (probably) of a weakly oriented amphibolite with large dark grey spots (metablasts) (find no. 748).

For all adzes the shape follows the original orientation of the rock. No relationship has been established between the type of amphibolite and the shape of the adze.

A comparison of the amphibolites of Hienheim with those from Southern Limburg shows that there is a difference between the types of rock found in the two areas. The fine, inhomogeneous amphibolite is absent in Southern Limburg. Only one single specimen of the coarser homogeneous type could be mistaken for an adze from Elsloo, Stein or Sittard.

The composition of the material from Hienheim is given in table 13 for the excavations up to and including 1973. The last excavation, that of 1974, had not been completely analyzed when the table was made. Still, we have seen most of the finds of this excavation, and there is no reason to expect that these latest finds will change the picture very much.

Table 13. Adzes, adze fragments and waste from Hienheim (excavations up to and including 1973).

type of amphibolite	*artefact or fragment*	*fragment with traces of grinding*	*fragment with traces of sawing*	*fragment*
"fine inhomogeneous"	16	3	–	–
"homogeneous"	14	5	2	16
exceptionals	3	–	–	1 (rough-out)

The presence of fragments of "homogeneous" amphibolite without traces of grinding is striking. These might originate partly from broken adzes. The fact that they are not encountered in the category "fine inhomogeneous" amphibolite can be attributed to an other way of breaking, so that the fragments are recognized more easily as adze fragments. Other specimens, however, cannot even be presumed to be a an part of an adze, because they show remains of the original surfaces which indicate that they were broken off of natural blocks of amphibolite. These surfaces are irregularly smooth and stained by iron oxide. Since there are also fragments with traces of sawing, we tend to interpret all pieces without traces of grinding as waste of the adze manufacture. Concentrations of fragments were not found though and there is no indication at all of workshops (workshop waste was found, it is true, but it belongs to the Middle-Neolithic population, which followed the LBK (de Grooth in press). The amphibolites are the same). The manufacture of adzes apparently was an occupation that took place incidentally and everywhere. We dare not say whether all adzes were made in the settlement. As no fragments of the "fine inhomogeneous" amphibolite have been found, adzes of this rock could have been made elsewhere (we consider the three pieces with traces of grinding as fragments of artefacts that are no longer recognizable as such rather than waste products).

The question of where the amphibolites came from must be answered of course. A local manufacture supposes a local raw material. However, there are no outcrops of amphibolite in the vicinity of Hienheim, where limestone is the only solid rock (see III.3). The residual deposits contain no amphibolite either. The only other place to find derived rocks of reasonable size would be the gravel bars on the valley floor of the Donau, as the material of the higher terraces is too fine (Schmidt-Kaler 1968). An examination of pebbles and cobbles with a diameter of over 5 cm revealed no amphibolite; this is confirmed by the gravel counts of Van de Wetering (van de Wetering 1975b, van de Wetering 1976 personal information). We do not wish to exclude the possibility that there may nevertheless have been amphibolites of Alpine origin in the bed material of the Donau, but the rocks are certainly not abundant. Moreover, the incidental and rare pieces would probably produce a much more heterogeneous group than the material from the settlements.

We think that we may conclude from the above that the amphibolite was obtained elsewhere, either in the form of blocks or adzes. If the rocks were supplied in the form of blocks then the source of the rock should not be too far from the settlement, thus in the Oberpfälzer and the Bayerische Wald. The nearest source, an outcrop on the Steinbügel north of Wörth a.d. Donau, was sampled for a comparative examination. As the crow flies, the outcrop is 50 km east of Hienheim. (Our attention was drawn to this site by Dr. W. Bauberger (München)). The results of the investigation give no reason to attribute the amphibolite from the settlement to this outcrop (see Appendix IV).

The more or less homogeneous amphibolite of Hienheim bears a resemblance to the Chamer axes from the typesite of the Chamer Gruppe: Knöbling-SSW (Wolf 1973). The origin of these axes could not be indicated either. Insofar as they were examined, the outcrops in the region of Knöbling-SSW appear to contain no completely identical material (Bauberger et al. 1973). Therefore at present we cannot identify the exact origin of the different types of amphibolites from Hienheim. A very intensive search may reveal an area with corresponding amphibolites. In any case they will not come from the same area as the amphibolites of Southern Limburg.

We have discussed so far the search for outcrops. We do not wish to suggest by this approach that the raw material for the adzes must have been taken directly from a rock-wall. We prefer the idea that the inhabitants gathered blocks of rock which had become detached from their original geological environment as a result of weathering. It is also possible that bed material was collected in streams which eroded the outcrops. We do think, however, that the raw material came from the vicinity of outcrops. Only there could a reasonable concentration of the desired material be found. For all four settlements under consideration, the fact remains that the rocks are so easily classified according to type that it is not feasible to assume that the fragments were picked up incidentally here and there. We make an exception for the residual group (the so-called exceptionals). These can be considered as "single finds".

Thus most of the adzes, or the raw materials for adzes, were imported in all four settlements. There is one aspect which we have hardly mentioned so far and that is the possibility that the adze-makers shifted in the course of time from one type of rock to another. Insofar as we can verify, there is no question of a change in the pattern in Hienheim. On the other hand, there are indications of a change in Southern Limburg. As table 12 shows, more adzes were made of amphibolite than of basalt in period I, whereas the numbers are about equal in period II. Of the three basalt adzes from the older LBK, only one single specimen could belong to the earliest phase of occupation, phase Ib. The date is not even really certain, because the adze (Sittard 465) does not come from a closed find. However, the artefact was found in a field where all closed finds belong to Ib. A second adze (Sittard 66) has been dated later, i.e. in Id, whereas the third (Elsloo 102) cannot be dated more accurately. On the other hand, several amphibolites are known from the early phases of I. In this connection it should be mentioned that among the finds of the nearby settlement in Geleen-Kluis, which must be dated early, we found no basalts but we did find amphibolites (see for Geleen: Waterbolk 1958/1959). These differences in the numbers of amphibolites and basalts could mean that the important of basalt adzes increased in the course of time. Since the origin of the basalt was perhaps closer than that of the amphibolite, this could imply an increasing regionalization of the LBK. The contacts over long distances (amphibolites) may have been reduced, and the contacts over medium distances (basalt) may have been intensified. However, we do not wish to make final judgments, given the relatively small numbers of well-dated adzes. We hope to extend our data by analyzing adze assemblages from nearby settlements areas and thus to obtain an insight into possible shifts. Then perhaps the degree of contact with those settlements now located in Belgium will also become more clear.

The fourth category of artefacts relates to a collection of rocks with flat sides, concave sides or grooves which were apparently produced by artificial friction. This category is usually described by the name querns and grinding-stones.* These artefacts are very common, but intact specimens are seldom found.

The querns and grinding-stones are usually discussed summarily in publications. It is striking that the group is classified first on the basis of the material; only afterwards attention is directed toward the shape of the objects. The publications concerning Elsloo and Sittard are no exceptions in this respect. The querns and grinding-stones of Stein have not been described. The comparable artefacts of Hienheim have not been published yet.

The raw material for the querns and grinding-stones is usually sandstone or quartzitic sandstone. Quartzite was used also in Hienheim. The division into groups of material is based mainly on the composition and the structure of the rock. Bohmers and Bruijn divide the finds from Sittard into two groups. The first group consists of a relatively coarse-grained, hard, quartzitic sandstone. The second group consists of a much softer sandstone. The rock is more finely grained than that of the first group, but the average grain-size varies. Bohmers and Bruijn also mention a difference in colour. The quartzitic

* Adzes and pieces of iron oxide, which de facto are also stones with traces of grinding, are not included in this category.

sandstones are yellowish white or grey; the finer sandstones vary in colour between grey, red and brown. The first group of material comprises all artefacts which are interpreted as querns, the second group is called a collection of grinding-stones (Bohmers & Bruijn 1958/1959 p. 207). The artefacts with traces of grinding found in Elsloo are divided by Modderman into three groups. The first group corresponds with the first group of Bohmers and Bruijn and contains coarse-grained stones, which are considered to be parts of querns. The second group comprises fine-grained sandstones and quartzitic sandstones. The specimens are described as polishing or grind-stones. The third group includes a series of red sandstone fragments which may show irregular grooves (Modderman 1970 p. 44). The second and the third group of Modderman together form the second group of Bohmers and Bruijn.

We think that it is certainly wise to create a separate group for the "red sandstones". When sorting the find material from Elsloo, Stein and Sittard, we experienced difficulties in classifying the specimens in only a few cases; in such cases the choice was between group two and group three. The "red sandstones" are not really red. According to the Munsell system, some specimens must be described as moderate brown 5 YR 4/4 and others as light brown to moderate yellowish brown 5 YR 5/6–10 YR 5/4 (Munsell Rock-Color Chart 1951). The rock used is a sandstone consisting of angular or subangular quartz grains which touch each other and are cemented together with limonite. In order to arrive at a better description, a few thin sections were made; the description can be found in Appendix IV. This description shows that the individual pieces are not completely identical. The rock weathers easily and then becomes crumbly. This is probably the reason why one-third to one-half of the individual pieces show no demonstrable traces of modelling or use. In the other specimens these traces are in a more or less advanced state of obliteration. Furthermore, these traces are by no means always the grooves mentioned by Modderman. Sides flat due to grinding are also frequently seen. The artefacts in question are far from rare in the three settlements of Southern Limburg. Elsloo has provided 96 well-dated rubbish assemblages with "red sandstone" (Modderman 1970 p. 44), Stein 22 and Sittard 33. A number of these assemblages comprise several specimens. Thus the 33 assemblages of Sittard represent at least 60 separate artefacts. The pieces of sandstone are small in size. The largest dimensions do not exceed 10 cm. Because of the weathered condition of the fragments, it cannot be seen whether there is waste from manufacture. Therefore we āre not able to determine whether the artefacts interpreted as small grinding-stones were made locally from larger pieces of sandstone. The origin of the material must be sought in the deposits of the Maas. The soft and friable rock does not belong, of course, to the material transported by the river; it is present in the terraces as a rock cemented in situ (verbal information from P.W. Bosch 1977).

The first and the second group are far less homogeneous macroscopically than the group of "red sandstones". In fact, some artefacts are difficult to attribute to one of the two groups, especially where small fragments are concerned. The first group (querns) obviously contains objects made of a sandstone or quartzitic sandstone which varies in colour from very pale orange 10 YR 8/2 to pale yellowish brown 10 YR 6/2. The rock consists of well-sorted quartz grains, which are subrounded to subangular and have a diameter of 0.15–0.30 mm. A fuller description of some examples can be found in Appendix IV; the thin sections are also discussed. In addition to fragments of this lightly coloured rock, there are at least as many pieces that are made of sandstones and quartzitic sandstones of a different type. The grain size, the degree of sorting and the quartz content differ. Some fragments belong in the group of querns because of their size and shape and in the group of grinding- and polishing-stones because of their material. In addition, the second group is far from homogeneous. It consists of moderately fine to very fine sandstones. We have not submitted these rocks to a more detailed analysis, although the quern and grinding-stone artefacts are the

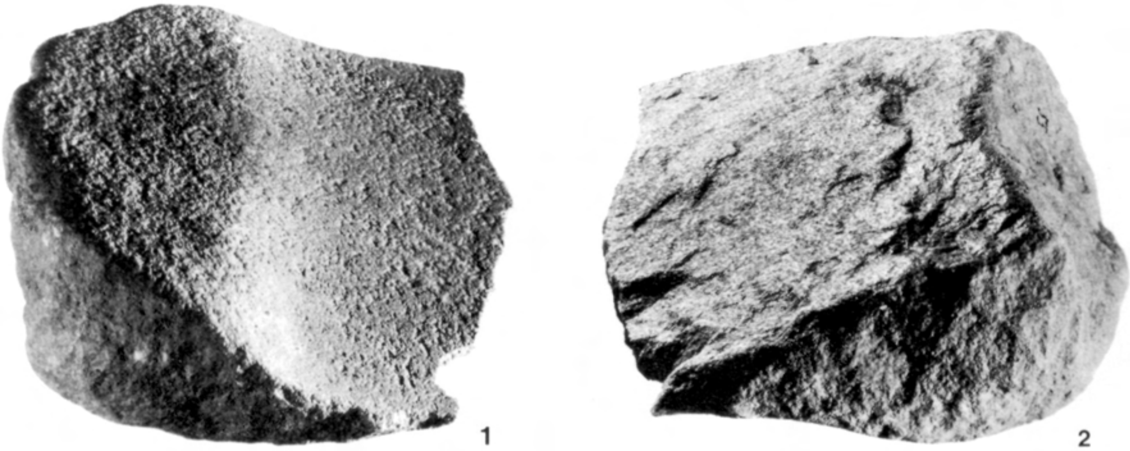


Fig. 13. Quern-fragment from the LBK settlement at Elsloo. Scale 1:2 Left: surface, worn down by grinding
Right: reverse of the same fragment showing its provenance from a gravel bed.

most common artefacts in settlement waste together with pottery and chert artefacts. Perhaps a study combining the morphological characteristics of the objects with a petrographic analysis could provide a satisfactory description of artefacts, choice of material and function. But such a study falls beyond the scope of our study. Our study of the groups pertained only to the origin of the materials used, and this is clear. Many artefacts still show remains of a surface which has not been changed by man. The rounded shapes and naturally flattened surfaces show that the original rocks were transported by a river (fig 13). The most probable place of origin is therefore the bed of the Maas. According to P.W. Bosch the types of rocks which were used indeed occur in the river bed in large numbers and also in the form of big blocks. They belong to a group of rocks which is very common in the younger Maas terraces and therefore also in the gravel bars, namely the group of Devonian and Upper Carboniferous sandstones (P.W. Bosch 1977, personal information). Probably the rocks were picked up in the gravel bars and trimmed on the spot. We have found so few pieces of rock without traces of manufacture that we assume that trimming did not take place in the settlement. When necessary, the blocks were also more or less ground to size. At least, this can be seen on the upper surfaces of those artefacts which have been interpreted as the upper stone of a set of querns. Of course, it can no longer be verified where this grinding to size took place.

The stones with grinding surfaces found at Hienheim can be divided in the same way as the artefact fragments from Elsloo, Stein and Sittard. However, the frequency of specimens of one category is different. The group of sandstones, which we equate with the group "red sandstones" from the settlements in Southern Limburg, contains only three specimens from the material excavated up to and including 1970 (the material of the excavations in 1971, 1973 and 1974 had not been completely sorted and dated at the time of our investigation). One specimen is a so-called "Pfeilglätter", the second one has four grooves and the third piece is characterized by a flat side. There are no indications that the three later excavations have provided more of this type of material. In our opinion, the striking scarcity of the group can be explained in two ways. The first possibility is that the tools in question were seldom used in Hienheim. The second possibility is that the artefacts have disintegrated completely. We prefer the latter explanation, since we repeatedly observed concentrations of yellow or brown sand during the excavations which might represent disintegrated sandstone artefacts. During the latest excavation a not quite disintegrated piece of sandstone could be salvaged only after impregnation with synthetic resin. Because of the extremely small number of artefacts, we have not looked for the origin of the raw material in question.

The two other groups are very common. The distinction between querns and grinding-stones is easier for the material from Hienheim than for that of Southern Limburg. The ratio between the number of fragments in the first and second groups is approximately 4:1. Slightly less than half of the quern fragments appears to belong to one and the same type of rock. It is a quartzitic sandstone which when freshly fractured has a colour that can be described as yellowish gray 5 Y 8/1. The main component is formed by subangular to angular quartz grains with diameters of up to 1 mm; the matrix is silicified, but the degree of silicification varies. Sometimes more highly silicified parts occur as lenses in an less silicified rock. The thin sections made of some quern fragments are described in Appendix IV. There is not a single indication that the raw material for the subgroup of querns described was obtained from a gravel deposit. Furthermore, gravel as a source is not obvious, since the deposits of the Donau contain no blocks the size of a quern. That is why we searched for rock in situ. In the vicinity of Hienheim there appears indeed to be a rock which resembles the description of the querns, namely a quartzitic sandstone which belongs to the Schutzfelsschichten (for the Schutzfelsschichten see p. 22). The Schutzfelsschichten consist mainly of loose quartz sands, but these sands have been cemented here and there into sandstone, quartzitic sandstone and quartzite. The hardened blocks of rock can be several cubic metres in volume (Schmidt-Kaler 1968 p. 37). Remains of Schutzfelsschichten with quartzitic sandstone crop out at several places in the neighbourhood of Hienheim. Schmidt-Kaler mentions an outcrop near Hagenhill 7.5 km north-west of Hienheim, and several outcrops across the Donau near Bad Gögging and Sandharlanden (Schmidt-Kaler 1968 p. 38–40). In the Höhenberg outcrop near Bad Gögging in particular we have found quartzitic sandstones, which bear a close resemblance to the rock of the querns. The outcrop in question lies 4 km from Hienheim as the crow flies. See Appendix IV for a further description. The resemblance does not mean, of course, that the inhabitants of Hienheim got their querns from the Höhenberg. It is quite conceivable that comparable outcrops occur elsewhere or at least that they occurred during the existence of the LBK settlement. However, we feel that the results of our investigation indicate that the rock need not be considered an import. From the material excavated in Hienheim it is not possible to determine where the querns were finally shaped: near the outcrop or in the settlement. It is true that there are many pieces without traces of grinding, but it is not clear whether they represent waste from manufacture or fragments of broken specimens.

In addition to the above mentioned group of quartzitic sandstones, which includes not only small pieces but also nearly all big quern fragments (weighing up to 5000 gr), there are also querns of quite different sandstone types and real quartzite in Hienheim. Most types of rock occur only once or a few times. We shall not describe them here, because we have not been able to conduct an extensive study of their thin sections. We are fairly certain that none of the types of rock used can be found within a radius of 10 km around the settlement.

The group of stones with a grinding surface, which are called grinding-stones, appears homogeneous. They are made of a very fine sandstone which sometimes contains quartz veins. The quartz grains are subangular and well-sorted. The colour of the rock is pale brown 5 YR 6/2 to pale yellowish brown 10 YR 6/2. As in the case of the querns, it is improbable that the sandstone for the grinding-stones was obtained from the Donau deposits, since specimens have been found which are much too big (the biggest grinding-stone studied measures 16 × 11 × 5.5 cm). The homogenity of the group suggests that they came from one single outcrop or from a series of related outcrops. We do not know (yet) of any outcrop of this sandstone in the direct neighbourhood of the settlement.

It can be concluded from the above that we cannot point out the origin for about one-half of the querns and for all of the grinding-stones. It seems likely at present that these materials were brought in from locations more than 10 km away. We dare not say now that there really was import. It is clear, however, that there is a difference between Hienheim and Southern Limburg with respect to the nature of the origin of the raw materials for querns and grinding-stones. The reason lies undoubtedly in the absence of a river with useful bed material.

Stones which have not visibly been manufactured by man into artefacts are usually neglected in literature, although we suspect that they are at least as frequent in the waste assemblages as fragments of querns and grinding-stones.

The publication concerning Sittard mentions only stones with percussion marks and small pebbles which show a local lustre (Bohmers & Bruijn 1958/1959 p. 208). In his publication on the material from Elsloo, Modderman lists only hammerstones (Modderman 1970 p. 44). For the finds from Stein, Modderman refers to the situation in Elsloo (Modderman 1970 p. 97), and in the first communications on Hienheim there is no mention at all of the natural stones. However, large numbers of stones were found in all four settlements, many of which showed no traces of wear. As the stones do not occur naturally in the loess-covered settlement areas, they must have been brought there by the inhabitants.

Insofar as we could verify, the stones of Elsloo, Stein and Sittard all came from a gravel deposit; we think of course of gravel bars in the bed of the Maas. The assemblage is of a heterogeneous composition. The stones for example differ markedly in size. There are pebbles weighing only a few grams with a diameter of 1 to 2 cm, but also large blocks weighing several kilograms and measuring several decimeters. Furthermore, many types of rock are represented in the material, quartzites and quartzitic sandstones being predominant. There are no indications that these pebbles, cobbles and blocks should not have come from the Maas gravel.

Only a portion of the stones found in Hienheim came from gravels. The largest stones with marks of rolling measure less than 10 cm. This is completely in accordance with the dimensions of the coarsest fraction of the Donau gravel. We assume for this reason that these stones came from the bed of the Donau. Besides the pebbles, the waste assemblages frequently contain blocks and fragments of rock which cannot possibly have come from a river. There are for instance pieces of silicified rocks (in very large quantities), limestone and dolomite. These are rocks which can be found in the vicinity of Hienheim, either in situ or secondary in residual loams. Furthermore there are some quartzites. The origin of the latter is not clear, but we do not exclude the residual loams.

Summarizing, we think that the conclusion is justified that most, if not all, "natural stones" have a local origin.

The sixth category is paint. As far as the settlements in Southern Limburg are concerned, the category consists only of hematite. In Hienheim we can include not only hematite but also graphite. One could disagree with our opinion that these rocks were used as paint. In the case of hematite, a function as polish has been suggested (Bohmers & Bruijn 1958/1959 p. 208 and other authors). However, we consider the presence of hematite-containing pastes on decorated pottery as an indication that the rock was also appreciated for its colour.

In Elsloo, Stein and Sittard, the use of hematite has left traces in two different ways. Most frequent are the traces of hematite powder in the pores of quern fragments, but more spectacular are the pieces of rock themselves. These usually show ground surfaces with parallel scratches. It is assumed that these developed when the hematite was pulverized on the above-mentioned quern fragments. Two types of hematite are present, namely a soft oolithic hematite and a somewhat harder and compacter rock. Both types are shown in fig. 14. In Elsloo where 30 pieces of hematite, spread over 24 waste assemblages, have been excavated, two-thirds of the pieces are of the oolithic type and one-third of the compact type. Modderman had already found that the pieces of hematite are not divided evenly over the different phases of occupation (Modderman 1970 p. 45). Only two pieces can be dated as period I, whereas 26 pieces belong to period II. The finds from the cemetery of Elsloo, which is not discussed here, even suggest a peak in use during the last phase (phase IId). The quantity of material is too small to investigate whether the proportion of oolithic hematite to the more compact type differred in the different phases of occupation. Stein and

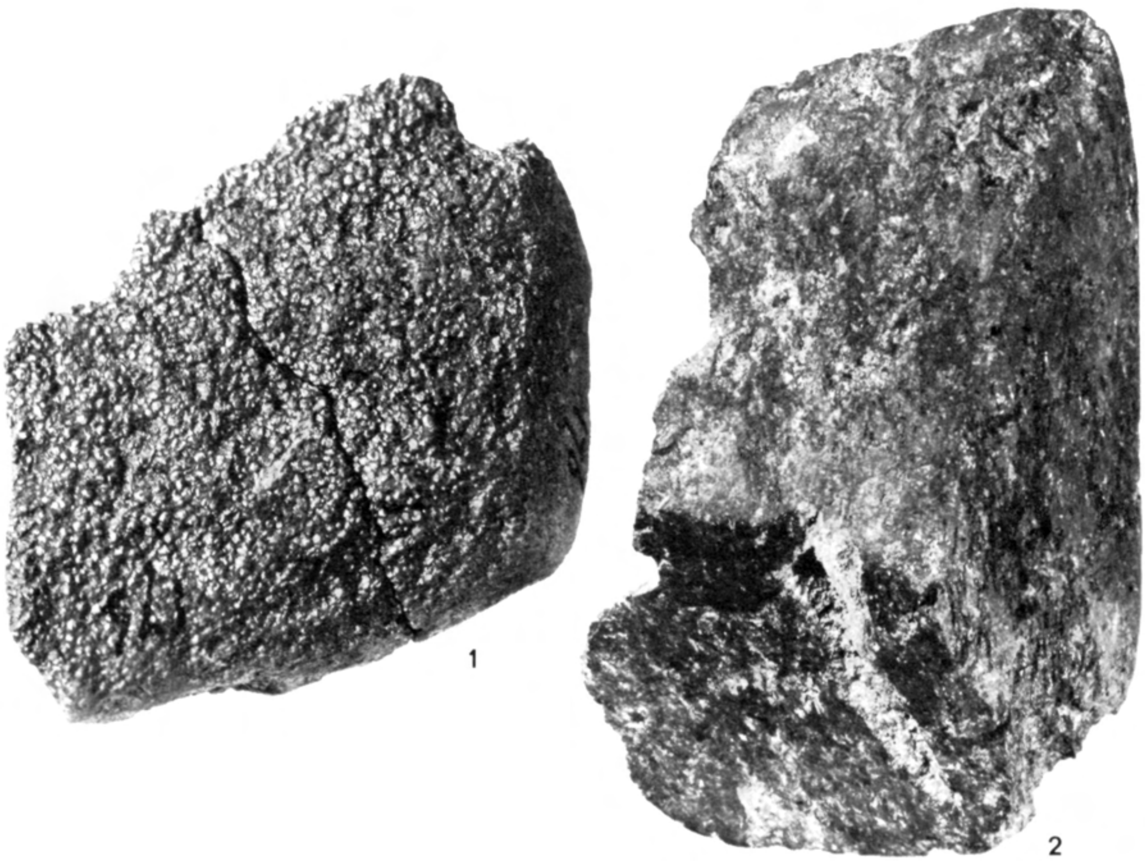


Fig. 14. Hematite from the LBK settlement at Elsloo. Scale 2:1
Left: oölithic type. Right compact type.

Sittard have provided less hematite: 4 and 5 pieces were found, respectively. In both settlements the oolithic as well as the compact type are represented.

We can give no explanation for the abundance of hematite in Elsloo on the one hand and the small number of pieces in Stein and Sittard on the other. Hematite is the only material which exhibits such a difference. The conditions were the same in all three settlements, so that it is not likely that hematite from Stein and Sittard disintegrated because of corrosion. Nor was the excavating technique essentially different, and the settlements were excavated under the direction of the same person. A possibility might be that the parts of the settlement excavated in Stein and Sittard were less densely populated when most of the hematite was used or thrown away. Elsloo, insofar as excavated, counts 51 houses which have been dated in period II; 26 pieces of hematite belong in this period. In Stein at least 31 houses are considered to belong in period II, whereas not a single piece of hematite could be dated. The excavated part of Sittard includes 9 houses and 3 pieces of hematite from period II. When we look at the last phase of occupation distinguished in Southern Limburg, phase IId, then Elsloo has 14 houses and 6 pieces of hematite, Stein 12 houses and no hematite and Sittard 2 houses and again no hematite. We conclude from these numbers that the scarcity of waste in Sittard may, but the scarcity of hematite in Stein may not, be explained without reservation by the absence of occupational traces from the phases in question.

Neither oolithic nor compact hematite occur within a radius of 10 km around the settlements. The material must have been imported. Hematite sources are known from the valleys of the Lahn and the Dill; the hematite from LBK settlements is sometimes related to these sources (Koch 1936 p. 143, Schietzel 1965 p. 71). The rock, however, is also present in the Eifel and in the Ardennes. It would be useful if an inventory of the hematites were combined with an extensive study of the waste from all LBK settlements west of the Rhein. Almost every settlement contains some pieces, but the number is always too small to form a basis for an extensive study. A combination of all finds, however, should provide enough material to make a study useful.

Hematite is not absent in Hienheim either. The material has been found in 38 waste assemblages in the excavations up to and including 1970. The finds consist of 44 fragments of this rock. There are no indications that a change in the use of hematite took place in the course of time. We have not seen remains of powder on querns. It is not clear to us whether this may be due to the surface condition of the quern fragments or to the properties of the hematite. However, traces of grinding have been found on the pieces of hematite. Many pieces were used so economically that they are now almost too small to hold; their largest dimensions do not exceed 2 cm. The hematite is compact but much softer than the compact hematite which we know from Elsloo. Besides worn pieces there are a few pieces which have hardly been used. These show that the hematite comes from a sand or sandstone deposit where it appears as thin bands. The plates have a thickness of 10–15 mm. We do not know yet where the hematite comes from. It is true that iron oxide can be found on the Michelsberg between Hienheim and Kelheim (Schwarz, Tillmann & Treibs 1965/1966 p. 44), but this is a limonite which looks quite different from the iron oxide which was excavated in Hienheim. To our knowledge no soft fine iron oxide that gives a reddish brown streak on unglazed china exists within a radius of 10 km around Hienheim. We also are not aware of any, perhaps extremely small source within a radius of 30 km. However, we find it not unlikely that the source of the hematite must lie farther away. In that case the raw material would be an import. Outcrops can undoubtedly be found beyond a 30 km radius, e.g. in the ore formation of Amberg (which, by the way, also includes the limonite of the Michelsberg) (Tillmann 1964 p. 142 and 144–145).

Besides hematite, a second material that can be interpreted as a paint, has been found in the settlement

IV.5 FIREWOOD

Although obvious hearths have never been found in or outside the houses, it may be assumed that the inhabitants of the LBK settlements kept fires. One of the indications thereof is the observation by Modderman, that some parts of the houses show more traces of burnt loam and charcoal than others. "It was observed repeatedly that the concentration of traces that point to fire, such as burnt loam and charcoal, is the largest in those ghost-posts which constitute the north-western cross-row of the central part. I feel that this can be explained only by the fact that a relatively large quantity of burnt material was lying near the posts, when the wood mouldered. One thinks in the very first place of the remains of a hearth." (Modderman 1970 p. 110, our translation). Given the presence of charcoal and in view of the many forests in the environment of the settlements, it is natural that the fires were fed with wood. Firewood is bulky material which is awkward to transport. Therefore it is likely that the fuel was gathered in the immediate surroundings of the settlement.

We have no insight in the quantity of wood which was necessary for the fires. Nor could literature about the quantities burnt by contemporary inhabitants of forest-clad areas be found. As the ethnographic literature studied never mentions shortages of firewood, nor the activities necessary to get it, it may be assumed that firewood presented no special problems.

One may wonder whether there was any preference for certain kinds of wood. After all, there are differences in burning properties. The choice of firewood is a subject of investigation which has received little attention so far in archeology. In this connection, only the work by Schweingruber can be mentioned. On the basis of a large number of analyses of charcoal from very different prehistoric settlements, this author arrives at the conclusion: "Charcoal from fireplaces gives in most cases a relatively genuine picture of the environing forest." (Schweingruber 1976 p. 103). This would mean that there was no pronounced preference for certain kinds of firewood.

As the LBK settlements which we are to describe, have provided no hearths with charcoal remains, we cannot verify if Schweingruber's findings are also applicable to Elsloo, Stein, Sittard and Hienheim. In such settlements charcoal remains are only present amongst waste. These charcoal remains have already been mentioned in III.4 p. 37 and 43, and in IV.4 p. 80 and 81. We think that the fragments of the waste-filled pits represent mainly, or even entirely, the remains of intentionally burnt wood and not of burnt-down houses. Of course, all the burnt wood need not be gathered originally as firewood. Probably chips and other waste pieces, which originated during construction activities, as well as rejected construction parts and broken domestic objects were added to the stock of firewood. However, it is likely that most of the firewood was really gathered as such. This view is supported by Schweingruber's observations (to be discussed below) concerning charcoal splinters from Langweiler-2.

The pieces of charcoal found in the museum collections of Elsloo, Stein and Sittard, are all oak. This certainly does not mean that mainly oak was burnt in these settlements. The presence of only one kind of wood is the result of the fact that mainly large pieces for the purpose of C14 dating were gathered during the excavations. Therefore it is better to turn to the settlement Langweiler-2 Ldkr Düren (BRD) instead of the three settlements in Southern Limburg. Langweiler-2 is situated at 30 km east of Sittard. The charcoal from this settlement was examined by Schweingruber (Schweingruber 1973). In 85 waste assemblages, he identified the following wood species (table taken from Schweingruber 1976).

Table 14. Charcoal from 85 waste assemblages from the LBK settlement Langweiler-2.

		number of fragments	%	*frequency in assemblages in % (85 = 100)*
Pomoidea excl. Sorbus	(apple etc.)	373	27	67
Ulmus sp.	(elm)	430	31	34
Quercus sp.	(oak)	267	19	35
Corylus avellana	(hazel)	169	12	29
Fraxinus excelsior	(ash)	123	9	33
Prunus spinosa cf.	(blackthorn)	43	3	10
Acer sp.	(maple)	2	0.1	1

We feel that Schweingruber has demonstrated convincingly that the charcoal must have come indeed from firewood. He has examined 50 pieces for the presence of fungal hyphae; their presence indicates that the wood was dead and mouldered when it got burnt. Mouldered wood can have been used only as firewood. 11 of the 50 examined pieces showed fungal hyphae. In view of the condition in which the charcoal has been conserved, this number is sufficient to conclude that the greater part of the wood must have been mouldered. Besides, the charcoal fragments originate partly from young, light branches, which again points to firewood. It should, however, be pointed out directly, that the list of species cannot be complete, because charcoal of soft woods is absent. They could have disappeared by erosion. The still identifiable species all have been obtained from the local vegetation; so the results of the identification are not in contradiction with the idea that the firewood has a local origin. The woods in question are from the Alno-Padion, the "Carpinion betuli" or from several seral stages of these forests (see III.4 p. 37). However, the proportion in which the species were found, is not the proportion which one would expect on the basis of the reconstructed vegetation. Especially the share of the group of the Pomoidea and Prunus spinosa is exceptionally large (the Pomoidea comprise apple, pear and hawthorn). Schweingruber thinks that the high frequency can be explained from a far-going degradation of the local forests as a result of agriculture (swidden cultivation). Thereby man became increasingly dependent on the wood of plants which belong in the different seral stages of a regenerating forest. The above-mentioned plants and shrubs (with hazel?) indeed belong to seral stages. We wonder, however, if a general and complete degradation of the forests is the only possible explanation. It is equally possible that parts of forests which were going through a seral stage, were selected for gathering firewood. If the ideas of Knörzer and Groenman-Van Waateringe are correct, the firewood might also have come from the forest edges along the fields (see IV.2 p. 69). These authors assume that the fields were in permanent use; in that case a hedge-like vegetation developed around the fields, in which grew precisely those plants which are overrepresented in the charcoal. Finally, it is also possible that the inhabitants of Langweiler-2 had a preference for firewood from Pomoidea. Wood from this group of plants is much appreciated for its good burning properties (Houtzagers & De Koning 1938).

The above considerations suggest caution in accepting without any reservation that the burnt wood in Langweiler-2 gives a relatively genuine picture of the environing forest, i.e. of a degraded deciduous forest. It is equally possible that man made a choice from what was locally available.

The charcoal finds from Hienheim suggest a preference for oak-wood. However, we reckon with the possibility that the predominance of oak-wood is the result of a selective corrosion (see Appendix II). If the selective corrosion had indeed an even stronger influence in Hienheim than it must have had in Langweiler-2, it is of course impossible to draw conclusions about a human choice. Since it is hardly of Hienheim, namely graphite. From the parts of the settlement which were excavated up to and including 1970, four lumps of this material are known. The largest piece, find no. 360, measures 4.5 × 2.5 × 1.5 cm; the same piece is pierced half-way through. The material was undoubtedly imported; the nearest sources of graphite are the sites in the Passauer Wald near Passau (Kappel 1969 p. 28 and 40, Bauberger & Teuscher 1964 p. 11). As the graphite from Hienheim has a coarse texture and much graphite from the Passau area seems to be coarse as well (Kappel 1969 p. 38), the rock may have indeed come from these sources. However, we have absolutely no proof for such an origin.

The last category is called miscellaneous, and was introduced of course of cover all materials that were not included in the preceding six categories. In the case of our settlements, it comprises two types of material, namely bone and pitch.

Bone tools have been found only in Hienheim. As previously mentioned, this material has disappeared completely from the settlements in Souther Limburg (see p. 44).* In the excavations up to and including 1970, 4 bone artefacts, i.e. bones with traces of manufacture, which must belong to the LBK occupation, were found in Hienheim. They are a fragment of an awl, a fragment of an unknown artefact and two waste pieces from which chips have been cut. According to Dr. A.T. Clason, the first object is made from the long bone of a small animal (a sheep, a goat, or an even smaller wild animal). Nothing at all can be said about the other items (A.T. Clason 1977, personal information). Since, according to Clason, all bones found in Hienheim probably come from animals which lived in the vicinity of the settlement (see p. 48), we assume that the bone used for artefacts was a local material. There is no reason whatsoever to assume import.

The pitch remains mentioned above can be seen as small black crusts on some chert artefacts. We have not examined these remains in detail. From the analysis by Funke it is known that similar pitch traces on Early-Neolithic artefacts from Armeau (Yonne, France) consisted of birch pitch (Funke 1969). This is probably also the case for the material from Elsloo, Sittard, Stein and Hienheim. To our knowledge, birch pitch is the most obvious pitch. Birches were part of the local deciduous forest at the time of the LBK, although they were not predominant. The pitch can certainly have been won from local birch-bark.

RAW MATERIALS: A SURVEY

In the above we discussed mainly those raw materials which we know for certain to have been used by the inhabitants of the settlements. They consist of three kinds of building material, namely wood, loam and small plant remains, as well as twelve types of material for mobile goods, namely clay (or loam), sand, chert, amphibolite, basalt, dark grey quartzite (or lydite), sandstone (or quartzitic sandstone and quartzite), a category that must be described as "miscellaneous rocks" (which also includes the raw materials for adzes other than amphibolite, basalt or dark grey quartzite), hematite, graphite, bone and pitch. Probably the loam listed as a building material is the same clay used for mobile goods, that is for pottery. This was the case in any event if the pottery indeed was made of loess. We then have fourteen types of raw material. Of these fourteen, two are present exclusively in Elsloo, Stein and Sittard, namely basalt and dark grey quartzite or lydite. One raw material is restricted to Hienheim, namely graphite. Thus the

* It must be mentioned that one bone artefact is known from the cemetery of Elsloo. In grave 71 the point of a bone needle or awl was found (Modderman 1970 p. 57).

settlements have eleven raw materials im common, which does not mean that the raw materials are identical in all four settlements. This is true, however, as far as Elsloo, Stein and Sittard are concerned. The inhabitants of these three settlements used exactly the same raw materials. We know of no material that was used exclusively in one or two of these settlements and, perhaps with the exception of hematite, we have seen no quantitative differences. The raw materials in Hienheim are not exactly the same as those in Southern Limburg, at least not the mineral materials but they are always equivalents. The difference between Elsloo, Stein and Sittard on the one hand and Hienheim on the other hand indicates that the raw materials have a different origin. As the two settlement areas are located 500 km apart, we had of course expected this result of the raw material analysis. Elsloo, Stein and Sittard are very close together. The longest distance between them, that between Elsloo and Sittard is 8 km. It is possible that these settlements indeed shared sources of raw material, although the fact that the raw materials of Elsloo, Sittard and Stein are indistinguishable does not necessarily imply that the sources of the raw materials were exactly the same. It is possible that the inhabitants did obtain certain raw materials from different sources but that we are unable to demonstrate any difference between these materials. It is impossible for example to attribute individual rocks to specific gravel bars of the Maas.

The starting point of our study has always been that the inhabitants of the LBK settlements tried to obtain their raw materials as close to home as possible. Our findings do not contradict our starting point. It seems at present that the source of most of the raw materials was in the immediate vicinity of the settlements. Only two raw materials clearly do not fulfill the expected pattern. The first is rock for adzes or the adzes themselves. Apparently these artefacts had to meet such high standards that local material, with a few exceptions, was not suitable. The second is paint. Paints are also not locally available. Because the amphibolite and basalt for adzes as well as the hematite and graphite for paints could not be found even within a radius of 30 km, that is the area that can be visited within one day, we refer to these materials as imports. We refrain from making assumptions about the course of events with respect to this 'import''. Besides adzes and paint, other ''foreign'' objects also found their way into the settlements, such as the ''Limburger'' ceramics of Elsloo and Stein (Modderman 1970 p. 142).

The chert supply is situated between local and import. There are no indications that the majority of this raw material originated in the immediate vicinity of the settlements, but the rock can be reached within one day, at least from the viewpoint of the geographical situation. We do not know whether other population groups made direct access to the chert sources impossible. A similar reservation also holds for the raw materials present within a radius of 10 km. As will be seen in chapter V, it is not likely that the gravel bars of the Maas, for instance, where so much rock must have come from, were included within the real territory of Sittard or even Elsloo. Such considerations, however, lead us into the field of social contacts, which fall outside the scope of this study.

We have the impression that the situation as described in the preceding paragraphs is generally valid for LBK settlements, but this cannot be more than an impression as yet because we do not have at our disposal enough data for other settlements. It would be interesting for instance to investigate where the raw materials for the querns, the chert artefacts and the adzes in a large number of settlements came from. We presume that for each of these three categories there will be differences in the distance between the settlement and the place of origin. The reason is that we think that materials for querns were transported only over short distances, chert over medium distances, and amphibolite for adzes over long distances. We hope that it will be possible in the future to test this model on the basis of many observations.

credible that almost only oak-wood was burnt, it is better to refrain from further comment.

Unfortunately no more analyses of charcoal assemblages from LBK settlements are available, so that it is impossible to judge what the real course of affairs was. Besides, it is doubtful whether the firewood question will ever be solved completely. The investigation will be hampered in many places by the occurrence of selective corrosion, since the latter is related to the type of soil on which the settlements were built. The eluviation of clay particles from the loess and the subsequent illuviation of these particles into the charcoal may lead to the total destruction of the structure of the charcoal particles. A complete quantitative investigation is impossible in such cases. At the most, the different kinds of resistant charcoal can be compared with each other in the way it was done in Langweiler-2.

IV.6 THE INFLUENCE OF THE INHABITANTS OF THE SETTLEMENTS ON THEIR ENVIRONMENT

The inhabitants of Elsloo, Stein, Sittard and Hienheim undertook many activities in their environment. We have been able to reconstruct a number of them. The most important of these are: felling trees, laying out fields, feeding cattle and gathering rocks. The activities undoubtedly changed the surroundings of the settlements. It may be asked how rigorous the changes were. Another, related question is whether and to what extent life in the settlements was influenced by the changes brought about by man.

In chapter III the environment was divided into five components, namely climate, substrate, vegetation, fauna and neighbouring populations. We shall leave the last component out of consideration. Of course the inhabitants of a settlement can exert an influence on the existence of other people, but we do not consider ourselves competent to discuss the activities concerned. Thus, four components remain to be dealt with. The order of chapter III will not be followed: the influence of man on the vegetation will be dealt with first, because in our opinion the influence on this environmental component was the most important one.

The natural vegetation suffered from almost all activities of the inhabitants of the settlements. It must have been removed for the fields, it served as food for the cattle, it provided raw materials and it served as fuel. We cannot imagine that the forests which we have reconstructed in III.4, were not affected by this exploitation. However, the effect may have been different in the distinct landscape units as shall be explained in the following.

In IV.2 a location of the fields in the loess landscapes or in the not too wet parts of the river-valleys was suggested. If the fields were indeed laid out in these landscapes, it is here that the largest clearings occurred. The real clearings apparently remained of small size, since the demonstrated weed flora points to overshadowed fields (see IV.2 p. 68). It depends on the agricultural methods what happens to such fields. the small clearings may remain open for a long time or, on the other hand, after abandonment, be overgrown quickly. That is why different suggestions can be brought forward as to the eventual effect of the fields on the vegetation. If the fields were in permanent use, which Knörzer and Groenman-Van Waateringe suggest in our case (see IV.2 p. 69), then the forest would for a long time retain the aspect of a tall deciduous forest with small clearings, where the sun can penetrate to the ground. A specific, hedge-like vegetation develops on the boundary of the fields and the forest. If, on the contrary, the fields are used for a short time only, then the forest can re-establish itself. As has been mentioned in III.4, the speed at which a forest regenerates, depends on the nature of the cutting activities (III.4 p. 37). Laying out small fields could be compared with patchcutting, that is, the harvest of local groups of trees while leaving a large area of uncut forest around them. According to Horn, this method results in the fastest possible return of the original vegetation (Horn 1975). However, it depends on the length of the fallow period whether the original deciduous forest can re-establish itself completely. If, namely, the seral stages are also cut for new fields, a total regeneration cannot occur, the natural vegetation being replaced in the long run by secondary growth, i.e. by one or several seral stages. Even the stage of a secondary growth of shrubs and trees may not be reached if the abandoned fields are used for the intensive grazing of cattle. The landscape changes in such cases into a park landscape of grazing land with some tall trees, which were spared when the fields were laid out, and with shrubs which are not eaten by cattle. It is not at the moment possible to choose between the above-mentioned possibilities, although it is unlikely that the stage of a park landscape was reached (see also IV.4 p. 86).

The grazing of cattle on abandoned fields has been mentioned, but fields are not the only possible grazing grounds. In IV.2 reference was made to clearings in the wetter parts of the river-valleys. Moreover, the cattle perhaps received additional feeding of tree foliage, such as elm-leaves. The elm was part of forests on richer loam soils and more precisely of the "Carpinion betuli" described in III.4, and of the Alno-Padion. It is to be expected that, given the composition of the present forests which belong to these groups, the elm was especially common in the Alno-Padion and therefore in the river-valleys. The presence of a rather high percentage of elm pollen in the pollen diagrams of Maaseik and of the Heiligenstädter Moos indicates that elm was indeed abundant in the large river-valleys, at least in the beginning (see III.4 p. 36 and p. 43). However, the diagrams from the smaller valleys in Southern Limburg show surprizingly little elm (III.4 p. 30) and its share in the vegetation here is unclear. Besides, the importance of the role of the elm in the economy of the settlements cannot yet be estimated either. A first indication could lie in the observation, that the elm in the Heiligenstädter Moos is reduced in numbers at a time coinciding with the presence of a LBK settlement in Hienheim. To what extent there is question of a real correlation cannot, at the moment, be established. We refer to IV.2 p. 76 for the discussion. It may be surmised that river-valleys had a specific importance for cattle-breeders, so that not only the vegetation in the loess landscape and the dry parts of the valleys, but also the vegetation of the wet grounds along the rivers will have undergone change at the hands of the inhabitants of the settlements.

As wood was an important raw material, which was needed in large quantities, the consumption of wood must also have left traces in the vegetation (see IV.4 p. 86). The source of the wood cannot be located for certain, but because of the bulky mass of tree-trunks, a major part of the constructional material will undoubtedly have come from the direct surroundings of the settlements. Given the position of the settlements, this means that the constructional material was supplied primarily by the loess landscape and in the second place by the stream-valleys (for the location of the settlements see figure 2, 3, 16 and 17). To a certain extent wood will have become available by laying out fields, but the importance of this share remains speculative.

The extremely scarce data on firewood make it impossible to say which wood-lands were used for that purpose. As firewood is clumsy to handle, we think that the material was fetched preferably from the vicinity of the settlement.

It is evident from the above that little is known concerning the nature and especially concerning the importance of the effect that the presence of settlements had on the natural vegetation. The impact is likely to have been the greatest in the direct surroundings of the settlements lessening as the distance increased. Since the surroundings of the settlements were part of the loess landscapes and also, though to a lesser extent, of the river-valley landscapes (see also V), the vegetations there would have experienced the greatest influence of human activities. The other landscape units distinguished in III.3 were situated at a greater distance from the settlements; probably they were not affected or hardly so. However, we can but guess in our considerations concerning the influence on the vegetation, because this influence has never been measured convincingly. As stated in IV.2 p. 69, the presence of fields, for example, cannot be observed in the pollen diagrams from the areas which we studied. This may be due to the fact that the appropriate diagrams came from places which are too far away from the LBK settlement areas. It is also possible that the interference was too small to be measured with the present techniques. However, one thing is certain, namely that the influence of occupation never led to a complete deforestation. Many trees must have remained, also in the last phases of the occupation history. We refer to IV.4 p. 87 for our arguments.

The vegetation has been discussed first, because this was probably the environmental component, on which the influence was the greatest and the most direct. The influence on the remaining components is related largely to changes in the vegetation.

The influence on the climate can have been but very modest. Concerning the power of man to influence the climate, Thornthwaite has written; ".... man's greatest potentialities in changing the climate lie in changing the characteristics of the earth's surface over a considerable distance. Generally the influence of man upon climate is displayed over normally small areas where some obvious change has been made on the surface." (Thornthwaite 1956 p. 568). We feel that this statement is certainly applicable to situations in the past. The most important change which the inhabitants of the LBK settlements caused to the earth's surface, was the removal of vegetation. The importance of this process was unlikely to be such that it could bring about changes in the climate. The process at the most influenced the micro-climate a little. As a possible effect, one could think of the local disappearance of a wind break.

The impact of man on the substrate can take several shapes. Changes in hydrology, relief and soil may be mentioned. The cutting of trees and the laying out of fields can be the beginning of deforestation and, as was argued in III.3 p. 19, deforestation has a profound effect on the hydrology. The runoff increases after deforestation, especially in the summer season, which makes the discharge of watercourses more irregular. We feel, however, that also in this respect the removal of vegetation by the inhabitants of LBK settlements was not extensive enough to have much influence. There can be no question of large scale deforestation and the effect on the total hydrology will therefore have been minimal.

The relief may change as a result of the erosion induced by man. Man himself acts as an eroding agent when he removes rocks from their original context. As the inhabitants of the settlements did indeed displace rocks, they changed the existing situation, but the quantities that were found of the different rocks in the settlements, are relatively small. The effect of, for example, loam digging and quarrying on the relief must therefore have been negligeable. An indirect effect on the relief occurs by soil erosion as a result of deforestation. Although the destruction of the vegetation does not seem to have been important during the LBK occupation, it appears that nevertheless some erosion was already present in this period. We remind the reader of the observation by Van de Wetering, who in Hienheim found a pit, which had been dug through a layer of displaced loess (colluvium) (III.3 p. 25). His conclusion is that the erosion and the colluvation resulting therefrom must have started already before or during the LBK occupation. It is possible that the erosion in question was in fact caused by an event which took place before the foundation of the LBK settlements. It is more likely, however, that the colluviation occurred during the occupation, for instance as a result of the development of paths. Of course the effect may have been restricted to the site itself. The question is very much whether the process already exerted a real influence on the relief.

The influence of man on the soil can consist of a change of the soil profile by mechanical processes (e.g. the erosion referred to), as well as of a change as the result of the extraction or addition of certain substances. The cultivation of plants may impoverish the soils used. In IV.2 p. 71 the possibility of an exhaustion of agricultural soils has already been mentioned, because the process influences the yield of the fields. Unfortunately we know nothing about the extent of exhaustion or about the manuring to counteract it. Our opinion is that tilling the land did bring about some changes of the soil. The effects probably remained restricted to those landscapes where the soil was indeed tilled. As for the other landscape units, we can imagine no influence on the soil that is worth mentioning. Another case of influence on the soil is the effect of man on the soil in the settlement itself. The waste deposited there undoubtedly had a fertilizing effect. In the very first place an increase in the contents of phosphorus, nitrogen, carbon and calcium may be considered (Cook & Heizer 1965), but the extent of accumulation of these substances can no longer be established. Not only were the settlement areas occupied after the LBK period, but they are also subject to sheeterosion and leaching. The filling of pits, foundation trenches, post-holes and ghost-posts (i.e. the marks left by the posts themselves) is considered sometimes as a relic of the original soil, but this is incorrect. The filling of the pits is in fact soil mixed with a large quantity of waste. In addition to material from the house-floors, the ghost-posts certainly also contain remains of the wooden posts themselves (the shape of the ghost-posts prompts the assumption, that the posts or post-stumps rotted in the ground, see IV.4 p. 84). The filling of the post-holes and foundation trenches might possibly provide the most reliable measurements, but the concentration of phosphate, for example, must still have been influenced by the later occupation. However, the colour of the filling of post-holes and foundation trenches makes it clear in one case, that pollution increased in the course of time: at a place where different house-plans intersect in Hienheim, the colour of the older soil traces is lighter than that of the later ones (Modderman in press).

In III.5 the relationship between the vegetation and the fauna was mentioned: here the emphasis was placed on the difference in game population between a dense and an open vegetation. The game population increases as a landscape shows more clearings. Consequently, as a result of felling trees and laying out fields in a forest, the deer population, for example, may have increased, perhaps even to such an extent as to cause a nuisance to agriculture. It is possible that the damage to the crop led to an intensification of the hunting. Unfortunately the data on hunting are far from sufficient to answer the question whether hunting became more important in the course of the occupation period. In the area where the most has become known about animal remains, namely Central Germany, an increase of the hunting could not be demonstrated (Müller 1964 p. 61). Given the low percentages of wild animals among the excavated bones, hunting never became really important (see IV.2 p. 74). Whether man was, at this point, an instrument in the extermination of certain animal species in his surroundings is equally difficult to determine.

In conclusion, it may be said that little is known about the influence of the inhabitants of Elsloo, Stein, Sittard and Hienheim on their environment. The principal direct influence was most probably exerted on the vegetation, especially on that of the loess and the stream-valleys. The lack of insight in the changes of the environment makes it impossible to say anything about the problems which these changes might have evoked. The disappearance of the LBK population from Southern Limburg is sometimes related to environmental problems. This area, which still counted a large number of settlements in phase IId (see table 3 on p. 50), seems to have been abandoned rather suddenly. The settlements in what is now Belgium, south-west of the area which we are describing, disappear almost at the same time as those in

Southern Limburg (de Laet 1974). In the adjacent area of the Rheinland there were difficulties in the same period, at least, this is deduced from the appearance of earthworks (Kuper & Lüning 1975 p. 93). Kuper and Lüning suggest economic problems as a possible cause. It is to be doubted whether these economic problems had anything to do with environmental problems induced by the inhabitants, such as a deterioration of the quality of the agricultural soils. Personally we think that this is not very likely since it is difficult to imagine that an environmental crisis arose everywhere at the same time. Moreover, the population could have moved to a new loess-area. In Southern Limburg at least, there are a number of smaller loess plateaus with streams in the vicinity, which would surely have been suitable for establishing LBK settlements. The areas near Oirsbeek and Merkelbeek spring to mind: nevertheless, these areas were, as far is known, never occupied. Therefore we feel that the changes brought about by the inhabitants of the settlements themselves are not the cause, at least not the only one, of the disappearance of the Early Neolithic population from the entire region. Besides, the phenomenon of depopulation did not occur in the settlement area in which Hienheim is located.

V

THE LOCATION OF THE SETTLEMENTS

We assume that the first inhabitants of the settlements themselves chose the site where these would be founded. Many factors will have played a part in the choice of the site, a number of which will have been of a purely economic reason. However, economic reasons need not be the only determinants for the location of a dwelling site. Unfortunately we can but partly trace the motives underlying the choice of a dwelling place. We know the final result and we possess some material remains which tell us something about possible economic determinants. At first sight this does not seem very much, but still we think that the available data are sufficient to make a study of the location of the settlements viable, since it is precisely the economic factors which must have weighed the most heavily in the choice of a settlement site, as this site must have offered the actual means of existence. That is why in the following we wish to relate the location of the settlements Sittard, Stein, Elsloo and Hienheim to what we learned about the economic activities of the inhabitants.

In chapter III we divided the environment of a settlement into three zones of activity, namely a zone with a radius of 2 hours' walking distance, a zone with a radius of 6 hours' walking distance, and the world beyond. The zone with the radius of 2 hours' walking distance would be the area where most of the economic activities took place. After Higgs and Vita Finzi, we have called this area "site territory". In the scope of the locational analysis we deal in the very first place with this "site territory". It appeared in the reconstruction of the environment, that the site territory could be divided into different landscape units. According to the definition, the settlement is located in the centre of the site territory, but the different landscape units are not distributed regularly around this centre. Therefore it makes sense to submit the distribution of the different landscape units over the site territory to a closer study. The distribution has been given already in figures 2 and 3, but we have shown it again, slightly simplified, in figure 15 in the form of the circles under discussion.* It appears that a number of landscape units have a peripheral location with respect to the settlements under study. In the site territory of Sittard these are the landscape of sands and gravels which belong to the Higher Terrace, and the landscape of the Tertiary sands. These two units are absent in the site territory of Stein; here the area of the sandy loess on gravel is a peripheral unit. In its location, Elsloo is very similar to Stein, since the distance between the two settlements is only 2500 m. In the site territory of Hienheim, which is characterized by a different set of landscapes, the unit of the Tertiary sands and loams can be considered as a peripheral unit. We assume that peripheral units have played no part, at least no part of primary importance, in the choice of the settlement location. There remain four units for each settlement which may have been of importance. At Sittard they are the loess plateau, the dissected loess landscape, the river valley landscape, and the area with a thin layer of sandy loess on gravel. Stein and Elsloo have the first three units in common with Sittard, the eolian sand is the fourth unit. The site territory of Hienheim is dominated by a loess area, a limestone area, a river valley

* The loess area near Hienheim is smaller in extent in figure 15 than in figure 3. Figure 3 is based on the Geological Map of Bayern 1:25 000, no. 7136. On this map a loess layer of 5 cm is still indicated as loess. A new map by H.T.J. van de Wetering allowed the elimination of areas with a very thin loess cover. Figure 15 shows loess covers of more than 30 cm.

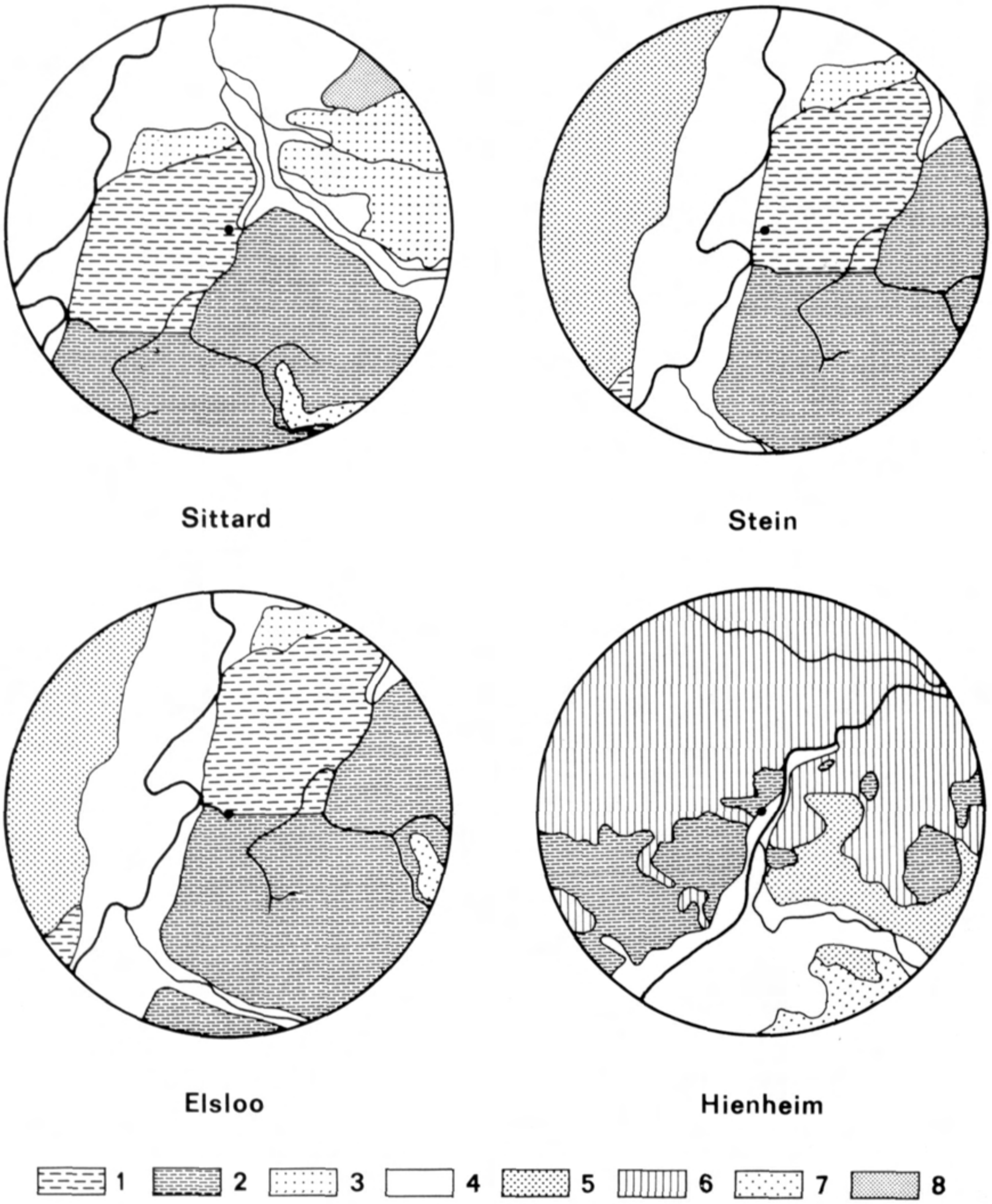


Fig. 15. Distribution of landscape units within a radius of 10 kms around the LBK settlements. 1: loess plateau, 2: dissected loess landscape, 3: thin cover of sandy loess on gravel, 4: river-valley landscape, 5: eolian sand are, 6: limestone area, 7: Tertiary deposits, 8: sands and gravels of the Higher Terrace.

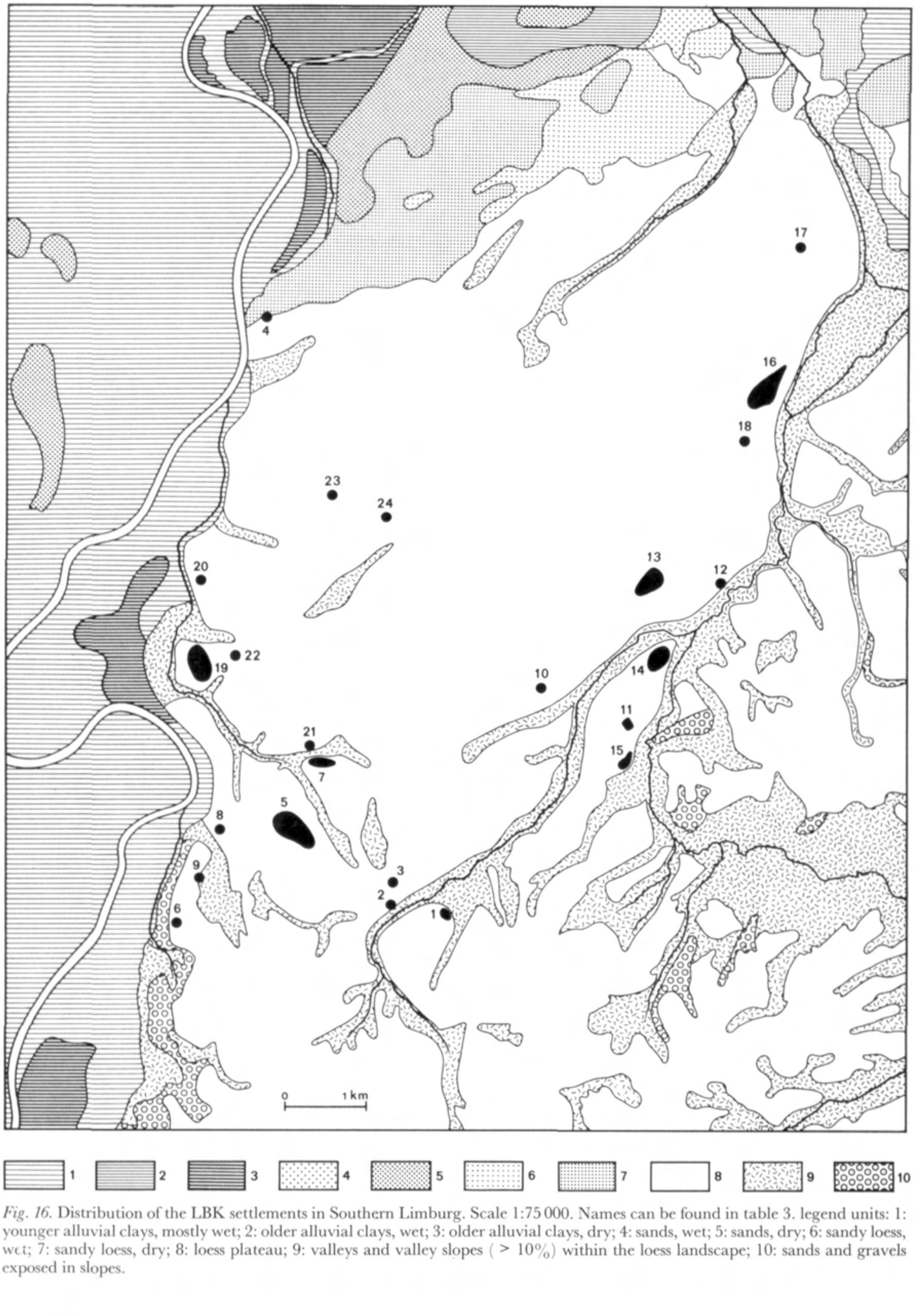


Fig. 16. Distribution of the LBK settlements in Southern Limburg. Scale 1:75 000. Names can be found in table 3. legend units: 1: younger alluvial clays, mostly wet; 2: older alluvial clays, wet; 3: older alluvial clays, dry; 4: sands, wet; 5: sands, dry; 6: sandy loess, wet; 7: sandy loess, dry; 8: loess plateau; 9: valleys and valley slopes (> 10%) within the loess landscape; 10: sands and gravels exposed in slopes.

landscape, and an area with eolian sand. When we have a look at the location of the settlements within these units, we see that Sittard, although located on the loess plateau, is not in the middle of it, but on a place where the dissected loess landscape and the river-valley landscape are nearby. The same applies to Stein and Elsloo. The last settlement is even located on the boundary of the loess plateau and the dissected loess landscape. Also Hienheim lies within a loess area and in the immediate vicinity of a river-valley landscape.

The fact that all four the settlements described were built on a loess substrate, is nothing new; the remark was made already when the settlements were discovered and Modderman mentions the fact in all his publications (Beckers & Beckers 1940, Modderman 1958/1959a, Modderman 1965/1966, Modderman 1969). The location of the settlements on a loess substrate fits precisely in the picture which archaeologists have had of the LBK since Schliz (Schliz 1906). The situation is so characteristic, that it is considered as one of the attributes of the LBK culture. That is why it is obvious to see the presence of a loess area as one of the determinants for the location of our settlements. However, it cannot have been the only factor, since not one of the settlements lies in the centre of a loess area. We think that the eccentric situation is not coincidental. On the maps 1:200 000 (figures 2 and 3) and also on the maps 1:75 000 and 1:50 000 (figures 16 and 17), which give a more accurate picture, can be seen that neighbouring settlements have a similar eccentric location (apart from two exceptions in Southern Limburg). There must have been at least one other factor that exerted a pull on the location of the settlements. The maps with a scale of 1:200 000 suggest for Sittard the dissected loess landscape or the river-valley landscape, for Stein the river-valley landscape, for Elsloo the dissected loess landscape, and for Hienheim the river-valley landscape. However, there is still another possibility, namely that not one of the large units, but a smaller landscape element is the factor sought, namely open water. The maps of figures 2, 3, 16 and 17 show that the settlements lie near streams or rivers. It is a well-known fact that LBK settlements are nearly always found along a watercourse. Schliz already mentioned this and the observation has been repeated many times (Schliz 1906). For the areas which we are studying, we refer in this respect to Modderman for Southern Limburg and to Brunnacker and Kossack for a comparable area in Niederbayern (Modderman 1958/1959a p. 3, Modderman 1970 p. 202, Brunnacker & Kossack 1957 p. 48). Therefore we consider open water as a second determinant for the place of the settlement. We are not yet ready to answer the question whether the river-valley and dissected loess landscape also played a part.

Both requirements, the presence of loess and the presence of open water, still allow some variation in the choice of a settlement site. thus it is not yet clear why in Southern Limburg so far settlements have only been found in the plateau landscape or on its edge, whereas there are no settlements in the dissected loess landscape. According to Modderman, the dissected loess landscape is unfit for occupation because the areas which are attractive on account of their loess cover lie too far from open water and the edges of the landscape in question would also be too eroded and show too much relief to meet the requirements. We fully share Modderman's opinion where the area south of the LBK occupated area is concerned. This area is dissected by only one watercourse: the Geul. The valley of this stream has very steep slopes without loess cover. Therefore it seems to us that this part of Southern Limburg does not meet the requirements for the location of LBK settlements. The situation is different in the area east and south-east of the plateau landscape described here. Water certainly occurs here and the valley slopes are not steep everywhere. The difference with the plateau landscape resides in the fact that the landscape is divided by valleys and dry valleys into a number of small plateaus, whereas the area between the stream Geleen and the Maas, which we call "plateau", is one large, flat area. It is possible that the inhabitants of the LBK settlements preferred

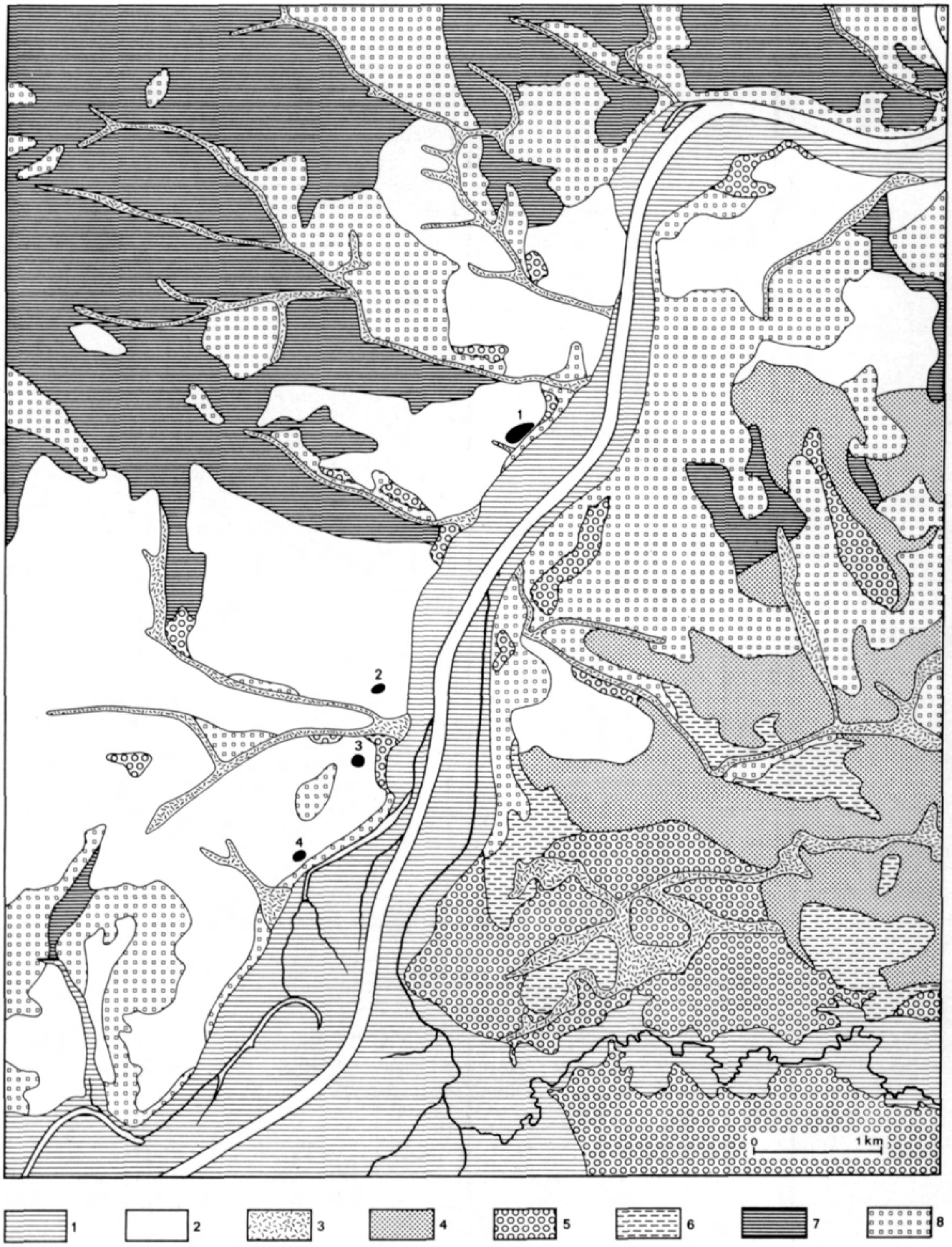


Fig. 17. Distribution of the LBK settlements near Hienheim. Scale 1:50000. 1: Hienheim "am Weinberg", 2: Hienheim-Fuchsloch, 3: Irnsing-Schanze, 4: Irnsing-1, legend units; 1: younger alluvial loams; 2: loess; 3: colluvial material; 4: sands; 5: gravels; 6: shallow, stony soils on sandstone; 7: fine sandy to silty loams on limestone; 8: shallow, stony soils on limestone.

one large plateau to a series of smaller ones. On the other hand, Elsloo lies in reality on a plateau of its own, which corresponds to the type that is found in the dissected loess landscape. This, moreover, also applies to other settlements, such as Beek-Kerkeveld-Hoolstraat and Elsloo-Geulle (fig. 15, nos 1 and 6). Therefore we are reluctant to consider the factor "dissected landscape" as a negative factor in the choice of a place for a settlement. The loess area of Hienheim plays no part in this discussion, because this area offers no choice; there is only "dissected loess landscape".

While the relief differences are not considered as a negative factor where the choice of a certain landscape unit is concerned, we do not wish to exclude that the relief played a part in the choice of a site for a settlement. It must be said that the settlements Sittard, Stein, Elsloo and Hienheim all lie on level ground. According to Van den Broek, the settlement area at Sittard has an inclination of approximately 3% in the direction of the stream Geleen (van den Broek 1958/1959 p. 12). Modderman describes the area of Elsloo as rather flat (Modderman 1970 p. 4). Stein also lies on a relatively level piece of land (Modderman 1970 p. 80). Contour-maps on which the settlements are indicated, can be found in Modderman (Modderman 1958/1959a fig. 2, Modderman 1970 plate 2). Besides, the situation becomes clear from our figure 16. This figure does not give contour-lines, it is true, but the legend unit "loess plateau" speaks for itself. Slopes of 10% and more are absent here. Hienheim is built on a loess-covered terrace of the Donau. A contour-map and a section are given in figure 18. The map has been drawn after the topographical map of Bayern 1:25 000, sheet 7136 Neustadt a/d Donau; the profile was made by Van de Wetering (van de Wetering 1975b). Thus the settlements would have been built on relatively even terrains. We must, however, draw attention to the fact that this conclusion is based on the recent situation. In III.3 it was commented that the present relief does not correspond to the relief which was present during the Atlantic, as it has been flattened by erosion since then. Even those areas which are at present flat will have shown more differences in height, as shows the reconstruction of the original surface of the area in Hienheim (figure 4). Besides, part of the settlement areas in Sittard and Stein were probably covered by a later "Plaggenboden" (Modderman 1970 p. 80 and 81). Undoubtedly this had a equalizing effect too. The said reconstruction shows, however, that the effect of the flattening was relatively small in Hienheim. We feel that the same applies to the areas of Sittard, Stein and Elsloo and we think therefore that the settlements were built indeed on relatively even pieces of land.

The question is whether evenness was a requirement essential to the location of a settlement. It is possible that our four settlements show this feature for another reason. Settlements built on slopes, and certainly settlements built on loess-covered slopes, are more subject to erosion. The entire category "settlements on slopes" might have disappeared by erosion. This aspect of the geographic distribution of the LBK settlements has not been and can hardly be studied. It is known, however, that on apparently flat areas entire settlements are in the process of disappearing or have disappeared already (Modderman 1976). Although we cannot be sure therefore, that a flat building site was a factor that counted in the choice of a settlement place, it is to be imagined that even ground was preferred over a slope. We shall return to this later. Besides, the relief can have influenced the place of the settlement in another way as well. The impression exists that the location of Hienheim was co-determined by the presence of a small valley, which joins the valley of the Donau. The LBK settlements in the surroundings have a similar location. In Southern Limburg, with its different topography, the effect of side valleys cannot be demonstrated.

When we look for factors other than the relief which may have determined the choice of a certain loess landscape, we arrive at the climate. In his dissertation Sielmann has indicated the possibility that the

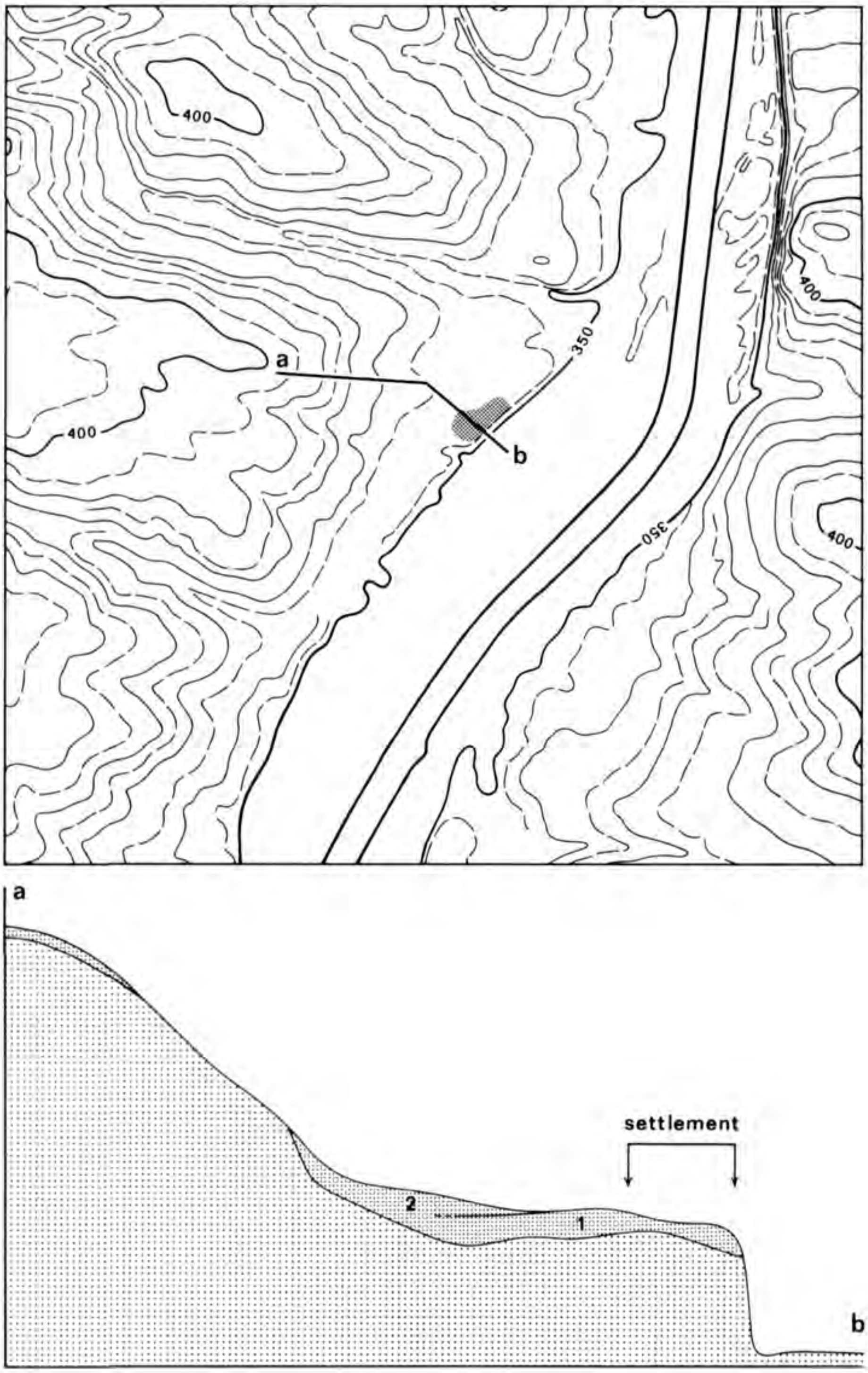


Fig. 18. Hienheim, contour map, scale 1:25 000; section, horizontal scale 1:8 000; vertical scale 1:800; 1: loess; 2: colluvium.

climate may be a factor of importance (Sielmann 1971). He related the distribution of the LBK settlements in South-Western Germany to different aspects of the climate. His conclusion is that in the first place the annual precipitation exerted an influence on the location of the settlements (Sielmann 1971 p. 185). Sielmann later extended his study to Southern and Central Germany (Sielmann 1972, 1976), which has not changed his interpretation. He adds, however, that in Bayern, besides the annual amount of precipitation, the temperature must also have played a part (Sielmann 1972 p. 33). The influence of the climate meant in essence that the driest places within a loess area were always selected (Sielmann 1972 p. 35). Following Sielmann, we have included the factors of mean annual precipitation and mean annual temperature in our considerations.

Climatological differences can hardly have carried any weight in the choice of the place for the settlement near Hienheim. The small loess area on the left bank of the Donau offers no variation in this respect. The climate might possibly have played a part in the choice of the entire loess area as living area in comparison with other loess regions in Niederbayern. In as far as we view this subject at the moment, the areas that qualify for occupation show few differences in climate. We find the study of Bayern by Sielmann unsatisfactory and hope in the future to be able to give a new analysis, using other maps and charts.

The climate of the loess area in Southern Limburg shows variation in precipitation. The distribution of the mean annual amount of precipitation over the whole of Southern Limburg is shown in figure 19. This figure is a combination of figure 2 and the precipitation chart from the Atlas van Nederland (Atlas van Nederland sheet V.2).* Figure 19 shows that the amount of precipitation increases rapidly towards the south-east (the great differences are related to the relief). The LBK settlements turn out indeed to lie in the driest part of the loess area. However, the precipitation chart offers no answer to the question why the dissected loess landscape east of the loess plateau was not occupied.

We have not looked further for climatic aspects which might have varied per loess landscape, such as the difference between day and night temperature or the mean number of days with a snow cover. We did not do so, because we feel that aspects of this type cannot be derived directly from recent climatic charts and be applied to situations within another climatic period. Sielmann thinks it is justified to use the relative distribution of independent climatic factors, because the climate has not changed basically since the Atlantic. He mentions the circulation system (westerlies), the distribution of land and sea (coastlines), the sea currents and the mountains (relief) (Sielmann 1971 p. 75). We agree with Sielmann to the extent that we also feel that the global division in dry and wet areas or in warm and cold regions will indeed have remained the same. Still there are differences. In III.2 the publications by Lamb were quoted, which indicate that especially the circulation type was slightly different during the Atlantic from what is normal nowadays. This phenomenon results in a different distribution of the precipitation over the year and a different course of the temperature curve. This is why we feel that the more detailed aspects of the climate cannot be deduced from recent climatic charts. For that purpose one would need charts of the period to be studied. Making such charts does not yet seem to be possible at the moment.

At present, no factor can be isolated which could explain the absence of LBK settlements in the dissected loess landscape east of the area which was occupied. We see no other factors in the cartographic picture which might have influenced the location of our settlements. In addition to the soil type, the relief and the climate, the vegetation is sometimes included in the list of potential pull-factors despite the fact that it is a secondary factor derived from climate and substrate. "...we may think of climate (temperature,

* the amounts of precipitation mentioned in the Atlas concern the period 1931–1960. The figures stated in chapter III.2 date from a preceding period and are therefore slightly different.

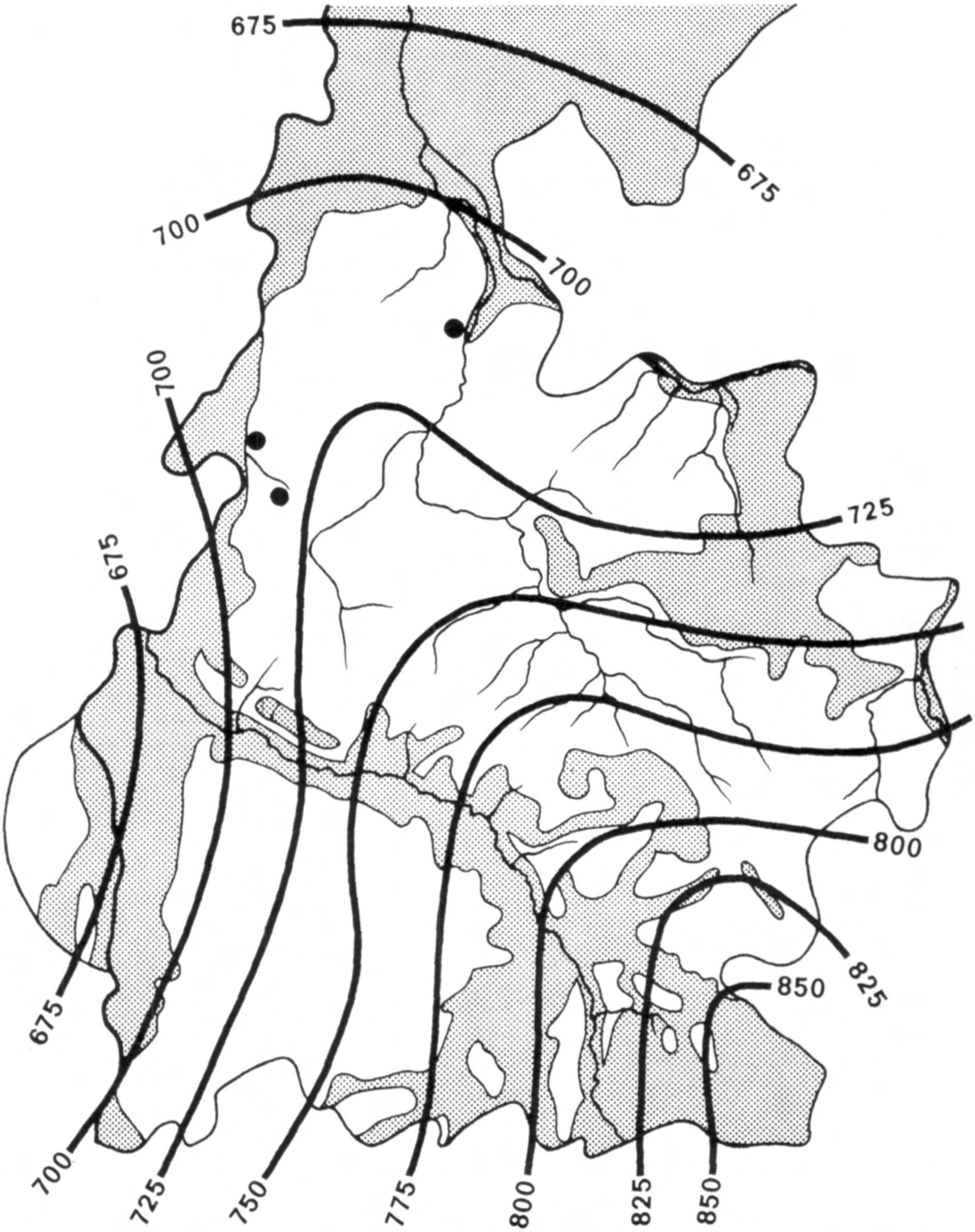


Fig. 19. Map of Southern Limburg showing the mean annual precipitation in mm, the distribution of the loess (white) and the water courses within the lœss-covered areas. The dots indicate the position of Sittard, Stein and Elsloo, which represent the whole cluster of LBK settlements. Scale 1:200 000.

moisture, light etc.) and substrate (physiography, soil, etc.) as the two groups of factors which together with population interaction determine the nature of terrestrial communities and ecosystems." (Odum 1971 p. 363). We do, however, feel, in agreement with many others, that the choice of a vegetation type was the real choice made by the founders of the settlement. We consider that people, consciously or unconsciously, judged the substrate and the climate by means of the direct observation of the vegetation. However, when considering the factors that influenced the location of settlements, the vegetation type should not be considered independently beside climate and substrate. It often happens, however, that the analysis of the vegetation cannot be left out. This is the case when not only climate and substrate, but also man has had a share in determining the vegetation type. We can imagine for instance that a clearing in the forest, caused by a Mesolithic population group, was very attractive to the founders of a LBK settlement. For such an analysis, however, one must dispose over a reconstruction of the vegetation, in which local differences within a single landscape unit with a single climate type are known. Our vegetation reconstruction is insufficient in this respect. Therefore a consideration of the vegetation can bring to light no new factor that might have exerted pull on the location of the settlements.

Summarizing the above, we arrive at the conclusion that we can indicate only two factors which, in our opinion, have influenced the choice of a settlement place with some certainty. These two factors, which can be called classical, are a loess substrate and the presence of open water. Climate and relief were possibly additional factors, but this is not clear, at least in the areas which we studied. Too little is known about the vegetation. When we say that loess and water are a condition for the presence of a LBK settlement, this does not mean that there are no exceptions. We know of exceptions to both conditions in Southern Limburg. North of Sittard, outside the area under consideration, there are two settlements on a sandy soil (see the distribution map in Modderman 1970 plate 1). Furthermore, two find sites lie in the centre of the loess plateau, far beyond the reach of water (see figure 16). Not much is known about the nature of the settlements on the sand. The find sites without water must have been extremely small, considering the number of the finds. Probably we are not dealing here with settlements such as Sittard etc., but with a limited, perhaps not even permanent occupation.

At the beginning of this chapter it was stated that the location of a settlement was, for an important part, determined by factors of economic nature. The choice of the loess as substrate has long been recognized as one dependent on economic motives. In the first decades of the 20th century it was thought, under the influence of Gradmann, that the loess was preferred, because this substrate was clear of forests. Landscapes with dense forests would have been unattractive for various reasons. Firstly, Neolithic man would not have been able to lay out fields in a forest. Then these landscapes were difficult to pass through. Finally they did not offer sufficient food in the form of game to pioneers. This interpretation had to be abandoned when pollen diagrams demonstrated that the loess was covered with forests during the Atlantic (Bertsch 1928, Firbas 1949, Müller 1953/1954, Lange 1965). Buttler gave a different explanation for the choice of loess. He started from the assumption that the inhabitants of the LBK settlements lived in pit-dwellings. Loess is very suitable for digging pits. The walls remain erect, even in deep pits, and the loess itself is dry (Buttler 1938 p. 6). Since the time that the pits are no longer interpreted as dwellings, this explanation is of course no longer useful either. But Gradmann and his contemporaries like Buttler, mention still another favourable feature of the loess, namely the great fertility of this soil type. This is the interpretation that is accepted generally nowadays and with which we completely agree. The loess is still considered as the best arable soil in the two areas under study.

Sittard, Stein, Elsloo and Hienheim would thus have been founded in a place where the soil type desired for laying out fields was present in the immediate surroundings of the houses. Such a location is completely in agreement with the model that Chisholm constructed for the location of "farms", regardless the technology of the agriculturalists. We have already mentioned this model in III.1, when it was suggested that there is a limit to man's readiness to displace himself for a certain kind of work. The activities related to laying out fields and maintaining them, to the harvest and the transportation of the crop are of such a nature that the distance between the house and the field is kept as small as possible. Chisholm writes: "A point which emerges... is the frequency with which the same orders of magnitude keep on recurring among peoples of widely different technical achievements and inhabitating areas with markedly different physical characteristics. Any distance up to about a kilometre from the dwelling is of such little moment for any but specialized systems of irrigation and garden farming that little adjustment is called for in either the pattern of settlement or of land use. Beyond about 1 kilometre, the costs of movement become sufficiently great to warrant some kind of response; at a distance of 3–4 kilometres the costs of cultivation necessitate a radical modification of the system of cultivation or settlement – for example by the establishment of subsidiary settlements – though adjustments are apparent before this point is reached. If the distances involved are actually greater than this, then it is necessary to look for some very powerful constraining reason which prevents the establishment of farmsteads nearer the land." (Chisholm 1968 p. 131).

We attempted in IV.2 to verify whether the fields were indeed laid out on loess. This was done by means of the analysis of the weed flora. Our conclusion was that on the basis of the plant remains recovered, no arguments contrary to this idea could be presented, but that absolute proof could not be given either (IV.2 p. 68).

The location of the settlements near water undoubtedly has an economic reason as well. The inhabitants needed water and this could be reached only at places with surface water. However, the settlements do not lie directly alongside the watercourse (see IV.3). The desire to have loess close to the house apparently prevailed over the wish to have water at hand.

The watercourses, by the way, can have had a second function, namely that of traffic route. Some authors reckon with this possibility (Schliz 1906, among others). We do not wish to exclude traffic over water and the use of boats. It is true that no LBK vessels are known, but this may be due to the fact that no organic material was conserved on the majority of sites (see also III.1). We do think, however, that most transportation took place over land. In the case of Hienheim it is conceivable that the contact between this settlement and its neighbours took place by boat (see figure 17). But the location of Sittard, Stein and Elsloo with respect to each other is such, that water traffic would have been devious (see figure 16). According to our vegetation reconstruction, the area between the settlements was covered with an easily traversable forest (III.4 p. 35). Therefore we think that the principal traffic routes went over land.

A third activity in which the presence of water can have been of economic significance, is fishing. Fish remains are found occasionally in LBK settlements. They appeared in Hienheim and Taute even mentions many remains in the Felsdach Lautereck (Taute 1966 p. 495). So fishing was certainly practiced. Still, the composition of the food remains from most of the settlements creates the impression that gathering food in the wild was not an important part of the daily life (IV.2). We assume therefore, that great importance should not be attached to the presence of water as fishing water where the choice of a location for the settlement is concerned.

The location of the settlements along watercourses need not be related exclusively to the open water itself. It may be that the valleys, which belong to the watercourses, also played a part because of their vegetation, which in the valleys must have been much more varied than on the loess plateau. It was characterized by a rich undergrowth. In IV.2 it was brought forward that the valleys could have been used for grazing cattle. The vegetation there would have been more suitable for feeding relatively large numbers of animals than the forests on the loess, certainly so before agriculture had created any clearings. Should this suggestion turn out to be correct, then the valleys would be of importance to people who not only practiced agriculture, but who also kept cattle. Proof that the valleys were used for grazing cattle could not be provided so far.

Besides their importance for cattle-breeding, valleys may also have significance for agriculture. In IV.2 we pointed out, that it is possible to lay out fields on the soil in the valleys, provided at least that no flooding occurs during the growing season. However, we considered the loess soils more important than the river loams. We wish to point out nevertheless, that Kruk attributes a greater importance to the fields in the valleys than to the fields in the drier parts of the landscape. "Most of the cultivated fields were presumably situated on inundational terraces and at the edges of valley slopes. Owing to the high and durable edaphic potential of the soils that covered this zone it was possible to use constantly the same portion of land even without fertilizing it. The impoverishment of soil was naturally compensated by the surface flow of humus and inorganic materials from the higher parts of slopes, and by cyclic floods. The zone farmed might have also included the drier parts lying deep in the valley margins (or terraces situated above inundational level). These areas presumably differed somewhat in character from the more humid ones, not so much however as to necessitate the use of a different method of soil working." (Kruk 1973 p. 255). Kruk arrives at this interpretation on the basis of the location of settlements in a loess area in Poland. "The Danubian I population nearly always colonized the lower parts of the valley slopes. The settlements were situated at their edges immediately above the inundational terrace covered with silts of various rotation. The occurrence of these soils must have constituted a major criterium in the choice of the settlement sites, since the smaller valleys, the bottoms of which were covered with other formations of river accumulation (e.g. deposited loess) were neglected." (Kruk 1973 p. 250). We do not wish to adopt Kruk's interpretation, since the smaller valleys in our areas were certainly populated. Elsloo is an example. Also in Niederbayern many examples can be found of settlements along,small streams. We think it possible nevertheless, that certain plants were cultivated specifically in gardens in the valleys.

The valleys were possibly also exploited as route ways as is suggested by certain authors in discussing the distribution of the LBK culture (Buttler 1938, Quitta 1960). We think, however, that the presence of traffic routes in the valleys is improbable. The natural vegetation in the valleys consisted, in our opinion, of carrs on wet places and of an Alno-Padion on the slightly drier parts. Both types of forest are characterized by much undergrowth and are therefore difficult to pass through. It is true that the seldom flooded parts supported also forests of the "Carpinion betuli", in which the going is easier, but in most cases the dry parts are discontinuous in a river valley with a meandering river. Therefore it seems more probable that the roads did not pass through, but along the valleys. The tracks then in use were possibly determined only to a small extent by the watercourses, except in mountainous terrain.

In the above the relief has been regarded as an uncertain factor as far as this study concerned. It is obvious, however, that building houses on an even ground offerend advantages over building on a slope. At least, we assume that in the past too the floor of a house was preferred to be horizontal. Special measures must be taken to obtain this result on a slope. Considerations of this nature imply that even terrain was a positive factor in the choice of a settlement site, although no direct proof is available. The possible effect that the presence of a small side valley may have had on the location of Hienheim, could be the result of the fact that the boundary between the loess-covered river terrace and the alluvial plain consisted in a steep terrace edge. The access to the main valley is easiest by the mentioned side valley.

After the above analysis of the location of Sittard, Stein, Elsloo and Hienheim, and the possible economic significance of this location, we wish to consider again the site territory defined in III.1. We have introduced the site territory with a radius of 2 hours' walking distance or 10 km in our study to have a starting point for the investigation of the relation between the inhabitants of the settlements and their environment. Perhaps it is now possible to confirm to what extent the site territory corresponds with the area that really had economic importance for the settlements in question. By "reality" is then understood the reconstructed "reality".

One of the questions is whether the radius of 2 hours' walking distance calculated by means of data from the literature, can and must be adapted as a result of the reconstruction. It was demonstrated in III.6 that more settlements could be found within a distance of 10 km. Some of these settlements must have existed simultaneously. This means that the theoretical "site territories" overlapped each other to a very considerable extent. From this fact we draw the conclusion that no real importance should be attached to the site territories with a radius of 10 km. We see three alternatives that might replace the model of a site territory with a radius of 10 km and might describe the "reality" better. The first alternative is a reduction of the radius to such an extent that overlapping is avoided. This can be done for example by the construction of Thiessen polygons. This procedure involves a division of the available area into plots of land which each belong, more or less exclusively, to a certain settlement. The settlement is as autonomous as possible. The second alternative is that not the settlement, but a loess area with several settlements is considered as an economic entity. The settlement is then not extremely autonomous, but functions within a large entity. The territory would then be an area that might extend itself until 10 km beyond the most eccentrically located settlements. The third alternative is a combination of the first two, whereby we envisage a settlement which is autonomous as regards its food supply, but which functions within a larger entity where such activities as obtaining raw materials are concerned.

The maps of figures 16 and 17 could be used to construct Thiessen polygons, but we forgo this for different reasons. One reason is that not all the settlements are known, at any rate in Southern Limburg. New settlements are discovered here now and then, lying buried under a colluvium layer and which appear only in digging activities. A second reason is that some find sites, which are now represented by separate dots, could belong to one and the same settlement complex (e.g. Beek-Molenstraat and Beek-Proosdijveld, nos. 2 and 3 in figure 16). In the third place we think that the boundaries of Thiessen polygons are too rigid for a dissected landscape such as the south-western edge of the loess plateau in Southern Limburg. We feel that the territories of the settlements near Elsloo are not correctly described by the construction of Thiessen polygons. A fourth reason is that the settlements were probably not of the same size. The dimensions of the polygons would then have to be weighed in relation to the different sizes. As we do not even know their size by approximation such weighing is impossible.

But also without drawing polygons it is clear that a stretch of loess and a part of a valley with a watercourse can be assigned to nearly all settlements. However, these sections were only of equal value in the case of Hienheim and its neighbours. The conditions in Southern Limburg are not completely identical. Settlements, such as Stein, of which the territories border on the valley of the Maas, had a direct access to the river-valley landscape and to the gravel bars in the river, which the other settlements lacked. If the first alternative is accepted (a reduction of the radius of the "site territory"), the inevitable conclusion is that the settlements cannot have been completely selfsufficient. The sites on the river would for example have had to supply rocks to the "hinterland". It may also be questioned whether the variability in access to river-valley landscape effected the size and the composition of the live-stock of the settlements. Unfortunately such an effect cannot be measured, because there are no animal remains.

The second alternative: no extreme local autonomy, but a regionally organized economy, is, in our opinion, not a good model. We cannot imagine how the inhabitants of a number of separate and, we think, equivalent, settlements would work together in a collective system. We see settlements as Sittard, Stein and Elsloo as settlements that co-existed. There are no indications of a central authority and it is assumed generally that the exponents of the LBK culture did not know any (Tabaczyński 1972).*

Data allowing a well founded choice between the first and the third alternative, are absent. We personally prefer the third alternative, in which the inhabitants of the settlements did exploit their own piece of loess, but also had direct access to certain commodities beyond. One could even think of the right to grazing land in the river-valley landscape.

The third model implies that the original concept of a site territory as "the territory surrounding a site which is exploited habitually by the inhabitants of the site" (Vita Finzi & Higgs 1970) is not completely applicable. The reason is that part of the economic activities took place in an area which was also used by other settlements, and another part in an area which does have a territorial character. In our case we should like to reserve the concept "site territory" for the "own" loess area with adjacent watercourse, and include the rest in the much wider concept "home range". The latter comprises also non-economic activities, has vague boundaries, and shows overlapping with the home ranges of other settlements (see also III.1). Our ideas of the location of the settlements and their exploitation of the hinterland are shown in the following scheme (figure 20).

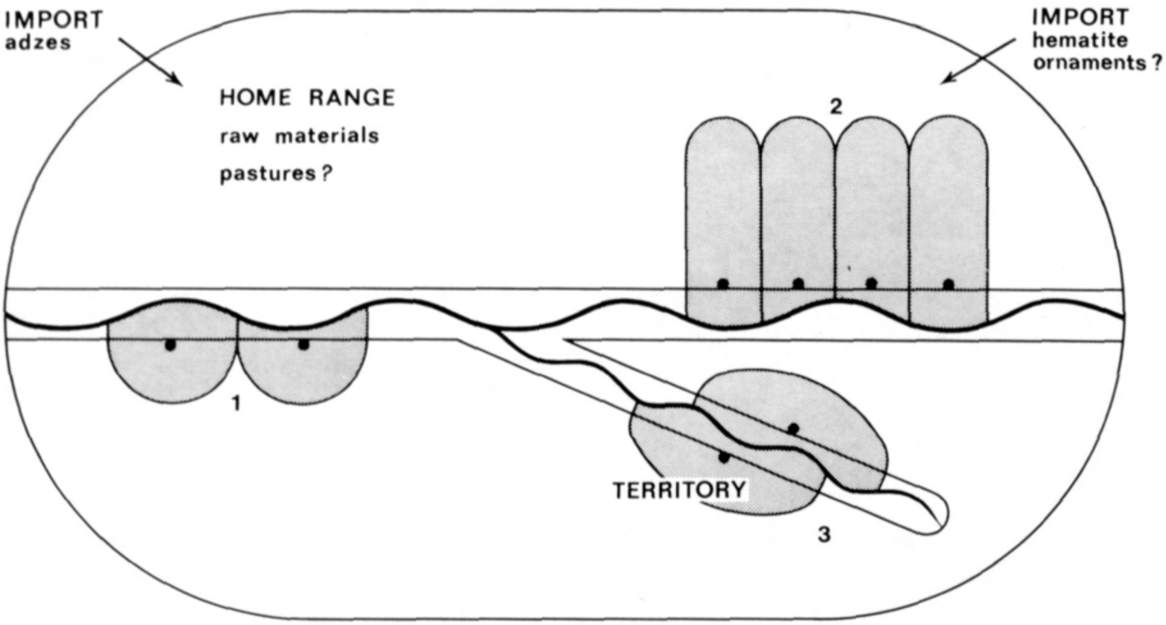


Fig. 20. Model for the location of the LBK settlements. Three alternatives are given for the shape of site territories (nos 1, 2 and 3).

* We wish to note here that some of the find sites shown on the distribution maps could perhaps have originated in subordinate settlements, such as houses that were built to guard certain fields. The find sites Urmond-Graetheide and Urmond-Hennekens should perhaps be interpreted as such.

Next, the attempt can be made to determine the size of the site territory and of the home range. As we have shown in figure 20, we think that the site territories need not necessarily have been semi-circular. A location along watercourses can imply that the dimensions parallel to the watercourse differ from the dimensions at right angles to the watercourse. The territories are then oblong and are described not by a single radius, but by two dimensions at right angles to one another. In an ideal case, these dimensions might be obtained through a distribution map, showing all contemporary settlements. Furthermore, it should be known whether the settlements counted the same number of houses or whether they were of different sizes. As has already been mentioned, our distribution maps do not meet these requirements. Still, we can say something about the dimensions of the site territory. We know, for instance, that south of the settlement Sittard (figure 16 no. 16), at a distance of 2500 m, there was another settlement on the same bank of the stream Geleen (Geleen Noord no. 12). Both settlements existed simultaneously at least during phase IIc. On the right bank of the Ur, we know not only of Stein (no. 19), but also the settlement Stein-Heideveldweg (no. 21) during period I. These settlements are at a distance of 1700 m from each other. More mutual distances cannot be given for Southern Limburg, because either the settlements are not dated sufficiently well, or they are separated by a valley. We are left with the impression that the distance from a settlement to the boundary of its territory, measured along the watercourse, was 1000 m at the most. We expect, by the way, that in the future new settlements will be discovered between the already mentioned settlements, so that the mutual distances would become even smaller. In the surroundings of Hienheim, only one of the LBK settlements has been dated sufficiently well. It is Hienheim-Fuchsloch, at a distance of 2300 m from Hienheim. For the other two settlements mentioned in III.6, namely Irnsing-Schanze and Irnsing 1, no dates can be given. Should they have existed simultaneously with the first two settlements, then the four of them were located in a row along the Donau, with mutual distances of 2300 m, 750 m and 1000 m. The dimensions of the territories, parallel to the river, would thus again be in the order of 2000 m or less.

The dimensions at right angles to the watercourse cannot have been great either. We refer to the location of a settlement like Elsloo (no. 5). At least during phase IId, Elsloo existed simultaneously with Elsloo-Heide (no. 7), Elsloo-Julianastraat (no. 8) and Beek-Proosdijveld (no. 3). The distances to these find sites are 750 m, 1000 m and 1250 m respectively. In the surroundings of Hienheim we have a hold fast in the size of the loess area. The presence of loess near Hienheim itself is restricted to a strip with a depth of 500 to 1000 m, measured from the river valley. Near Hienheim-Fuchsloch (no. 2) the loess boundary is at 2000 m from the river valley. The hinterland of the other two settlements corresponds in size with that of Hienheim. We think that we may deduce from the situation as depicted on the map, that the site territories, measured along the watercourse, were not wider than 1000 to 2000 m and, measured at a right angle to the watercourse, were not deeper than some 1000 m. In reality the territories were perhaps even smaller. The distribution of comparable settlements along the Merzbach on the Aldenhovener Platte in the Rheinland indicates, that at least the width can have been much smaller in some cases, namely some hundreds of metres. The depth is set here at 1500 m at the most (Kuper et al. 1974).

We wish to point out that our rough estimate of the maximum size of a site territory also approximately indicates the size of the available loess area, since most of the valleys are narrow and their surface covers but a small part of the total area. If one assumes that the loess soils indeed represent the area used for agriculture, then the size of this area corresponds with the ideal dimensions, namely less than 3 × 3 km, as described by Chisholm (Chisholm 1968 p. 131, quoted by us on p. 138). The estimated site territory seems therefore not to be unreasonable.

Another kind of check might consist of testing whether such a territory was indeed sufficient for the inhabitants of the settlements. However, carrying out such a test involves many problems. It must be known, in the first place, how many inhabitants a settlement counted. There are two methods of estimating the number of inhabitants. The first method calculates the number through the size of the settlement or the number of houses; the second method calculates the number through the graves in a cemetery belonging to the settlement. Both procedures are difficult to apply in our case, because the size of most of the settlements is unknown and cemeteries appear to be rare or at least difficult to find. The only settlement in the two areas under consideration of which the required data are available, is Elsloo. Both the size and a cemetery are known of this settlement.

200 to 250 houses would have been built in Elsloo in the course of its history (Modderman 1970 p. 204). It seems unlikely, however, that the oldest houses remained intact during the 400 $\pm$ 50 years that Elsloo was inhabited. The real number that constituted the settlement at a given moment, must therefore have been much smaller. This number depends on the life-span of the houses and therefore on the life-span of wooden posts embedded in loess. This factor is unknown, because this building technique is no longer used nowadays. We might read the maximum life-span from table 6 of IV.4 (p. 82), in which a life-span of 25 years is stated for indigenous wood in contact with the soil. As Modderman has never observed that construction elements in the houses had been replaced, the houses could have remained inhabitable for circa 25 years. The question is, however, whether in reality the houses may not have stood longer. The life-span of 25 years has been established by means of laboratory tests. We think it possible that inhabited houses, in which a fire was kept, remained intact for a longer time. Unfortunately, little information is available about the life-span of comparable prehistoric houses. Verwers is of the opinion that the houses of the Iron Age settlement in Haps, on a sandy soil, stood for 80 years (Verwers 1972 p. 121). Haarnagel mentions a life-span of 50 years for 4 "terp" houses, but the remark must be made here that the subsoil, in which the wood was embedded, has characteristics which are quite different from those of loess soils (Haarnagel 1976, written communication). All we can do at the moment is choose a life-span. We then take a short life-span, namely 25 years. This period has also been used by Modderman and Kuper et al. (Modderman 1970 p. 204, Kuper et al. 1974 p. 497). Using a life-span of 25 years means that Elsloo must have averaged between 11 and 17 houses at any one time. Modderman points out, however, that a population increase in the course of time should be taken into account. He suggests for the first phase a number of less than 9 and for the youngest phases a number of over 17 (Modderman 1970 p. 205).

The next problem is to determine the number of inhabitants per house. In our opinion this can be done only by means of etnographic data. It is difficult, however, to find acceptable etnographic parallels, that is data relating to houses that belong in a similar economic and social context. So far we hardly know anything about the social aspects of life in LBK settlements. On the other hand, the etnographic data are also scarce (Petersen 1975). Several authors have tried to develop formulae which could possess a general validity within certain economic and social limits. We name Naroll, Cook & Heizer, Clarke and Casselberry as authors who studied sedentary, non urban, population groups. Naroll suggests that the population of a settlement can be calculated by taking one-tenth of the total floor surface expressed in square metres (Naroll 1962). Milisauskas has used this formula to calculate the number of inhabitants of the LBK settlement B1 in Olszanica (Milisauskas 1972 p. 70). Cook & Heizer give a formula which relates to "Aboriginal California". "In aboriginal California the floor space per individual house was based upon a minimum average of 6 persons with 20 square feet available to each. Additional persons involved an increase of 100 square feet each." (Cook & Heizer 1968 p. 114). Later Cook refined the formula into: "For measuring space a fair rule of thumb is to count 25 square feet for each of the first six persons and then 100 square feet for each additional individual." (Cook 1972 p. 16). The formula applies both to singlefamily and multifamily dwellings. Naroll's formula as well as the formula of Cook & Heizer are subject to criticism. They are qualified as too generalizing (Casselberry 1974, Petersen 1975). The work by Clarke relates exclusively to Pueblo cultures (Clarke 1971), whereas Casselberry dealt with multifamily dwellings (Casselberry 1974). Clarke says that the population of a Pueblo amounts to one-third of the floor area as measured in square metres. Casselberry suggests: "the population of a multifamily dwelling can be roughly estimated as one-sixth the floor area of the dwelling as measured in square metres." But he adds: "Although this formula ($P = 1/6F$) correlates better with the data represented here than to the other formulae, it is far from a good predictor of population size. The primary reason for this is the large amount of flexibility in human population densities due in part to the various human proxemic systems. The formulae on the chart tend to underestimate the population of the various dwellings (the formulae referred to are those of Casselberry, Naroll and Cook, C.B.). It is equally possible, in fact very likely, that the same formulae would overestimate the population if other dwelling types were being considered. Thus it should be emphasized that each dwelling type must have an unique formula." (Casselberry 1974 p. 119). Casselberry applies his formula to the LBK settlement in Olszanica, among other settlements, apparently sharing Soudský's opinion, that the LBK houses were multifamily dwellings (Soudský 1962).

It results from the above that determining the number of inhabitants of a LBK settlement on the basis of the number and the size of the houses is still no more than guesswork. For lack of better, we have applied the formulae of Cook 1972 and Casselberry 1974 to those parts of the LBK houses in Elsloo, which Modderman considers as the living section. Hereby we differ from the procedure followed by Milisauskas and Casselberry, who calculate with the total roofed surface. We have considered all excavated buildings as dwellings. The formula of Cook gives for Elsloo period I an average number of 10 persons per house. There is not much variation. The smallest calculated value is 6 and the largest is 13, but these are extreme values. The application of Casselberry's formula gives 9 inhabitants; the lowest value, 5, and the highest, 13, relate to these extremes. In period II the dwelling sections become slightly larger, which results in averages of 12 and 11 respectively. This number is valid for most of the houses. There are few real exceptions. Most conspicuous is house 13, which has a large dwelling section and which, according to the applied formulae, would have counted 17 (Cook) and 19 (Casselberry) inhabitants. When we reckon with a settlement of circa 9 houses in period I and 17 houses in period II, the population of Elsloo would have increased from 90 or 81 to 204 or 187, that is from slightly under 100 to circa 200 inhabitants.

Modderman has calculated the number of inhabitants through an estimate of the family type that would have inhabited the houses. It would have been a family of 6–10 persons, including three generations. Thus he arrives at a number of 54–90 for the earliest phase and at a number of 102–170 for the latest phases.

The calculations based on the cemetery of Elsloo relate to the population in phases IIc and IId, because the excavated cemetery was in use during these phases only. On the basis of the number of graves and the duration of phases IIc and IId, Modderman arrives at the conclusion that the dead came from a village, which counted 160 persons at the most and at least 40 persons (Modderman 1970 p. 205–207).

In a new analysis of the grave-goods, Van de Velde arrived at the conclusion that the dead in the cemetery constitute no proportional representation of the population. Modderman already pointed out that children of 10 years or younger are virtually absent, a fact which he took into account when he calculated the population. Van de Velde, however, states that women are also underrepresented. The sex ratio is not 0.500 but 0.403. Van de Velde used this ratio to make a new calculation. He had to start of course from a number of assumptions. He sets the sex ratio at birth at 0.500. Further he assumed that 50% of the people died before they became adults. Only adults would lie on the cemetery, but for example women who died in the first childbed, would not have been buried. With the given sex ratio, 50 men and 34 women would eventually be buried out of an original population of 200. As 113 graves have been found in Elsloo, the original population would have counted 269 persons. Van de Velde thinks that the cemetery was not in use during the entire phase IIc + IId. He does not estimate the period at five generations, that is the duration of the phases according to Modderman, but at three generations. Therefore the population living in one and the same time would have comprised 90 persons (Van de Velde 1977 personal information).

The above shows that the different approaches provide divergent results. The formulae of Cook and Casselberry give a population of 200 for phases IIc or IId; Modderman's estimate on the basis of the houses gives 100–170 and his estimate on the basis of the cemetery 40–160 persons; Van de Velde arrives at 90.

The calculation of the population is not the only problem which we are faced with. If we wish to confirm whether a population could live off a certain piece of land, we need to know what that land yielded. In this respect not only food should be thought of, but also certain raw materials and firewood. With respect to the raw materials we should like to mention in particular the need of sufficient building materials. It is unlikely that the raw materials for mobile goods listed in IV.4, ever formed a problem in the quantitative sense. If they were present, they were also present in sufficient quantities.

We shall first have a closer look at the food supply. In IV.2 it is held that the food came mainly from cultivated plants and domesticated animals. Too little is known about animal husbandry and therefore we shall restrict ourselves to agriculture. The question is reduced thereby to the question whether the inhabitants of Elsloo had enough agricultural land or enough loess soil in their site territory from which to live. To answer this question we must know, among other things, what part of the daily food came from plants and what the yield was per hectare of arable. In IV.2 the problem of the ratio between food from plants and food from animals has already been discussed briefly (p. 77). This ratio cannot be established on the basis of the excavated material. Therefore an estimate has to be made and we shall reckon in the following with 50%, 65% and 80% of food from plants.*

The yield of the fields has been discussed already in IV.2. We mentioned the possibility that the yields could have been equal to those of the just deforested areas in Canada. This means a yield of circa 1 000 kg per hectare, if the yield of the first year is left out of consideration. Some part of this yield is required as sowing seed and part is lost during storage and processing. For this factor Abel states an amount of 200 kg per hectare (Abel 1967). So one hectare of arable would yield 800 kg of cereals for consumption. Perhaps this estimate is on the low side. Abel reckons with a net yield of 500 kg per hectare for the permanent cultivation of cereals in the "terpen" area (Abel 1967 p. 24). He also writes that loess areas are 2.5 times as favourable for agriculture. As there were undoubtedly still many tree-stumps in our fields, which will have reduced the effective area (like in Canada), we reckon nevertheless with 800 kg of cereals for consumption per hectare.

If, for the sake of convenience we only consider cereals and none of the other plants, then one hectare of arable would yield $800 \times 3100 = 24.8 \times 10^5$ Cal of food from plants. According to data from the FAO, a

* 65% is the share of food from plants in the diet of hunters and gatherers (Lee 1968). First we have taken this percentage and then a higher and a lower value.

population of 100, among whom 50 children, 25 adult males and 25 adult females, would need about 237500 Cal per day.* In a case where 65% of the energy demand has to be covered by the wheat yields, then Elsloo, with a population of 100, would have required circa 23 ha of loess in culture. At 50% this is 17 ha, and at the highest estimate, of 80%, 28 ha. If indeed 200 people lived in Elsloo during the last phases, these figures must of course be doubled.* When the above-mentioned areas are related to the site territory, then the surface covered by the fields is smaller than the estimated maximum size of a territory (100–200 ha). In the case of Elsloo a rather more specific definition of the territory is possible. Elsloo lies on a small loess plateau, which is enclosed by valleys. This loess plateau covers circa 170 ha. If the entire plateau belonged to Elsloo and therefore did not have to be shared with Elsloo-Heide, Elsloo-Julianastraat and Beek-Proosdijveld, then the site territory of Elsloo would have covered 170 ha. Of course, part thereof was occupied by the settlement itself, but there was room enough for 17–56 ha of arable. This does not necessarily mean that the inhabitants could live off the land, since we do not know for how long the fields were cultivated. Regular shifting could never have gone on indefinitely, since the fields covered one-ninth to one-third of the maximum possible surface. This could lead to the conclusion that the fields were kept in use for a long time or perhaps even permanently, or that they lay fallow for short times only. In our opinion such conclusions may not yet be drawn at the moment. They would be based on calculations carried out with a series of estimated quantities, among which the size of population, the share of wheat in the food and the yield of the fields are the most uncertain ones.

We shall now have a closer look at the building materials. It was stated in IV.4 that especially the availability of organic building materials may have presented problems. We shall restrict ourselves here to the question whether the site territory could have supplied sufficient timber for building a settlement. Estimates on this subject were formulated in IV.4, with the reservation (p. 85) that the lack of detailed knowledge of the vegetation made it impossible to calculate exactly how large the area was that could supply the necessary quantities of boles. On p. 86 followed an estimate of the area that could have been exploited for building the 200–250 houses. The margins turned out to differ from 50 ha in the most favourable case to 1000 ha in the most unfavourable case. It is clear that only in the most favourable situation, in which there were 1000 trees per ha of which a quarter could be used, the settlement can have been built of the wood from the site territory. Of course it is possible that timber was also imported from outside the territory, but we think that this is less probable, especially since Elsloo is surrounded by settlements, which also needed timber. However, our calculations are based on the assumption, that each house was built of new timber. The situation becomes more favourable when parts of older houses were re-used in the houses. It is possible that ridge-poles and rafters could be used for a longer time than the roof-supports or the wall. Although it does not appear from the excavated soil traces that posts were removed from the soil to be used again, the secondary use of non-embedded parts should not be excluded. Moreover, the possibility of a secondary growth of suitable trees was not included in the calculations, which is also perhaps not quite correct.

A third material which was certainly available but the quantity of which is also of importance, is firewood. Unfortunately, nothing can be said about this material.

* An adult male would consume 3200 Cal, and adult female 2300 Cal and a child 2000 Cal per day. The figures are valid for "reference people". We have not counted with the extra calory demand of pregnant and nursing women (FAO 1957).

* Similar calculations have been made by Piggott and Soudský & Pavlů. Piggott uses criteria taken from Classical Antiquity and arrives on this basis at 60 ha of arable per 100 inhabitants (Piggott 1965 p. 52). Soudský & Pavlů use data from Russian agricultural regions. They arrive at the conclusion, that for a group of 100 individuals, 20 ha of arable was sufficient (Soudský & Pavlů 1972 p. 325).

In answer to our original question, namely whether the inhabitants of a LBK settlement could live on a site territory of at the most 200 ha, but probably smaller in reality, it must be said that this has not been demonstrated to be impossible. At the moment a more concrete answer is not justified since too large a number of quantities has been chosen and these of course include a subjective element. Therefore we consider the preceding calculations of population, food and wood only as an attempt to show how we could calculate if certain quantities were known.

Besides a site territory, a home range has been postulated. We should like to know the size of this home range too. The home range extends itself theoretically to a distance of 6 hours' walking or 30 km outside the settlement. It is difficult to verify whether this limit has a real meaning. Considering separate settlements, as has been done in our study, is not sufficient a basis on which to judge the home ranges. For that purpose one should possess a survey of larger units. Perhaps an analysis of and a comparison between adjacent concentrations of settlements will show a division into larger and more complex units than the single site territory.

A few more words are needed on the landscape units, which were included in the considerations at the beginning of this chapter, because they fall within the site territory defined in chapter III. Now that it has been demonstrated that the real site territories must have been much smaller, the number of landscape units that matter has been reduced to a single, or at the most, to two units. Important for Southern Limburg are the loess plateau landscape and for the area of Hienheim the loess landscape. Perhaps the river-valley landscape should be added. The other units, which originally also seemed to cover a large surface and therefore could have played an important part, namely the dissected loess landscape, the area with a thin cover of sandy loess on gravel, the eolian sand area and the limestone area, now no longer fall within the site territory, but within the home range. We doubt whether they played an important part in the economy. The investigation has made clear that the inhabitants of the settlements obtained certain raw materials from these landscapes, such as chert from the limestone area. But then it concerns the use of a few materials, perhaps from very localized spots, and not the exploitation of an area. Therefore we feel that the landscape units themselves had no real significance.

When, at the end of this chapter, our ideas about the location of the settlements are summarized, it can be stated that the location was determined by the presence of a loess area and a watercourse. The loess area need not be larger than 100–200 ha. Most of the economic activities, and especially agriculture, took place within this area, but a number of activities were carried out beyond. A few necessary materials were not available at all and had to be imported from elsewhere. Of course we do not think that one single settlement on an isolated loess island of the given size could survive. The presence of neighbouring settlements, can have been essential, e.g. for the maintenance of the population and for social contacts. We cannot say more at the moment. The lack of especially the quantitative data which might enable detailed analysis is the greatest impediment.

VI

FINAL REMARKS

Now that the relations between the LBK populations of the four settlements Sittard, Stein, Elsloo and Hienheim on the one hand and their environment on the other have been discussed, we wish, finally, to cover a few points which have been raised by the study of the material.

One point concerns the usefulness of the reconstruction of the environment. In the first place, we still believe it was a sensible approach to zonate the environment for the purpose of the reconstructions. The reason is that in practice the study of the environment involves drawing maps which compels the choice of the size of the area to be drawn. As such a choice is made at the outset of the study, it can never be based entirely on facts. Our choice was made on theoretical considerations, and the radii of the zones were fixed at 10 km, 30 km and infinite. The 10 km and the 30 km were considered as maxima. We now wish to say something about the final value of the reconstructions, which have been based on this zonation.

The 10 km radius is indeed a maximum radius. The zone with the most intensive economic activity, which it should describe, appears in reality to have been much smaller. Besides, it need not have been circular. These two conclusions are the result of our locational analysis, which we intentionally placed at the end of our study. Although it might seem plausible to begin with a locational analysis, we consider that this is not possible without knowledge of at least some aspects of the environment. Thus, for example, one will have to know the neighbouring settlements. It is also possible to start with a partial analysis of the environment, to follow with a locational analysis, to complete the environmental reconstruction, to describe the relations between the inhabitants of the settlement and the environment and subsequently to adjust the locational analysis. However, the risk exists then that the area to be reconstructed is restricted too soon, that too little is reconstructed and that certain relations are overlooked. A disadvantage of our procedure is that perhaps too much is reconstructed. In order to see to what extent our study was too extensive and therefore irrelevant, we shall review the different aspects of the reconstructed environment within the 10 km radius. At the same time the contrary can be judged, namely if the reconstructions have been adequate.

Looking in the first place at the climate, we have been able to give a rather global reconstruction which is naturally not bound directly to the 10 km radius. The reconstructed differences with the present climate have been used in answering the question whether the dry valleys in the loess areas carried water continuously or not, in the discussion of the yield of the fields, in the search for an explanation of the elm decline in the pollen diagram of the Heiligenstädter Moos, and in the study of the location of the settlements. The reconstruction was adequate in these cases and apparently has presented few direct problems to the investigation. We feel that the climate, within the context of the relation settlement-environment, exerts its greatest influence on the yield of the fields. The fact that the yield could not be calculated is not only due to the absence of certain climatological details, but to the lack of other necessary data such as the quantity of sowing-seed used and the density of the weed vegetation on the fields. A modification of the reconstructed climatological data would at this moment imply only a change in the reconstruction of the watercourses in the dry valleys, which would influence nothing but the calculation of the distance between the settlement Elsloo and the open water.

The relevance of the reconstruction of the substrate is more questionable. The problem is related directly to the results of the locational analysis, by which the theoretical area with a radius of 10 km shrank to a real site territory of less than 100–200 hectare. One may wonder whether it was necessary to introduce details in the reconstruction of landscape units which eventually fell outside the area that is directly relevant to subsistence, at least as far as agriculture is concerned. The eolian sand area and the Jurassic limestone area may be cited as examples. That it makes sense to discuss the geology of the area within a 10 km radius, need not be argued, as only in such a description do the distinct landscape units begin to become apparent. Without a geological description, even the loess would not have been mentioned. We feel that there is certainly also sense in including the hydrology and the relief in the consideration. These aspects are of importance not only to the vegetation and the fauna, but they are also of relevance to communications and thereby to the contacts with neighbouring populations. The importance of a reconstruction of the soil profile is less evident. It has been of some consequence to the reconstruction of the vegetation, especially in the estimate of the tree growth on the Tertiary sands in Southern Limburg. As the relevance of this vegetation reconstruction is not great either, since the vegetation in question occurs only within the 10 km radius around Sittard and Elsloo, and even peripherally at that, the reconstruction of the soil profile could have been left out. The reconstruction of the profile in the loess deposits is the only reconstruction which, in retrospect, turned out to have been necessary, since the presence or absence of a clay illuviation zone is of importance in the judgement of the loess as a raw material for pottery and daub.

The reconstruction of the vegetation appears to have been far from adequate. This is felt especially in the determination of the location and the extent of the pastures and in the calculation of the area that provided the settlement with wood. Nor was it possible to say anything about the laying out and the location of the fields. Again one may wonder whether it was necessary to try and reconstruct an aspect, in this case the vegetation of landscapes that are not a loess or a river-valley landscape and therefore do not fall within the site territory. Still we think that these reconstructions are relevant. Without them we would not know whether any special commodities, such as grazing grounds, could be present in certain landscape units. Thus it is important to know that there were no moorlands yet on the sands in Southern Limburg. Had they been present, then they might have given reason to review our ideas concerning animal husbandry. We feel therefore that there is a potential loss of information if more extensive reconstructions of the vegetation were left out.

As the reconstruction of the fauna had to be based, as a result of the lack of well-conserved bones, for the greater part on the reconstruction of the substrate and the vegetation, it cannot be seen apart from the latter two. If, for instance, ideas on the composition of the vegetation change, then the reconstruction of the fauna will change accordingly. The reconstruction is hampered further by the fact, that we are poorly informed about the natural density of game. This obstructs a sound judgment of the hunting potential. We feel, by the way, that it also makes sense with respect to the resources for hunting and gathering, to look beyond the limits of the site territories which, perhaps, are defined only by agricultural activities.

Establishing the fact that the settlements were not isolated, but had neighbours, has been of great importance to the analysis of the location of the settlements. More details would have been welcome for this analysis. We were not able to give more than a rough and probably far too wide estimate of the distances between the settlements. In the ideal case it is essential to locate all settlement areas, with their population and the period during which they were occupied. So the reconstruction was certainly relevant, but again too many details were lacking.

We think that we have now answered the question whether the reconstructions within the 10 km radius were purposeful and adequate. The procedure followed indeed led to the reconstruction of too many factors, especially with respect to the soils.

The second theoretical zone, that with a limit of 30 km outside the settlement, appears to elude any appraisal of its real value. As was noted in chapter V p. 147, our study is still too restricted in scope for that. The only aspect which was examined more closely was the possibility of contact with neighbouring populations. The reconstruction appeared to be of significance in the search for the origin of adzes and was, in that respect, adequate.

The third zone describes the environment outside the two defined zones and has been included because it should not be assumed a priori that the environment beyond the 30 km radius would be completely without importance. Indeed that was not the case. The zone provided at least two categories of objects or materials, namely adzes or rock for adzes, and paints.

In conclusion, it can be stated that the environmental reconstruction indeed provided data, which were of use in the investigation of the relations between the inhabitants of the settlements and their environment and in this sense proved valuable, though it has also become clear that the information gleaned is far from sufficient. In chapter I it was pointed out that a reconstructed environment cannot be described with the accuracy that can be reached in the description of a recent environment. This lack of precision has manifested itself clearly.

In chapter II we warned against considering the four examined settlements Sittard, Stein, Elsloo and Hienheim as a random sample from the total of LBK settlements. They could, however, be compared mutually. The comparison might give reason to signal characteristics that might be of general validity within the LBK culture. This might be checked by means of a real test. Since we repeatedly made comparisons in the preceding chapters we can now attempt to establish whether indeed certain of the aspects noted could be of wider application. For this purpose the similarities and differences, which emerged from the investigation will first be enumerated.

In as far as can be established, the similarities are the following. The settlements Sittard, Stein, Elsloo and Hienheim are characterized by the same type of location, one which is determined by the presence of a loess area and a watercourse. The loess area and the valley of the watercourse were forested with a deciduous forest when the respective settlements were founded. The fauna living therein included, among other species, red deer, roe deer, wild boar and aurochs. The inhabitants provided in their subsistence by agriculture and animal husbandry. These activities were more important than hunting and gathering. The cultivated plants included at least emmer, einkorn, pea, lentil and linseed, grown on small fields laid out in the forest. The live-stock consisted mainly of cattle but there were also pigs, sheep and goats. The cattle were not kept in stables. The wild cattle from the surroundings of the settlement were used to supplement the live-stock. The area necessary for subsistence activities, at least for agriculture, cannot have been larger than 100 to 200 hectare and was probably smaller. The inhabitants of the settlements obtained not only food, but also raw materials from their environment. The raw materials found in Sittard, Elsloo and Stein are in no way distinguished from one another. The inhabitants of Hienheim used exact equivalents. In as far as could be established, the majority of the raw materials seems to have come from the surroundings of the settlements. Clear exceptions are adzes and paints. These must be considered as imports.

Besides these similarities, it was considered that certain differences, could, with reservation, be identified. These are related to agriculture and stock-breeding and are more of a quantitative than of a qualitative nature. It is possible that the inhabitants of Sittard, Stein and Elsloo grew the crops in different proportions than the inhabitants of Hienheim. In IV.2 the possibility was mentioned that less live-stock was kept in Hienheim than in the settlements in Southern Limburg. However, this is not certain, as the evidence is far from adequate. It consists in fact of the observation in Müddersheim, which was the model for Sittard, Stein and Elsloo, and of the poorly conserved bone material from Hienheim. However, we do not wish to exclude the existence of regional variations, the more so because the environment of the settlements shows some differences besides the obvious similarities.

In III.7 two differences were mentioned. The first is the difference in climate between Southern Limburg on the one hand and Hienheim on the other hand. The climate would have been more continental in the Hienheim area. Such a difference could have influenced agriculture. Perhaps the possibility, mentioned in IV.2, of a regionalization of the agriculture had something to do with climatological factors, but this is not clear at the moment.

The second divergence between the regions is the difference in landscape. The surroundings of Hienheim are characterized by partly other substrates than in Southern Limburg. It is conceivable that this difference exerted an influence on the cattle-breeding potential. Also the distribution of the substrates over the area has a different nature, because they do not occur in continuous stretches. The question is to what extent this variation influenced the relations between the inhabitants of the settlements and their environment. We feel that this effect was limited. Even where the extent of the landscape units had any economic significance, they are generally not smaller than the size of a site territory. The relatively small size will therefore have had little influence. In this statement we are aware of the fact, that we have used the size of the most relevant unit, the extent of the loess, to estimate the size of the territory, so that this statement is in a way based on a circular reasoning. Nevertheless we feel that the dissection of the landscape units around Hienheim could have affected the relations between the population and its environment in only one respect: the difference with Southern Limburg may have been noticeable in the contacts with neighbouring settlements. Sittard, Stein and Elsloo lay in a spacious landscape with, it seems, many neighbours. Hienheim gives the impression of having been somewhat more isolated.

From the above it is clear that more similarities were observed than differences as far as the relations between the inhabitants of the four settlements and their environment are concerned. It appears that the general validity of most similarities has already been tested. In chapter V we called the location of the settlements "classical". Indeed it has been demonstrated many time already, that the presence of a loess area (or an equivalent substrate) and of a watercourse have been determining factors in the choice of a settlement site. The fact that the surroundings were forested has often been discussed (see e.g. III.4 p. 40). The importance of agriculture and animal husbandry is nothing new either (see IV.2 p. 77). The species of plants and animals which were the basis of agriculture and stock-breeding have been demonstrated repeatedly in a LBK context. The following aspects should, however, be submitted to further confirmation. The first aspect concerns regional differences in agriculture. We gain the impression that these are real, but the number of studies published is insufficient for really well-founded statements. The second aspect relates to the size of the fields. The hypothesis as to their small size is based on observations from one region only. The third aspect is the relation between the composition of the live-stock and the environment of the settlement. Although Müller finds it unlikely, it is conceivable that the natural vegetation has something to do with the number of live-stock and the animal species that were kept (Müller 1964 p. 63). In the fourth place we should like to know whether the idea elaborated in IV.4 p. 120

regarding the origin of raw materials is generally valid. It should be investigated more particularly whether querns are local in origin, cherts were transported over medium distances, and adzes came from distant places. It should be possible, by systematically gathering data, to make more generally valid statements concerning these four aspects.

This study was announced as a case study in human paleoecology. It was an attempt to establish just how completely the relation between the inhabitants of Sittard, Stein, Elsloo and Hienheim and their environment could be described. The result is a description that mainly illuminated relations of an economic nature, only a segment of the interactions which must have existed in reality. Two reasons can be given for this limitation. One of them is that an important relation, namely the influence of the inhabitants on their environment, to a great extent eludes description because the necessary data are lacking. A complete analysis of the interaction between settlement and environment was therefore impossible. The second cause is our own lack of knowledge about the structure of the relations between people and between population groups. Consequently it was not possible to discuss the relations between neighbouring populations. Thus the result of our study has remained relatively one-sided.

APPENDIX I

POLLEN DIAGRAMS

For the purpose of reconstructing the environment around the settlement Hienheim, we made two pollen diagrams: one of the Heiligenstädter Moos and one of the Grosse Donaumoos. The diagrams are included in the enclosure which belongs to this publication. The description of the sampling sites, profiles and diagrams is given below.

THE HEILIGENSTÄDTER MOOS

The Heiligenstädter Moos (48°48'N, 11°47'E, 349 m above NN) is situated in the valley of the Donau river, just east of Neustadt a.d. Donau and adjacent to it. The fen covers a surface of 65 ha in the Holocene river valley. The western, southern and eastern limits of the deposit are formed by the terrace edge of the Late Pleistocene Lower Terrace. The situation of the fen between the surrounding settlements is shown in figure 21. The map is a simplification of a sheet of the geological map of Bayern 1:25000 No. 7136 Neustadt a.d. Donau (Schmidt-Kaler 1968). The same figure includes a profile through the peat, which has been taken from figure 27 of the explanation of this geological map. The profile was made by Laforce and Karglseder. It is obvious that the Heiligenstädter Moos is not a continuous entity, but consists of a series of channels which are filled up with organic deposits. We are undoubtedly dealing with abandoned river channels. According to Laforce and Karglseder, the river channels were filled up mainly with Carex-Phragmites peat, which changes downwards into calcareous gyttjas or into lake marl (Laforce and Karglseder, quoted in Hohenstatter and Vidal 1968).

The fen is drained superficially by a system of ditches. About two thirds of the surface are used as hayfield. There are also a few fields where maize and potatoes are grown. The rest is covered by a waste of shrubs and tall herbs: the remains of a fen carr. Rather large quantities of peat were cut in the past. This activity continues up to the present day.

As the Heiligenstädter Moos lies relatively close to Hienheim, namely at 8 km from this place, this fen was selected as the first site for palynological investigation. According to Dr. E. Hohenstatter, such an investigation had not been conducted before (Hohenstatter 1970, written information). For the sampling we selected the deepest channel found by Laforce and Karglseder. Of course this choice is arbitrary; we could not know beforehand which channel would contain sediments from the period we are looking for.

The sampling was done with a Dachnowsky corer. Figure 21 shows the point where the sample was taken. The series of organic deposits turned out to be 545 cm thick at the chosen spot. The stratigraphy is as follows:

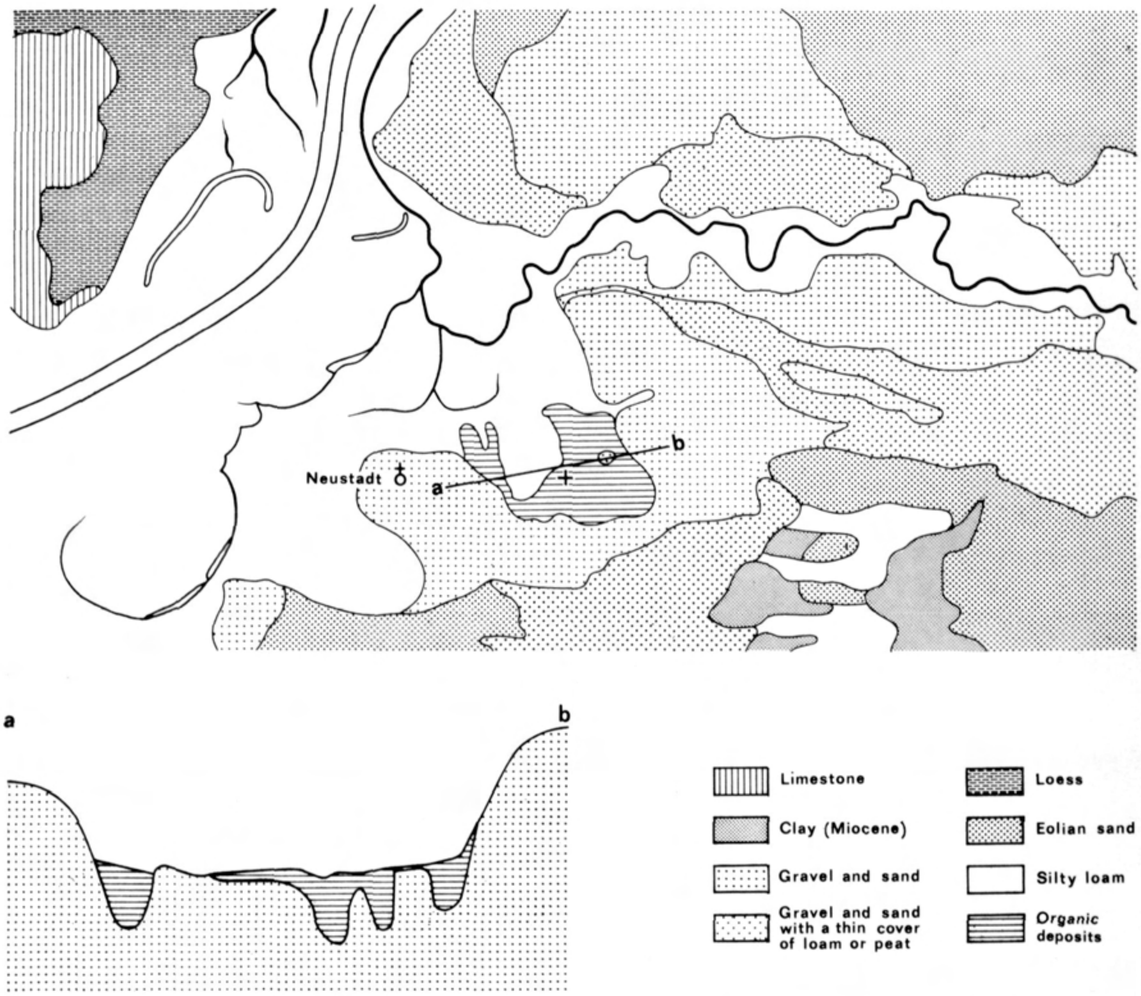


Fig. 21. The Heiligenstädter Moos: position, surroundings and section. The cross indicates the place of sampling. Map, scale 1:50000; section, horizontal scale 1:20000 verticale scale 1:400.

cm	
0– 30	amorphous peat with some sand
31–244	Carex peat with occasional Phragmites fragments becoming more numerous at base; Carex utricles and nuts; Menyanthes seeds; gradual transition to
245–287	swamp peat with a few molluscs (fragments and complete specimens); Cladium nuts; Menyanthes seeds; a piece of Salix or Populus wood; gradual transition to
288–324	complex of peat and calcareous gyttja; molluscs (fragments and complete specimens); gradual transition to
325–367	calcareous gyttja with molluscs (fragments and complete specimens); Menyanthes seeds; Potamogeton natans fruitstones; gradual transition to
368–474	calcareous gyttja with molluscs (fragments and complete specimens); at circa 405 cm a Potamogeton natans fruitstone; gradual transition to
475–545	lake marl
546–558	sand and gravel

It should be noted that the deposits between 245 and 545 cm contain a little mineral material. In the laboratory the core was cut into slices of 1 cm thickness. Each tenth cm was reserved for further analysis. Thus the distance between the analyzed samples is rather great. When the diagram was elaborated, it appeared that the curves of the different pollen types show a relatively stable course. We think that a sampling at each five centimeters or at each centimeter would not essentially change the course of the curves. In our opinion, an ample distance between the samples is sufficient in the case of the Heiligenstädter Moos to reach the goal set: a reconstruction of the vegetation in the surroundings of the fen.

The samples were treated subsequently with 10% KOH, 18% HCl, acetolysis and bromoform-alcohol sp. gr. 2.0. The conservation condition of the pollen turned out to be excellent.

We chose an upland pollensum for calculating the curves in the pollen diagram. This pollensum comprises all plants which grew outside the fen. The criteria for the classification of the plants are based on the recent habitat of the species that were retrieved. As we deal with older deposits, this method becomes more and more unreliable. In this respect we fully agree with the remark made by Janssen in a 1970 article (Janssen 1970): "One may ask whether the recent ecologic groups existed in the same way in the early Holocene." After enumerating arguments against such a hypothesis, Janssen arrives at the following conclusion: "All in all the conclusion must be that the use of pollen types as indicators of vegetation types works for the later part of the Holocene with a flora not too different from the present one. Before the Atlantic period the application of the present ecological tolerances may be of doubtful value." (Janssen 1970 p. 194). As we make the diagram in order to learn about the vegetation during the Atlantic and as the deposit starts in the Atlantic, as will appear further on, we think that we may use an upland pollensum. In the composition of the pollensum, we have left out of the sum all pollen types that might have originated from wet, eutrophic and mesotrophic locations, up to and including the Alnetum glutinosae and its seral communities. Plants from the Alno-Padion, in as far as not belonging to afore-said category, were kept within the sum. We have taken the data concerning the habitats of the plants in question from Bodeux and from Oberdorfer (Bodeux 1955, Oberdorfer 1970). Of course, the classification often presents problems. The pollen of the Cerealia-type was included in the pollensum, because the large numbers in the top of the profile originate from Secale. But as far as the rest is concerned, it is not clear which grass species provided the pollen. It could be Glyceria pollen, in which case the pollen type would not belong in the upland pollensum. Viscum is usually kept within the sum. We, however, left this pollen out of the sum, because Viscum can also occur on Salix. Hippophae has been left out of the sum, because we assume that this shrub was the pioneer on sand- and gravel-flats at the time that the meanders were abandoned by the river. The pollen of Hippophae namely occurs only in the bottom of the diagram. It is true that the shrub cannot have stood on the sampling place, because this lay under deep water at the time, but it could have grown in its immediate vicinity.

The zonation of the diagram is based on changes in the curves of the upland pollen. The most important of these curves are included in the main diagram. As the course of the curves, and more particularly the course of the tree pollen curves, shows a clear similarity with the curves in other South German diagrams, we feel that we should not introduce a numbering of our own in the nomination of the zones, but rather use the zonation by Firbas. However, we have placed a capital H before the Roman numerals. This will be explained later. The zones in the Heiligenstädter Moos are defined as follows:

H VI	Betula, Corylus, Quercus, Ulmus and Tilia have constant values. The curves of Fagus, Picea and Pinus are discontinuous. Abies is absent. A C14 date of 8000 ± 210 B.P. (GrN-7139) falls within this zone.
Boundary H VI-H VII:	First increase of Pinus, Picea and Fagus, strong decline of Ulmus. The boundary has been dated at 6250 ± 110 B.P. (GrN-7541).
H VII	Betula and Corylus have constant values, though slightly lower than in H VI; *Quercus and Tilia also have constant values, though slightly higher than in* H VI. Fagus and Picea are constantly present in low values. The curve of Abies is discontinuous.
Boundary H VII-H VIII:	The boundary is not sharp, it lies somewhere between pollen spectra 301 and 331. In the diagram a line has been drawn at the second increase of Fagus. This has been done because in many other diagrams the curve of Fagus is used to indicate the zonation. The second increase of Picea and Pinus takes place somewhat earlier. Abies becomes continuous slightly later. Tilia declines strongly at the same time as the increase of Picea and Pinus, an event dated by C14 to 5495 ± 65 B.P. (GrN-7140).
H VIII	Betula, Corylus, Quercus, Ulmus and Tilia are present in much lower percentages than in the preceding periods. Pinus, Picea and Abies show a maximum. Fagus continues to increase. Carpinus occurs for the first time.
Boundary H VIII-H IX:	Strong expansion of pollen of the Cerealia-type, which here belongs entirely to Secale. This is combined with a strong expansion of Plantago lanceolata and Chenopodiaceae. Pinus, Picea, Abies and Fagus decline.
H IX	This zone is characterized by distinct influences of human activity.

For zones H VI and H VII the correspondence with the zonation by Firbas is satisfactory. However, the boundary between H VIII and H IX and the description of H IX are different. The period Firbas IX is characterized by a constant, high percentage of Fagus pollen. In the Heiligenstädter Moos the continuous rise of the Fagus curve towards the maximum (the characteristic of Firbas zone VIII is interrupted by a series of phenomena which we interpret as deforestation. We think that the Fagus expansion in the area near the Heiligenstädter Moos could not reach its maximum, because the area was too densely populated by then. Firbas zone IX is considered generally to comprise, among others, the La Tène period and the Roman Age. The very large oppidum Manching at 20 km west of the Heiligenstädter Moos and the oppidum at Kelheim at 12 km north-east of the fen, date from the La Tène period. The inhabitants of the oppidum at Kelheim were concerned with the extraction and processing of iron-ore (Schwarz, Tilmann & Treibs 1965/1966). In addition to these two large centres, we know of occupational traces of minor extent from the La Tène period. For the Roman Age, suffice it to say that the Limes Rhaetica starts near Hienheim. Therefore traces of the Roman Age are predictably numerous. Remains of Roman buildings can be found, among other places, in Bad Gögging, at a distance of 1.5 km from the Heiligenstädter Moos.

Much wood was undoubtedly needed for human activities during the said periods. We assume, therefore, that the usual criterion for the nomination of zone IX cannot be applied in this area. To illustrate the deviation from the standard zonation, we have placed a capital H before the Roman numerals, which indicates that we are dealing with a local zonation.

As mentioned above, the Heiligenstädter Moos consists of a series of curved, long and relatively narrow sedimentation basins. We assume that these elongated lakes were not filled up simultaneously. In our opinion, the basin in which our pollen landed did not cover 65 ha, which is the recent extent of the fen, but a much smaller area. The width of the filled-up channel is circa 100 metres. We therefore consider the original ox-bow lake as one of the small lakes in the sense of Tauber. This means that Tauber's effective area, that is the area from which 80% of all pollen originates, has a radius of 300 to 1000 metres (Tauber 1965). There are two types of substrates within this area: the Holocene river-valley of the Donau and the Late Pleistocene Lower Terrace of the Donau and its tributary the Abens. The former consists of fine sandy sediments which are rich in nutrients, and was flooded more or less regularly by the river until recently (see p. 23). In the vicinity of the fen the latter consists of quartz sands and gravels, which are poor in loam and nutrients; moreover, it belongs to the dry part of the Lower Terrace (see p. 42). We expect that the upland pollen originates mainly from these two substrates. Further, a part of the pollen will have come from some distance, carried by the wind, but initially perhaps also by river-water, since the deeper sediments show an addition of mineral particles.

The beginning of the filling up of the channel has been established by a C14 date at 8000 $\pm$ 210 B.P. (GrN-7139). The large error is due to the low suitability of lake marls for C14 dates (Mook 1974, written information). The beginning falls in our zone VI which, as far as the curves of the tree pollen and more particularly the low presence of Fagus is concerned, is comparable with Firbas zone VI. It is generally assumed that this period lasted from circa 7600 B.P. to circa 6000 B.P. (amongst others mentioned by Janssen 1974 figure 30). Since zone VI is a biostratigraphic unit, it need not start or end everywhere at the same time. The fact that our date is on the early side, allows no more than the conclusion, that zone VI began early at this place.

The vegetation of the surroundings of the Heiligenstädter Moos is dominated by deciduous trees during zone VI. Besides, there are shrubs, but in very low percentages. They are: Crataegus sp., Rhamnus cathartica, Ligustrum vulgare, Cornus sanguinea, Viburnum sp. and Sambucus nigra. The herbs that could be considered as forest flora are small in number. They are: Pulmonaria sp., Adoxa moschatellina, Pleurospermum austriacum and Melampyrum sp. The other upland herbs belong to vegetations of clearings. It is conspicuous that the Rumex acetosa type, Artemisia and Chenopodiaceae are predominant among the herbs. These plants are usually related to human activities. In our case one could think of the influence of a Mesolithic population, but in our opinion it is not necessary to attribute the presence of "ruderal plants" in the diagram to man. It is possible that the plants grew on spots that were kept open by animals. The size and the position of the clearings cannot be given.

The percentage of herbs is so low that we may assume that the surroundings of the ox-bow lake which was being filled up, were covered with dense forest, apart from the above-mentioned open spots which cannot be defined more precisely. It is difficult to distinguish between the vegetation of the river-valley and that of the dry sand area. The identified shrubs and the herbs Pulmonaria, Adoxa and Pleurospermum, however, only grow on soils with a certain loam content, richness in nutrients and sufficient moisture. We assume for that reason that they were present in the river-valley. They may have been part of a vegetation that we would class nowadays in the Alno-Padion. All trees belonging to zone VI possibly fit in such river-valley forests. It seems possible to us that the different forests which are considered to belong to the recent Alno-Padion, existed already in this period, and grew in the Donau valley. It is conspicuous, however, that little Fraxinus pollen was retrieved. This tree accounts, at least nowadays, for a considerable part of the forest population in a river-valley. Fraxinus should be represented reasonably in a diagram like that of the Heiligenstädter Moos, even when the bad distribution of the pollen is taken into account. We wonder therefore whether the ash had an important share in the river-valley forests. If this was not the case, the Alno-Padion was different from nowadays.

The vegetation on the high sand and gravel area of the Lower Terrace cannot, as far as we can see, be reconstructed from the diagram. We can imagine that the Betula pollen, a part of the Corylus and Quercus pollen and perhaps also some Tilia pollen had their origin in this area. Pinus is absent in this vegetation. At least we see no reason in the discontinuous Pinus curve to assume that this tree occurred locally.

During zone H VII the vegetation remained about the same as in zone H VI. The only conspicuous difference is the percentage of Ulmus pollen. The elms decline rapidly at the transition from H VI to H VII. We are certainly not confronted here with the classic phenomenon, because that is dated between 5800 and 4500 B.P. with a climax around 5100 B.P. (Godwin 1961, Sims 1973). The Ulmus decline in the Heilgenstädter Moos took place at a much earlier period, set by a C14 date at 6250 $\pm$ 110 B.P. (GrN-7541).

We tried to find out which elm species was responsible for the decline. For that purpose we examined a series of elm species by means of a scanning electron microscope, namely: Ulmus carpinifolia Gled. (two origins), Ulmus glabra Huds. (two origins), Ulmus glabra Huds. exoniensis and Ulmus laevis Pall.* Unfortunately it appeared to be impossible to point out differences between the pollen of the examined species. Neither was it possible to divide the subfossil pollen from before the Ulmus decline into groups; mutual differences are practically absent. It is not very clear either by which tree Ulmus was replaced; it could have been Quercus. The interpretation of the sudden elm decline also presents a problem. We see no reasons to explain the phenomenon as a result of a change in the local edaphic conditions. None of the other species from the Alno-Padion show a comparable reaction and the local vegetation does not show changes either. Any evidence for possible fluctuations in the width of the riparian zone (see p. 161) is absent precisely in that part of the diagram where the Ulmus decline occurs. Besides an edaphic cause, a climatological reason could be considered. The elm decline coincides with a pollen zone boundary which

* A part of the examined pollen was gathered for us by Ir. H.M. Heybroek of Wageningen.

is characterized by the first increase of Pinus, Picea and Fagus. Everywhere in Southern Germany the increase of Fagus is used to indicate the zone boundary VI-VII (Firbas 1949), but the phenomenon has never been connected with a climatological change. Moreover it has been observed nowhere so far that the coming of the beech coincides with the disappearance of the elm. The decline appears to be a local event. Therefore we consider a climatological explanation not very acceptable for our elm decline. We do not wish to engage in a discussion about a third possibility: an elm disease, because evidence thereof is very hard to find. On the other hand, we do wish to discuss a fourth cause: we mean the influence of certain human activities. It appears, namely, that the elm decline in the Heiligenstädter Moos coincides more or less with the beginning of the Neolithic occupation of the area concerned. The oldest C14 dates available at the moment for this occupation are 6155 ± 45 B.P. (GrN-7156), 6235 ± 45 B.P. (GrN-7557) and 6220 ± 45 B.P. (GrN-7558) from the LBK settlement at Hienheim. Although the coincidence might be chance, we think now that intervention by man is the most plausible cause of the rapid elm decline. Of course, the correlation between the first Neolithic inhabitants and the elm decline will have to be observed in more places in Southern Germany, before a real relation can be spoken of. We refer to p. 76 and to p. 77 for a further discussion of the elm decline.

After zone H VII there are major changes in the pollen assemblage which reached the Heiligenstädter Moos. The first changes start at a level which has been dated by C14 to 5495 ± 65 B.P. (GrN-7140). Ulmus and Tilia have become rare; the numbers of Betula, Corylus and Quercus drop rapidly. On the other hand, Pinus, Picea, Abies and Fagus increase strongly. But Abies is present in such a low percentage that we wonder whether the tree occurred locally. We think that the Abies pollen was carried by wind from a place rather far away. Transportation by river water is impossible; at least the sediment at this level no longer shows mineral particles which could indicate that the fen was flooded regularly. Picea is also present to a moderate extent only, but this tree could have stood in the vicinity. The values in which Pinus and Fagus occur indicate that these two trees were of importance in the vegetation. We assume that both grew outside the river-valley and replaced Betula, Corylus, Quercus and Tilia there. At least we cannot imagine that Pinus and Fagus were present in the relatively wet river-valley. Usually, both trees are represented poorly on more or less regularly flooded places and on places that are influenced strongly by the ground-water. We think that the growth conditions in the Holocene river-valley were still favourable for an Alno-Padion.

Although Pinus and Fagus stood, in our opinion, on the higher places, we do not assume that they were part of one and the same forest. We may visualize the beech growing on the drier parts of the Lower Terrace, whereas the pine stood further away on the eolian sands. The limit of these eolian sands is at a distance of 1 km from the sampling point. Pollen that originates from a distance of 1000 metres, and certainly Pinus pollen, can be found in large quantities in small basins (Berglund 1973). We think indeed that the percentage of Pinus pollen reflects to some extent the influence of the eolian sands around the Abens. These sands are covered nowadays with a pine forest (see p. 41), which has been described extensively by Hohenester (Hohenester 1960). If our opinion is correct, this means that the present pine forests did not develop until the beginning of zone H VIII, therefore around 5400 B.P. Anyhow, they were not present yet during zone H VI, since the Pinus curve would then have been continuous.

The influence of man begins to show in zone H VIII. The curve of Plantago lanceolata becomes continuous half-way through the zone. We do not wish to attribute a special significance to the few pollen grains in the preceding zone. They could belong to the open spots already mentioned. Nor do we wish to emphasize the presence of two Plantago media or P. major pollen grains. In agreement with Groenman-

Van Waateringe, we think it risky to interpret such sporadic presences as human influence (Groenman-van Waateringe 1968).

To what extent man was responsible for the change in the composition of the forests, cannot be said. The really major interventions are not found until zone H IX. This zone is characterized by the decline of all tree pollen curves, with the exception of Betula. Betula usually profits by the light which becomes available when shadow-casting trees are cut. Moreover, the tree grows quickly in open spaces. The curves of a large number of herbs rise steeply during zone H IX. This phenomenon can also be observed in the diagram of the "local" and "ecologically indeterminable" pollen types. These categories apparently include species which were favoured by man. Particularly Plantago lanceolata, Chenopodiaceae, Compositae, Umbelliferae and Cruciferae propagate themselves rapidly. Moreover, the first crop plants, Secale and Cannabis, are observed in zone IX. All Cerealia type pollen belongs to the Secale type. We suggested already that zone H IX with its large scale deforestation would coincide with the La Tène Period or the Roman Age. Unfortunately this suggestion cannot be supported by means of a C14 date, because the peat layer in the top of the sediment contains too many roots. Unfortunately there are no younger peat layers from which the mediaeval vegetation history might be deducted. Perhaps they were removed by the cutting of peat.

The diagram of the local pollen types of course shows only the strictly local vegetation history. The curves with parallel courses were placed beside each other, and were arranged according to the habitat of the plants in question. In this way we obtained stratigraphic-ecological pollen groups. On the basis of the diagram drawn in this way, we reconstruct the history of how the ox-bow lake was filled up as follows:

Initially the water was too deep to enable the growth of higher water plants. The local pollen types, which occur in the bottom of the diagram, are not local in the very strict sense, but originate from the bank of the basin. We assume that there was a belt of alder and willow around the lake. Dry sand- and gravel-flats were covered with a Hippophae-brushwood. The cross section of the lake shows clearly that the riparian zone cannot have been very wide: the slopes are very steep. This could also explain the initial absence of a reedbelt with the tall plants, such as Sparganium, belonging thereto. At a somewhat later stage, namely around spectrum 31, this belt is observed for the first time. At the level of spectrum 61, the lake was filled with lake marl to such an extent that Myriophyllum spicatum or M. verticillatum could begin to grow in the lake. Myriophyllum spicatum occurs in waters of 1–5 m deep and M. verticillatum in waters of 0.5–3 m deep (Oberdorfer 1970). We are dealing probably with M. spicatum, because this plant is more common than M. verticillatum in calcareous water. Since the sediment is calcareous, the water must have been calcareous too. In addition to Myriophyllum, we have found a few grains of Nymphaea and Nuphar. These few grains could have been carried in by river water during inundations. But it is also very well possible that Nymphaea and Nuphar grew on the spot. The seed of Potamogeton natans was found twice at the same level, although the pollen of this plant has not been observed. Nymphaea, Nuphar and Potamogeton, together with Myriophyllum, may have belonged to a syntaxon from the Nymphaeion Oberd. 1957 em. Neuhäusl. 1959. These plant communities occur nowadays in eutrophic waters of 0.5–3 m deep which are sheltered from the wind, a description which entirely fits our picture of the Heiligenstädter Moos in the period concerned. Algae from the genus Pediastrum apparently also do well in this quiet water, considering the remains found.

From spectrum 171 on, riparian plants, with, however, the exception of Alisma and Sagittaria, begin to manifest themselves again. For one reason or another they were observed only in small numbers for a while. We shall return to this later. The plants of open water are replaced gradually by Equisetum (E. fluviatile?), Potamogeton sp., Sparganium sp. and Typha latifolia. When these plants became predominant, the lake had a depth of 250 cm at the most. We can imagine that the lake had become overgrown with plant communities which must be considered as belonging to the Phragmitetalia W. Koch 1926 em. Pignatti 1953 denuo em. Segal et Westhoff.

Finally the reed-swamp passed into a sedge-fen. Simultaneous with the rise of the Cyperaceae-curve, we found Cladium mariscus seeds. The pollen of this plant was also observed frequently. As Cladium occurs together with Menyanthes trifoliata, Monoletae (with, among others, spores of Thelypteris palustris), Lysimachia vulgaris type (to which belongs Lysimachia thyrsiflora, among others) and Rubiaceae (Galium palustre), we could be witnessing the beginning of the sedge predominance with a Cladietum marisci (Allorge 1922) Zobrist 1935. Later the Cladium-swamp probably passes into other associations of the Magnocaricion W. Koch 1926. The nature of the sediment changes at this level. The gyttjas pass gradually into Carex-peat with an addition of Phragmites.

However, there is something conspicuous in this transition zone, which does not fit in the succession Nymphaeion – Phragmitetalia – Magnocaricion, namely a temporary expansion of the alder carr between spectra 251 and 301. It would seem that the zone with alder and willow extended itself almost to our sampling site. Salix (c.q. Populus) wood has been found at this level. At a later stage, the belt seems to contract again: at least, far less pollen grains of this vegetation are found. A temporary change of the water-level could be the cause. Besides, the diagram gives us the impression that the width of the riparian zone has been subject to several more changes. The zone seems to have been very narrow between spectra 121 and 251. Between 131 and 171, even riparian plants as Sparganium are absent. Also after the major extention, that is after spectrum 301, the belt seems to narrow first, then to widen, and then to narrow again. When the Alnus-curve increases, the Cyperaceae-curve decreases, and vice versa. A large number of herbs fluctuate together with the Alnus-curve. This could mean that the alder forest was not very dense, but had numerous clearings. A number of the herbs found belong to the normal undergrowth of the Carici elongatae-Alnetum W. Koch 1926 em. R.Tx. et Bodeux 1955. But there are also herbs which are not listed by Bodeux, such as Compositae non Cirsium, Sanguisorba officinalis and Polygonum bistorta (Bodeux 1955). These plants are found in wetter or drier grasslands. We assume therefore that around the lake, later fen, there were a number of grasslands between wet and dry. These spots belong perhaps to the same phenomenon as the open spots on the dry grounds, which were found in the upland pollen. It is possible that beavers were responsible for the open spots.

Not only pollen, but also molluscs give indications of the local environment in the Heiligenstädter Moos. The molluscs which appeared during the treatment of the peat- and gyttja-samples, have been gathered and identified by W.J. Kuijper. He writes about these molluscs: "The finds comprise the following species: Valvata cristata Müller, Valvata piscinalis (Müller), Bithynia tentaculata (L.), Physa fontinalis (L.), Radix peregra (Müller), Planorbis carinatus Müller, Anisus vorticulus Troschel, Gyraulus albus Müller, Gyraulis laevis Alder, Armiger crista (L.), Segmentina cf nitida (Müller), Acroloxus lacustris (L.), Pisidium sp. and the land snail Succinea sp. The largest numbers are at circa 290–350 cm beneath the surface. As the size of the examined samples was only a few cm^3, no more than a few dozens of specimens were found. The fauna which lived here, was undoubtedly richer in species. Above species indicate that the sedimentation took place in still, clear, freshwater with much vegetation. The depth of the water cannot be reconstructed through the species found, but most of the above-mentioned animals do not survive a drying-out of their habitat, even if this is temporary, so that a very shallow water is not possible. A land snail of wet terrain (Succinea sp.) occurs in the entire shell-containing part of the sediment. This proves that there was always a bank nearby" (Kuijper 1975).

The results of the malacological analysis are in agreement with those of the pollen analysis. The level with the most abundant mollusc remains falls within our Nymphaeion: a plant community that also points to still, clear freshwater. According to Kuijper, species that are characteristic for this environment were not found, probably because the size of the sample was far too small.

As was to be expected, the vegetation in the former lake developed entirely independently of the vegetation on the dry grounds. The only zone boundary found back in the local pollen as well, is the boundary H VIII – H IX. The human influence apparently extended itself beyond the edges of the fen. The observed hydrosere passes through the sequence which is normal for this type of basins: predominantly open water, floating-leaved macrophytes, reedswamp, fen. The fen carr stage, if reached, could not be observed, probably because a part of the deposit is missing. In the Heiligenstädter Moos too it appears that "The essential nature of the autogenic sequence seems not to have changed throughout the Postglacial" (Walker 1970 p. 137).

THE DONAUMOOS

The Donaumoos (48°42′N, 11°15′E, ± 380 m above NN) is also called the Grosse Donaumoos, to distinguish it from the Kleine Donaumoos near Günzburg. It is a vast fen that covers circa 18000 ha south-west of Ingolstadt. The peat deposits developed in a funnel-shaped basin orientated from the south-west to the north-east. The "stem" of this funnel is located near Pöttmes (Ldkr. Aichach), the "mouth" merges into the valley of the Donau. As is shown on a peat depth chart from 1900, the thickest peat deposits are found in the "stem" and in its forward extention. The surroundings and the subsoil of the peat consist mainly of loamy sands, sandy loams and clays of the Upper Miocene freshwater Molasse (Schmid 1969). At the west side of the fen, a few patches of loess-loam are found on top of the Miocene deposits. To the north, there where the basin merges into the Donau valley, the fen is not adjacent to Molasse deposits, but to deposits of the Lower Terrace of the Donau.

According to Schmid, the Donaumoos-basin developed under the influence of a big river: "The south-west to north-east orientated funnel-shape of the Donaumoos-basin and the ± 100 m difference in altitude between the basin and the Tertiary hills west of the basin, allow no other conclusion than that the downcutting of the Donaumoos-basin was caused by a mighty river system" (Schmid 1969 p. 228 our translation). The valley would have developed in the Early Pleistocene. Schmid thinks that the Donaumoos-basin represents perhaps the former course of the Lech river. It is strange, however, that no river gravel was found at the base of the peat (Schmid 1969 p. 229), but the gravel deposited by the Lech could be buried by solifluction material during the Würm ice age. The Lech would have left the valley before the last ice age. The funnel-shape of the basin would have been emphasized by solifluction phenomena. During the Würm ice age the basin was closed at the north side by the deposition of gravel by the Donau. The dam of terrace material built in this way disturbed the drainage of the basin. According to Schmid, the edaphic conditions were already favourable for peat formation in the last stages of the Würm ice age. "The peat formation (Quellmoor) which with certainty started already in the Late Glacial and which continued until recently, was interrupted only in 1790 by the drainage started under Kurfürst Karl-Theodor" (Schmid 1969 p. 230 our translation). The Donaumoos has been reclaimed systematically since 1790.

Before the reclamation the fen consisted of a landscape dominated by tall sedges and willows, which was so wet that even in normal summers it could not be used as hayfield (von Aretin 1795). Spöttle writes that already before 1790 attempts were made to improve the drainage, but these were not very succesful (Spöttle 1896). Since 1791, however, the area has been drained permanently. It is used mainly as arable. The reclamation caused a considerable lowering of the surface. The level of the fen at Ludwigsmoos, where there is a gauge, has dropped 300 cm in the last 175 years. 100 cm of this difference in altitude must be attributed to peat-cutting, the remaining 2 metres are caused by compaction and wind erosion. Nowadays, compaction and wind erosion still have a strong influence. In a 1932 dust storm, 5 cm of the dried-out and pulverized peat disappeared within 24 hours (Seithz 1965 p. 18). For the future, a loss of level of 1.5–2.0 cm per year is taken into account (Scmid 1969 p. 224).

Paul tried in 1939 to make a pollen analysis of the Donaumoos. This attempt failed because the pollen turned out to be too corroded (Seitz 1965 p. 14). No attempt has been made since to examine the fen by means of pollen analysis (Hohenstatter 1972, written information). As the fen lies next to loamy deposits, which are somewhat like loess in as far as their potential vegetation is concerned (Seibert 1968), and as we failed at the time to find peat in the vicinity of loess, (see p. 38), we decided to try again to make a pollen diagram of the Donaumoos. In the preparation and execution of this plan, the "Bodenkulturstelle Mittelbayern" of the Bayerische Landesanstalt für Bodenkultur und Pflanzenbau was very helpful to us. After consulting a peat depth chart which was made in 1900 and which is available in this "Bodenkulturstelle", we selected a place near the village Walda, Ldkr. Neuburg a.d. Donau. Boring on this spot had two advantages: first, the greatest thickness of the peat had been measured here, and second, this site is at a distance of only 200 m from a slope consisting of sandy loam. The latter fact led us to expect that the vegetation on the loam would be represented in the sedimented pollen in any case.

The sampling took place by means of a Dachnowsky corer. The stratigraphy of the deposits at the site is as follows:

cm	
0– 35	amorphous peat with sand
36–185	Cyperaceae peat; Carex utricles and nuts; in the lower half of the deposit some molluscs (fragments and complete specimens); more or less gradual transition to
186–365	complex of Cladium peat, calcareous gyttja and lake marl with molluscs (fragments and complete specimens); few Carex utricles and nuts; many Cladium nuts; Chara oosporangia; gradual transition to
366–484	complex of Cladium peat, calcareous gyttja and lake marl with molluscs (fragments and complete specimens); many Cladium nuts; remains of Scorpidium scorpioides; abrupt transition to
485–555	compact, amorphous peat; fragments of Betula and Salix wood; remains of Scorpidium scorpioides; few Carex nuts; at the base of the deposit some Potamogeton sp. fruitstones and Menyanthes seeds; more or less gradual transition to
556–568	calcareous gyttja with plant remains and molluscs; remains of Scorpidium scorpioides; Menyanthes seeds; Chara oosporangia; gradual transition to
569–602	lake marl with few plant remains and some molluscs; remains of Scorpidium scorpioides; Najas marina fruit; fruitstones of Potamogeton sp. and Carex sp. nuts

603–607	sand and lake marl; molluscs; roots of Cyperaceae; Carex nut; few remains of Scorpidium scorpioides; some Chara oosporangia
608–617	sand

The core was treated in the same way as the core from the Heiligenstädter Moos. At the bottom, a spectrum was made of each cm of sediment; from 474 to 556 cm each fifth cm was counted, and beyond that each tenth cm. The pollen appeared to be very well preserved.

The analysis clearly shows that, as Schmid assumed, the formation of the organic deposits already started in the Late Pleistocene. the base of the compact peat (550–555 cm) was dated at 10440 ± 95 B.P. (GrN–7141). The fact that Late Pleistocene, as well as Early Holocene and also Late Holocene vegetation periods are represented in the deposit, raises problems in the choice of a pollensum. The criteria for the choice should be different at the bottom and at the top of the deposits. We think that a pollensum as used for the Heiligenstädter Moos cannot be applied directly to Late Pleistocene deposits (see p. 155). This gave us reason to show the deposits of the Donaumoos not in a single pollen diagram, but rather in two diagrams with different calculating methods. We publish only one diagram here, namely the part within which the Atlantic falls. The older part lies outside the scope of our present investigation and will be published elsewhere.

We chose an upland pollensum for the younger part of the deposit. The criteria for the composition of this sum are the same as in the case of the Heiligenstädter Moos diagram (see p. 155). The choice of the pollensum is not quite correct as far as zone D IV and the beginning of zone D V are concerned, which will be defined below, because it is almost certain that Betula and Pinus of spectra 96 through 131 were part of the local vegetation: a carr. Both zones, however, have been included in the diagram to give a sharp lower limit to the Atlantic: zones D VI and D VII.

As usual, the diagram has been divided into pollen assemblage zones, for which purpose we used the zonation by Firbas. As we did for the Heiligenstädter Moos, we added a letter to the Roman numerals to indicate that the zones are not necessarily simultaneous with the same zones elsewhere. The zonation is as follows:

D IV	Pinus dominates, thermophile trees are absent.
Boundary D IV–D V:	occurrence of the first thermophile trees: Corylus, Ulmus and Picea. Quercus and Fraxinus follow slightly later.
D V	this zone is characterized by the increase of thermophile trees. Tilia appears. On the basis of the curves of Corylus, Quercus and Ulmus, this zone can be divided into three subzones.
D Va	a subzone in which these three trees increase rapidly; they reach a first maximum, to which belongs a C14 date of 9250 ± 100 B.P. (GrN–7142).
D Vb	during this subzone the percentages, in which Corylus, Quercus and Ulmus occur, decrease again, to increase permanently in DVc.
D Vc	(This subzonation is not according to Firbas)
Boundary D V–D VI:	most pollen curves increase or decrease no further.
D VI	a zone without important changes.
Boundary D VI–D VII:	the curve of Fagus becomes continuous, first occurrence of Abies.

D VII	very much like D VI, only Betula, Corylus, Quercus, Ulmus and Tilia decrease gradually and Pinus increases. Fagus is present in very low percentages. A C14 date of 5840 ± 80 B.P. (GrN–7143) falls within this zone.
Boundary D VII–D VIII/IX:	rapid increase of the Fagus curve.
D VIII/IX	zone VIII of Firbas cannot be distinguished separately because of the very fast increase of Fagus. Zone IX is a period in which Fagus dominates and Quercus, Ulmus and Tilia decrease strongly. Corylus recovers. Further, Plantago lanceolata and Plantago major occur for the first time.
Boundary D IX–D X:	Fagus decreases and Pinus increases.
D X	is hardly represented. Pinus dominates.

The Donaumoos at the sampling site can be compared with a small fen, rather than with a vast sedimentation basin. We made our bore-hole in a lateral valley of the large, funnel-shaped basin in which the fen formed itself in the course of time. The plan and the profile show that the fen lies as a tongue between slopes. Therefore we wish to interpret our pollen diagram as a diagram of a small sedimentation basin, in which most upland pollen had a relatively local origin and came from the vegetation in an area with a radius of some hundreds of metres or at the most some kilometres around the fen (Tauber 1965, Berglund 1973). We expect that most pollen relates to the vegetation of the slopes around the fen. These consist mainly of sandy loams and loamy sands. The regional vegetation will not have been different from the local upland vegetation, because there are similar sediments everywhere in the surroundings (figure 22).

At the level where the diagram shown here begins, thermophile trees are still absent. We cannot well judge the vegetation of the upland in this period, since the fen carried the same trees as we would expect on the upland (see p. 164).

Most of the thermophile trees appear during zone D V. However, the expansion of the first thermophiles: Corylus, Quercus and Ulmus, does not take place gradually. The curves show a temporary decrease in subzone D Vb. This decrease, which took place just after 9250 ± 100 B.P., remains unexplained. We can point at no edaphic factor that might have caused a change in the course of the curves. The calculation of the curves is no longer influenced at this level by a wrongly chosen pollensum (see p. 164), since at the level of the decrease the plants that could have brought about such an effect, namely such trees as Pinus, had already disappeared from the strictly local vegetation. We think it improbable, to say the least, that there were trees in a Cladium fen. It seems premature to us to explain the decrease by a climate fluctuation. It is true that the Venediger oscillation occurred in this period (Patzelt 1972), but *we feel that a phenomenon in the Donaumoos should not be correlated to one in the Eastern* Alps. One should rather withold one's opinion until the phenomenon has become apparent in other diagrams from the same area.

Deciduous trees dominate zones D VI and D VII, but the pine has not disappeared from the landscape. We think that the pine held its own on the poorer soils and more specifically on the sands and the loamy sands. We may visualize an oak-pine forest here, possibly with hazel. The loams were covered, we suppose, with a richer deciduous vegetation which contained, besides oak, also lime, elm, ash, maple and hazel. In

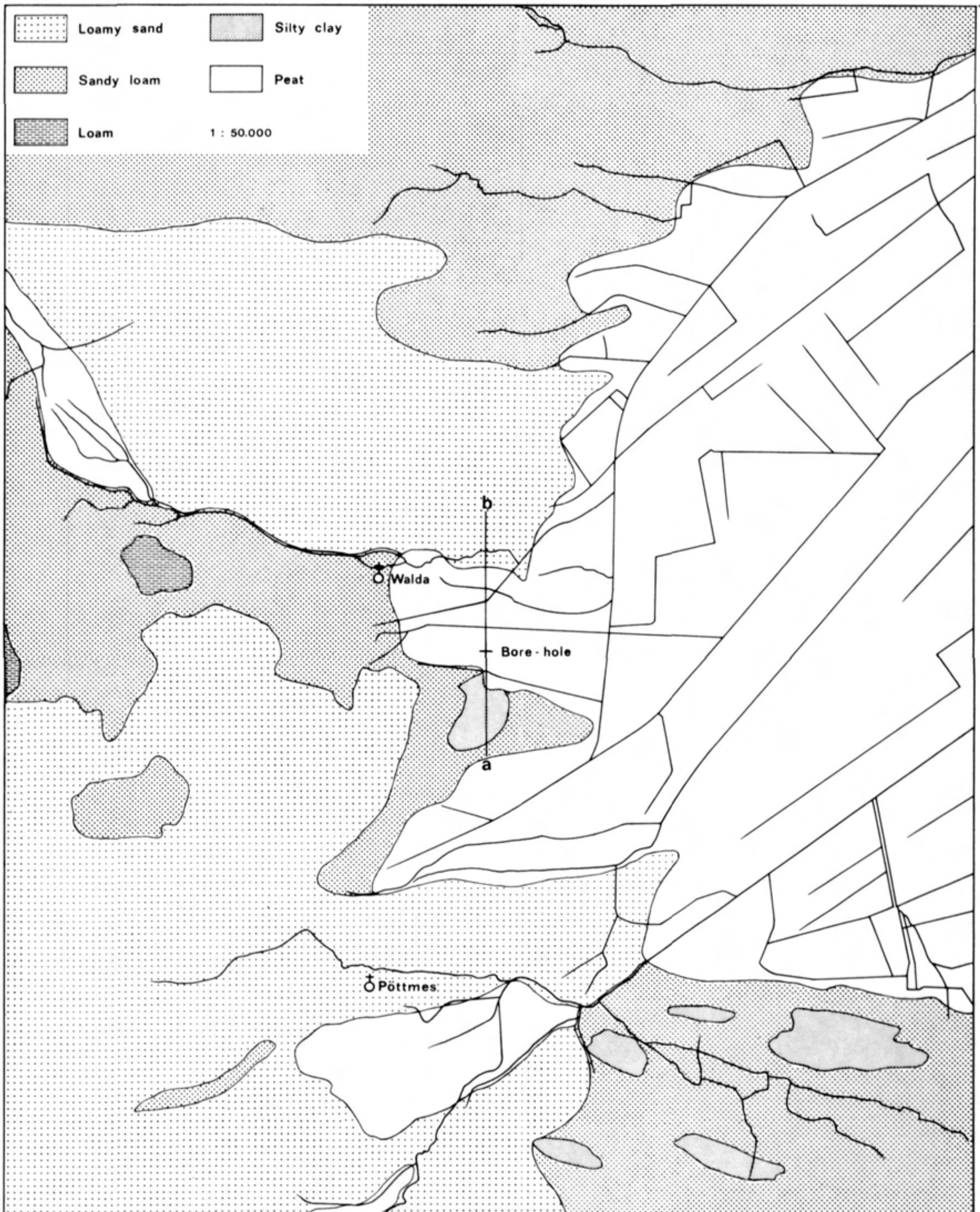


Fig. 22a. The S.W.-part of the Donaumoos and its surroundings. Scale 1:50000.

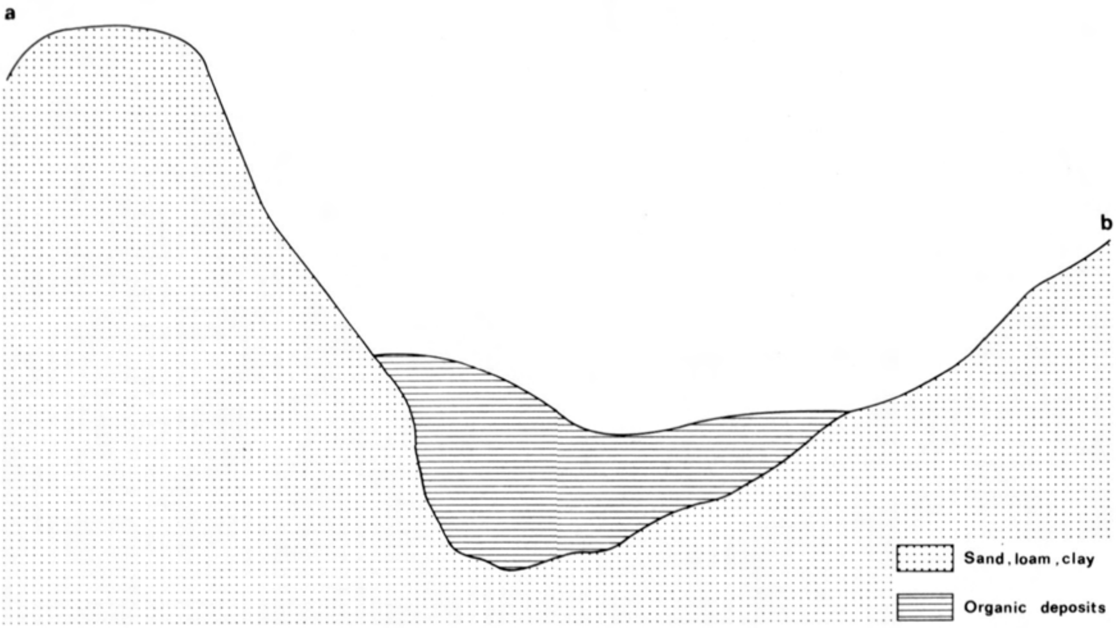


Fig. 22b. The S.W.-part of the Donaumoos, section, horizontal scale 1:12500, vertical scale 1:250.

contrast with our observations in the Heiligenstädter Moos, we find almost no shrub-vegetation. The typical forest plants are restricted to a single find of Pleurospermum and one of Melampyrum. The number of herb species which use to grow on clearings, is also smaller. Still, there is reason to assume that here too were some clearings. Artemisia occurs frequently and also Chenopodiaceae are found, be it sporadically. Spectrum 411 might represent a small clearing.

In the combined zone D VIII/IX the forests appear to change their composition. The beech becomes an important tree and seems to expand itself at the expense of the other deciduous trees, with the exception of Corylus. Ulmus disappears almost completely. As Pinus does not allow itself to be expelled, we assume that Fagus became a part of the forest communities on the loams. A beech forest, possibly a mixed beech forest, would then have developed on the loamy soils. This assumption is supported perhaps by the fact that in zone D X, that is the first zone in which human influence becomes apparent, it is precisely Fagus which declines strongly. Nowadays the loams are used as arable, and the sands for forestry. If we may assume that also in the period, in which zone D X falls, the loams were preferred for agriculture then this means that Fagus was rather common on the loams originally. Should this assumption appear to be incorrect, then of course this argument becomes void. Since we do not know the agricultural history of the area, we cannot prove our assumptions.

We think that the increase of Pinus should not be explained by the planting of pines, but by the disappearance of other pollen producers. Unfortunately zone X is virtually absent in the diagram, so that we miss the Middle Ages. We attribute this to the earlier mentioned loss of level by peat cutting and wind erosion.

The vegetation of the fen itself can be deducted not only from the lithology and the macroscopic remains, but also from the local pollen types. We have composed the local diagram in the same way as the diagram of the Heiligenstädter Moos, but the pattern is far less clear than in the latter fen.

The absence of indicators of open water is conspicuous: the sedimentation basin was never a lake, not even in the preceding period of which the diagram is not given here. During zone D IV and the beginning of zone D V, peat, now represented by a hard, compact, dark brown layer was formed in the basin. Remains of Salix and Betula wood were found in this layer. Closer to the edge of the basin we also found Pinus wood at this level; the latter finds were made during the borings for the cross section. In addition to wood remains, we found remains of the moss Scorpidium scorpioides and a few Carex-nuts in the peat.* We suppose that the deposit in question developed in a carr. Besides these macroscopic remains, the peat layer is characterized by the presence of pollen of Cruciferae, Lysimachia vulgaris type (to which belongs L. thyrsiflora, among others) and Gramineae. In the diagram, the Rubiaceae have been added to this group, because this pollen type, like the Cruciferae and the Lysimachia vulgaris type, is strongly correlated with Salix in the levels underneath. The peat layer passes rather suddenly, but not entirely without transition, into a deposit that must have developed under much wetter conditions. It is possible that the stratigraphy shows a hiatus here, but that cannot be seen clearly in the pollen curves. The peat is followed by deposits of calcareous gyttja, which alternate with spots of Cladium-peat. Until 366 cm beneath the surface, the Cladium-peat is mixed with remains of Scorpidium scorpioides. Higher up, almost no Scorpidium is found; Chara oosporangia are present instead. In the part of the deposit with Cladium-peat we found many Cladium pollen grains among the Cyperaceae pollen. This wet vegetation is undoubtedly also the origin of the sporadically found pollen of marsh plants: Potamogeton sp., Equisetum sp., Sparganium sp., Typha latifolia and Menyanthes trifoliata. All these plants could have belonged to the Cladietum marisci (Allorge 1922) Zobrist 1935 (sub nom. Mariscetum serrati). The Rubiaceae pollen (Galium palustre) and a part of the Gramineae and Monoletae undoubtedly were also part of the local plant community in which, by the way, we also wish to include Utricularia intermedia, although the single pollen grain of this plant was really found higher in the sediment. A subfossil Cladietum marisci as this one is described by Rybniček as Cladium mariscus subfos. comm. (Rybniček 1973). "It is characterized by the predominance of Cladium, while most of the other species are represented sporadically" (Rybniček 1973 p. 239). This agrees completely with our finds. From the structure of the sediment we gain the impression, in as far as such is possible from a small core, that the Cladium vegetation formed hummocks, between which there were open pools. The fact is that the Chara remains are always clearly separated from the surrounding off-white to light brown, strongly calcareous gyttjas. The Chara, which was found in large quantities in the upper half of the Cladium peat-calcareous gyttja deposit, could have grown in these pools. It is conspicuous that the oosporangia of Chara are absent in the lower half, but this could be coincidence.

At circa 185 cm beneath the surface, the Cladium peat – gyttja complex passes gradually into a Carex fen. At circa 125 cm, the percentage of Parnassia pollen increases spectacularly. We think that the plant community Tofieldietalia Preising apud Oberd. 1949 established itself on the fen. This reconstruction corresponds completely with the vegetation which the Donaumoos would have nowadays if human influence were absent (Seibert 1968).

Besides the pollen which we may attribute to the local sere of vegetations, there are pollen types which come from plants growing on wet places, which cannot or hardly be placed in the strictly local flora. We

* The moss remains from the Donaumoos profile were identified by Dr. A. Touw, the wood remains by Dr. P. Baas, both of the Rijksherbarium of Leiden.

feel that they represent the marginal vegetation of the fen. When gathering the data for the cross section, we found many fragments of alder wood along the edge of the fen, at the foot of the slope. These remains were not restricted to the upper levels, but extended down to 275 cm. They are probably the remains of a narrow alder belt which stood along the marsh on the boundary between fen and drier land. We think that this vegetation is the origin of the pollen of the alder and the other plants of wet habitat.

As observed above, we arrived at the conclusion that the Donaumoos, at least at the sampling site, has never been open water. The growth of the thick peat deposit could take place probably because of the continuous trickle of water. Near the sampling site a small stream flows into the fen. As we found no mineral material mixed in the peat, however, we think that this stream had hardly any influence on the peat formation. Therefore we think of seepage.

Our finds are supported by the examination of the molluscs.

To obtain more material for the examination of molluscs, two additional borings were carried out with an Edelman corer. However, the samples are still of small size for a malacological analysis. Still, a picture of the mollusc fauna could be obtained. The molluscs were described by W.J. Kuijper. We quote the following from his report: "The good condition of the material (outer skin present, Pisidiums in doublets) proves that the animals lived on the spot and that no transportation from other environments took place. The following species were found in the deposits from 5 to 0 metres deep:

freshwater: Valvata cristata Müller, Valvata piscinalis (Müller), Hydrobiidae, Bithynia tentaculata (L.), Galba truncatula (Müller), Galba palustris (Müller), Radix peregra (Müller), cf Lymnaea stagnalis (L.), Planorbis planorbis (L.), Planorbis carinatus Müller, Anisus leucostomus (Millet), Anisus vorticulus (Troschel), Bathyomphalus contortus (L.), Gyraulus cf laevis (Alder), Armiger crista (L.), Hippeutis complanatus (L.), Pisidium milium Held, Pisidium nitidum Jenyns, Pisidium hibernicum Westerlund.*

land:Carychium minimum Müller, Cochlicopa lubrica (Müller), Vertigo angustior Jeffreys, Vertigo antivertigo (Draparnaud), Vertigo moulinsiana (Dupuy), Vertigo pygmaea (Draparnaud), Vallonia pulchella (Müller), Vallonia costata (Müller), Succinea elegans Risso, Punctum pygmaeum (Draparnaud), Vitrinidae, Nesovitrea hammonis (Ström), Limacidae, Euconulus fulvus (Müller), Helicigona arbustorum (L.).

The species of the Hydrobiidae could not yet be identified by means of the one fragment. Perhaps it is a Paladilhia (Belgrandia?) or Bythinella species.

Molluscs are absent in the peat layer deeper than 5 m and in the uppermost metre of the Carex-peat deposit.

The molluscs which were found in the top of the peat layer, that is from 5 to 4.85 m beneath the surface, indicate that the biotope at this place was wet with ground-water practically at surface level or slightly thereunder. Here lived the land snails Vertigo pygmaea, Vallonia pulchella, Succinea elegans and the water species Pisidium obtusale and Galba cf truncatula. The latter two species can live very well without water, in a wet environment. Above this level (4.85–4.77 m) the water molluscs become predominant. At the transition (4.85 m) a Vertigo antivertigo was found: a land snail of a very wet terrain with much vegetation. From the then following deposits (circa 4.60–1.50 m) are the remains of a fauna which must have lived in shallow, clear, still water with a rich vegetation. Moreover, this environment must have

* The Pisidiidae were identified by J.G.J. Kuiper of Paris.

included places which rose slightly above the water (e.g. sedge- or grass-hummocks). On these places lived the land snails, which are found frequently in the deposits. The water level was probably fairly constant throughout the year. Periods of drought did not occur: this is demonstrated by species which cannot tolerate desiccation (Anisus vorticulus, Planorbis carinatus). One obtains a picture of a constant marshy area without trees.

This changes from 1.50 m beneath the surface onwards. The numbers and species of land snails increase markedly, especially beyond 1.35 m, which proves that the area projecting above the water grows in size. After 1.20 m the aquatic species disappear and the fauna is a land fauna of wet terrain. The absence of molluscs in the uppermost metre was probably caused by an acidification of the biotope. Such an explanation may also apply to the absence of molluscs in the peat layer of circa 5.50–5.00 m.

The species of the Hydrobiidae, found at a depth of 4.25 m, could be an indicator of seepage. Most representatives of this family live underground in springs, in streams connected with springs and in places where seepage occurs, that is to say in places with few changes in temperature, water composition and the like." (Kuijper 1975).

If, finally, we compare the diagrams of the Donaumoos and the Heiligenstädter Moos with each other, there appear to be not only many similarities, but also differences. In the upland pollen curves, the difference resides mainly in the curve of Pinus and in the number of species found where the shrubs and herbs are concerned. In zones VI and VII Pinus plays a far more important part around the sampling site in the Donaumoos than in the Heiligenstädter Moos, where this tree was perhaps initially absent. On the other hand, the Donaumoos diagram lacks the rich shrub- and herb-flora of the Heiligenstädter Moos. We attribute these differences to differences in the substrate. Human influence is much more apparent in the diagram of the Heiligenstädter Moos than in the Donaumoos diagram. The reason is probably a difference in the intensity of the prehistoric c.q. protohistoric occupation in the immediate surroundings. The diagrams of the local pollen types indicate that the two basins were filled up in completely different ways. The Heiligenstädter Moos was a lake which was filled up "normally"; the Donaumoos remained a swamp, probably as the result of never-ending seepage.

APPENDIX II

CARBONIZED PLANT REMAINS FROM HIENHEIM

During the first three excavation campaigns in Hienheim, those of 1965, 1967 and 1968, no special attention was paid to plant remains. Only occasional observations were made. Not until 1970 did a systematical botanical investigation take place. This investigation has become standard routine since 1971.

Samples are taken, if possible, from the filling of each well-dated pit, waiting until sections of the pits are available. The finds which appear in the excavation of the sections, date the samples, whereas the section provides information about the fill layers, if any. We take our samples from the section wall, and of course we take layers that are present into account. The sample size usually amounts to 2 dm^3. Practice has shown that this quantity is sufficient to determine whether there are plant remains in the pit filling. If seeds and the like are observed already in the field, then the sample is enlarged, if possible. Sometimes we have to remain content with a smaller sample.

The soil is hand-sieved on the spot by means of sieves with a mesh-width of 0.5 mm and ordinary water. Flotation has failed so far as a method of separating plant remains from the loess-loam filling of the pits in Hienheim. Laboratory tests show that, at the most, cereal grains and charcoal fragments come to the surface; pulses practically always sink. The residues from the site are sieved again in the laboratory and subsequently sorted under a microscope at a magnification at 10 times.

In the investigation both carbonized and uncarbonized seeds appear, as well as chaff remains, charcoal fragments, chert splinters and the like. We consider the uncarbonized seeds to be recent, since we think it impossible that uncarbonized plant remains stay intact in the well-drained soil for a long time. Among the uncarbonized seeds, we often find large numbers of Chenopodium album. Besides, Polygonum convolvulus, Melandrium album and Stellaria media occur regularly. These plants are part of the recent weed flora on the excavation site. Especially Chenopodium album and Polygonum convolvulus can present problems, as they can be taken for prehistorical seeds. In our lists, we have only mentioned those seeds* which, after having been broken, appeared to be carbonized inside. Loose seed-coat and pericarp fragments without carbon remains adhering to them, were not included. Our experience in Hienheim is that the recent seeds may even occur on the bottom of very deep pits. In such cases the soil at the top of these pits does not necessarily contain recent seeds. In disagreement with Knörzer, we feel that the distribution of the seeds over the contents of the pits can be no argument for the dubious finds being recent or not (Knörzer 1967a p. 17).

The carbonized remains are listed in tables 15, 16 and 17. The first two lists comprise all seeds (and some other plant remains) found in a LBK context. The third list concerns charcoal fragments. It was composed from the statements by Dr. P. Baas of Leiden (Netherlands) and Dr. F.H. Schweingruber of Birmensdorf (Switzerland). They examined a number of pit fillings which we had selected. Charcoal is a rather rare phenomenon in Hienheim. Most pit fillings, even the dark-coloured

* We often use the word "seeds" when also fruits and the like are meant.

ones, provide but a few fragments. Moreover, these are not larger than a few mm. As a test, Dr. Schweingruber examined the charcoal of 6 pit fillings, in which only very small particles were found. According to him, the conservation condition of the splinters is good. But many pieces are in a very advanced state of carbonization. He thinks it possible that a large part of the burnt wood has carbonized into powder and is therefore no longer recognizable as charcoal (Schweingruber 1975 written information). Moreover, the loess-loam filling of the pits is a very unfavourable sediment as far as the preservation of charcoal is concerned. It appears that a considerable part of the clay fraction has displaced itself in the course of time (van de Wetering 1975a). By the illuviation of the clay particles and the shrinking and swelling of this clay, the structure of the charcoal is gradually lost. Charcoal of hard wood is preserved better in these conditions than charcoal from soft wood (Schweingruber 1973 p. 153). This could explain the fact that Dr. Baas, who identified samples with larger charcoal fragments, could demonstrate only oak.

The charcoal which we found can of course not be considered a true reflection of the wood species which were present around the settlements. Man made the first choice, after which corrosion took care of subsequent selection. But the data are not in contradiction with the picture which we have formed of the vegetation around Hienheim. The plants found among the charcoal can all have stood near the settlement (see p. 43). It is almost impossible to say something about the use which the inhabitants of the settlement made of the different wood species (see further p. 81).

The presence of seeds is independent of the presence of carbonized wood. It is true that the same applies to the seeds as to the charcoal fragments, namely that in most soil samples only few specimens were found, but the larger number of seeds are not necessarily to be found in the pit fillings with much charcoal. When in a single pit both charcoal- and seed-concentrations are observed, as in pit no. 414, then the carbonized wood and the carbonized seeds are not mixed up. Therefore we think that the seeds were carbonized independently of the wood. We have discussed the possible causes of the carbonization in IV.2.

There are few pits in which systematic investigation revealed no seeds at all, but the density of the seeds, fruits, chaff remains and the like is small in most cases. Of the 24 LBK pits or parts of pit complexes which were analyzed in the campaigns of 1971, 1973 and 1974, only three pits provided nothing at all. The greater part of the samples contain some cereal grains or cereal grain fragments, heavily damaged halves of the spikelet forks of Triticum monococcum or Tr. dicoccum and a limited number of seeds of wild plants. We have the impression that this kind of remains is spread over the entire settlement area and must be considered as a widely scattered part of the dirt in the settlement. Concentrations of seeds are rare, as appears from the densities listed in table 15.

It is difficult to compare these data with those from other settlements, because little equivalent research has been done. In Rosdorf, Willerding found a density of 0.5–1.6 with one exception of 11.4 seeds per dm^3 of soil, which corresponds more or less to the figures from Hienheim (Willerding 1965 p. 57). The soil samples from the Rheinland, e.g. from Langweiler–2, provided more carbonized remains. About half the samples contained more than 10 seeds per dm^3, not even including the sometimes numerous chaff remains (Knörzer 1973). These densities might be inflated because Knörzer only received soil samples from dark-coloured layers for his analysis (Knörzer 1973 p. 140), but it is also very well possible that the densities in the Rheinland are indeed higher. It was no rule in Hienheim that dark-coloured fillings contained many seeds. On the other hand it is true that the light samples always provided little.

The sampled pits belong all but one to the types described by Modderman: longitudinal pits and pit complexes (Modderman in press). The exception is no. 415, a post-hole of house 31. Pits that could be interpreted as storage-pits, have not been found. Our results give no reason to distinguish between the fillings of longitudinal pits and the fillings of pits which form the so-called complexes.

As said already in the description of the sampling method, we paid special attention to the layer-structure of the pit-fillings. Only five sections gave us reason to keep different layers separated during the sampling. These are the numbers 1082, 1086, 1089, 1211 and 1259. These layers are indicated in the tables by a cipher behind the find number: 1 is the top and 2 or 3 is the bottom. In the case of 1082, 1086 and 1259 the conclusion must be drawn that the layers have a comparable composition. The layer-structure was far less clear in these pits than in numbers 1089 and 1211. In 1089, the dark-coloured top layer contains mainly peas, whereas the much lighter layer underneath appeared to be sterile. In number 1211 the uppermost part of the pit filling contained little material, whereas the finds were located precisely in a dark layer on the bottom of the pit. This layer might represent the remnant of burnt chaff, which would be the only one in its kind that we found in Hienheim (see p. 62).

The distribution of the finds over the settlement area might provide indications of the location of certain activities on certain places within the settlement. Nothing in our observations suggests that the activities that led to the carbonization of seeds and chaff remains, were concentrated in special places. We think that we may conclude from the fact that most pits contain carbonized remains, that the activities in question took place throughout the settlement, unless the carbon got spread equally over the settlement by the wind. This seems improbable to us, especially as far as the cereal grains are concerned. We do not expect that the investigation of the still unexcavated part of the settlement (60% of the area with traces of LBK occupation) will change our conclusion. The possibility remains that a special working place will be discovered, but we think that chances are small. A similar investigation in Langweiler–2 disclosed no clusters of pits with carbonized remains either (Farruggia et al. 1973).

The largests among the seed assemblages give us information about the nature of above-said activities. We have made a further analysis in IV.2 of the eight suitable assemblages. Five assemblages (325, 701, 764, 1140 and 1420) could be considered as the remains of a crop which was not yet threshed, one could be either the remnant of an unthreshed crop, or a stock (1089), one find (414) is perhaps the discarded remnant of a stock, and one assemblage (1211/2) could pass for burnt threshing-waste.

The further interpretation of the material is given in IV.2. Below we give only the description of the remains listed in tables 15 and 16.

DESCRIPTION OF THE CARBONIZED REMAINS, CHARCOAL EXCLUDED

CULTIVATED PLANTS

Triticum monococcum L. and Triticum dicoccum Schübl.

A large part of the cereal grains was damaged during the carbonization to such an extent, that the species can no longer be determined. The genus to which they belong, can sometimes not be identified either, but in those cases where it was possible, it turned out to be the genus Triticum. As all identifiable caryopses are from Triticum monococcum or Tr. dicoccum, we assume that by far the greater part of, if not all, cereal grains found can be considered to belong to einkorn or emmer. Besides, all chaff remains originate from these wheat species. Hordeum has been demonstrated in Hienheim, but not in a LBK context.

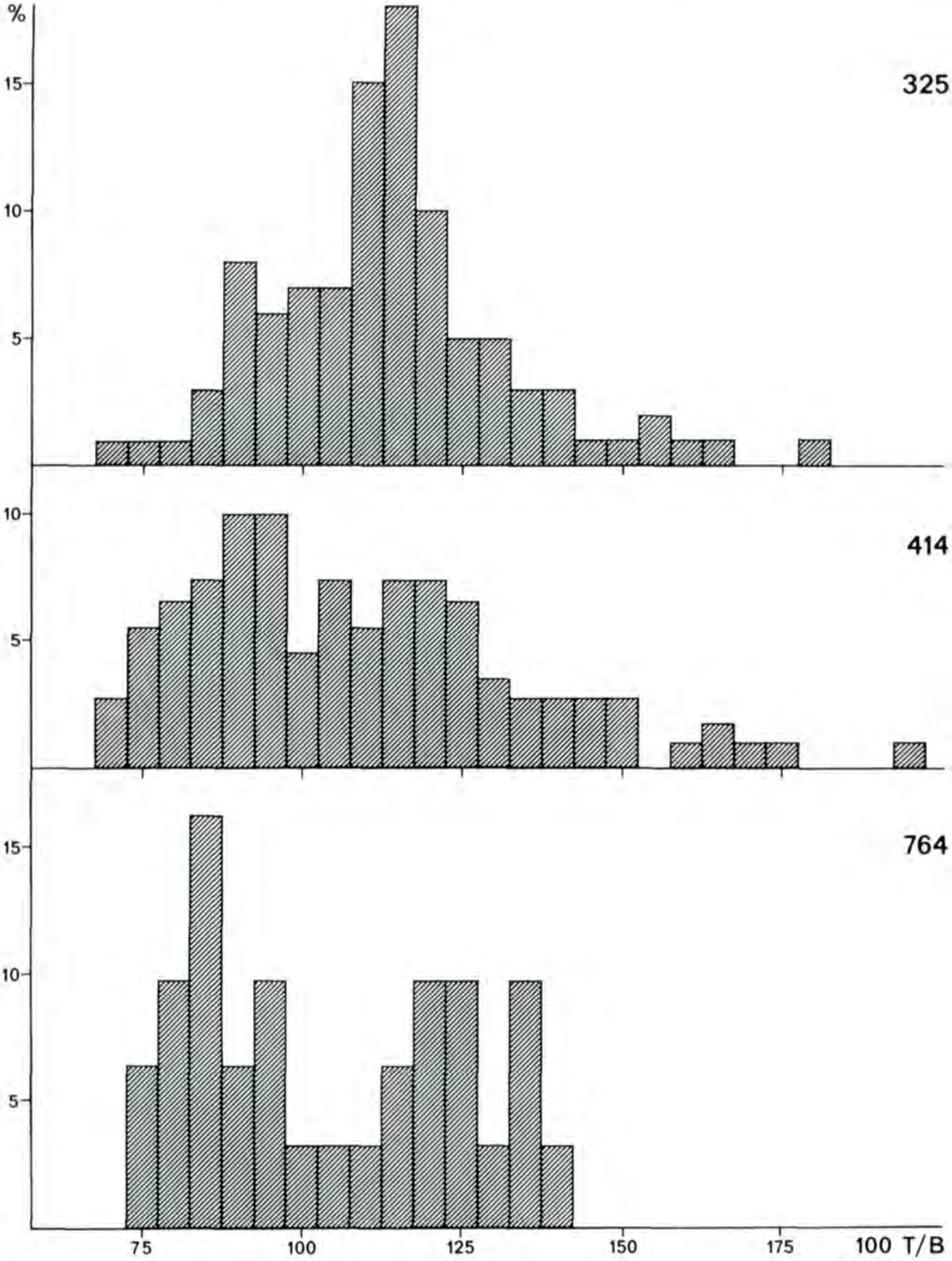


Fig. 23. Thickness : Breadth index for Triticum from the samples Hienheim 325, 414 and 764.

It is often difficult to make a distinction between emmer and einkorn. Both wheat species occur as a mixture in the assemblages. This is illustrated for one identification characteristic in figure 23, where the 100 T/B index of three assemblages is shown. The division is bi-modal. The overlap of the constituting parts makes it difficult to state the exact numbers of emmer and einkorn. We laid the separating line at 100 T/B = 100, as is usual, but this does mean that some grains, which we list as einkorn, are in fact emmer grains, whereas the opposite also occurs. Therefore we can give no histograms of the frequency distribution of the length and the 100 L/B index.

Not only grains, but also chaff remains were found. These comprise spikelet forks and glume bases. They are listed together in table 15. There are two numbers in the column. The first is a statement of the number of spikelet forks + glume bases, which was found in the samples. It is also the maximum number of spikelet forks. The second number is the minimum number. It is the number of spikelet forks that would be found if all glume bases were paired.

The spikelet forks originate partly from emmer, partly from einkorn. An exact separation cannot be made: there are spikelet forks which in all respects are typical for einkorn, as well as specimens which are typical for emmer. The dimensions of spikelet forks from one sample, no. 325, are given in figure 24. The dimensions are the dimensions introduced by Helbaek: breadth of the spikelet forks (dimension A) and breadth of the glume bases (dimension B). The distribution of both dimensions is continuous. There are few specimens with a dimension A larger than 2.0 mm. This appears to be normal for emmer found in a LBK context. At least, Knörzer mentions for the Rheinland no breadths of more than 2.0 mm (Knörzer 1967a p. 10, Knörzer 1974 p. 184).

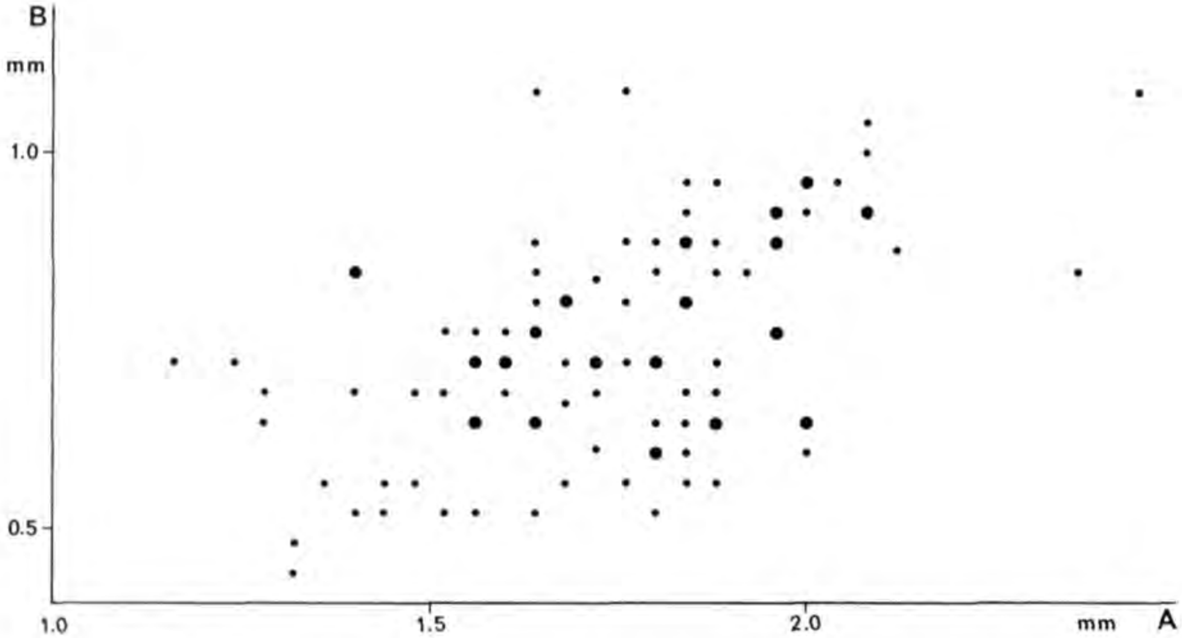


Fig. 24. Dimensions in mm for spikelet forks from Hienheim 325. A = breadth of the fork, B = breadth of the glume base, small dot = one specimen, large dot = several specimens.

Pisum sativum L. (fig. 28, fig. 32)

Whole and half specimens of the pea were found, as well as many fragments. The seeds have a special, ellipsoid or cylindrical shape. Most of them are dented. Of a number of specimens the hilum and the seed-coat remained intact. The hilum is oval: the dimensions of 52 hilums from find no. 414 are 1.05 (0.5–1.4) by 0.67 (0.3–1.2) mm; the ratio length/breadth is 1.66 (1.1–2.7). When slightly magnified, the seed-coat has a smooth surface; a magnification of 50 times shows that it is covered with small warts. The warts are slightly bigger than those of carbonized specimens of recent peas which we studied (Pisum sativum ssp sativum and ssp arvense), but they are finer than the warts of Pisum elatius. Because of the shape of the hilum and the smoothness of the seed-coat, the seeds of Pisum found must be considered to belong to the cultivated species Pisum sativum. Besides, the wild species is not indigenous to the surroundings of Hienheim.

The seeds are small. The dimensions of the specimens from two find numbers are given in the histograms of figure 25. Carbonization tests with recent seeds of Pisum sativum ssp sativum and ssp arvense show that carbonization reduces the size of pea seeds by 2 to 10%. Therefore, the LBK seeds were slightly bigger originally.

The sizes are not different from the dimensions quoted elsewhere for LBK peas. A number of sizes have been collected in figure 26. The data have been taken from Baumann & Schulze-Motel 1968, Knörzer 1967a, Rothmaler & Natho 1957 and Willerding 1965. The site Evendorff is situated in the département Moselle in France and has not yet been published (identification and dimensions by C.C. Bakels). It should be noted that the dimensions are not completely comparable, because the method of measuring was not exactly the same everywhere. For Hienheim and Evendorff we chose the maximum diameter as the dimension to be measured. Since the seeds are often flattened off or indented, we think that measuring the length, the breadth and the thickness does not always make sense. In the other finds we always took that dimension of the quoted dimensions which is the largest: for the peas of Rosdorf for instance, this is the length. In Hienheim, the length and the maximum diameter appear to be close to each other. The difference averages 0.1 mm.

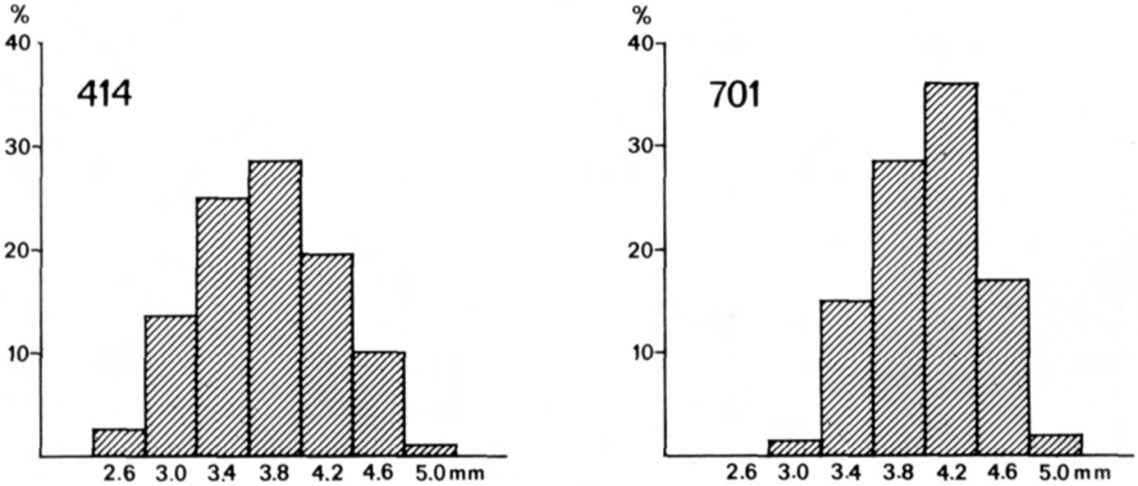


Fig. 25. Maximum diameter of Pisum sativum from Hienheim 414 and 701, N = 200.

The dimensions of carbonized peas appear to be slightly smaller than the dimensions quoted for the impressions. An impression from Hienheim has a diameter of 6.0 mm; four impressions from Nerkewitz Kr. Jena (DDR) have diameters of 6.1, 5.4, 5.0 and 6.4 mm (Tempír & Gall 1972). These peas probably absorbed water, which made them swell.

The pea was a widely spread cultivated plant at the time of the Linearbandkeramik.

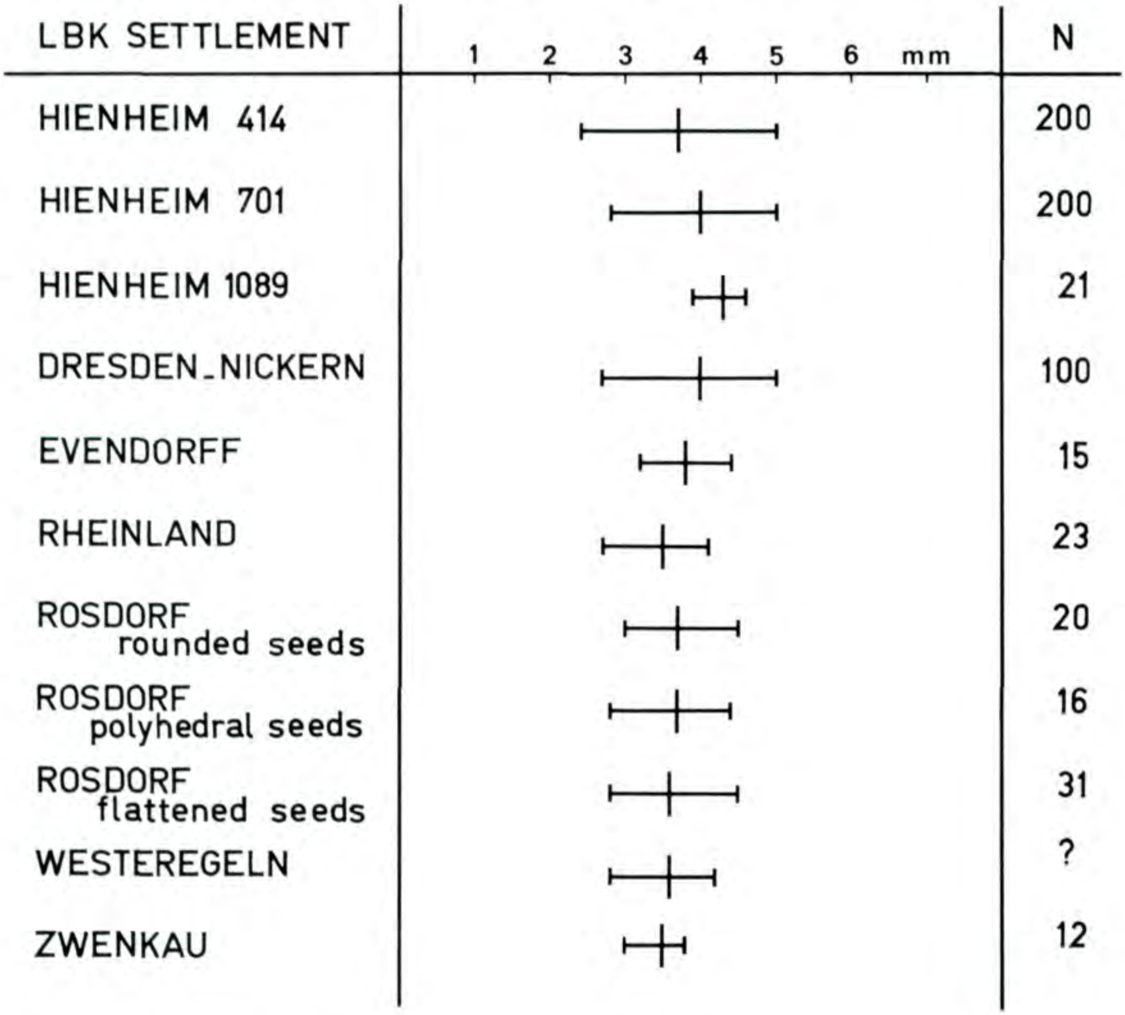


Fig. 26. Sizes of carbonized peas found in LBK context.

Lens culinaris Medik. (fig. 28, fig. 32)

The lentil is represented by only a few specimens, namely by two whole lentils and the fragments of cotyledons of at least four specimens. None of the lentils still has a seed-coat and a hilum. Confusion with other Papilionaceae is not possible, however. The whole specimens have a diameter of 1.9 and 2.8 mm.

The thickness is 1.0 and 1.4 mm respectively. The cotyledons belonged to seeds with a diameter of 2.4, 2.7, 3.1 and 3.2 mm. The thickness of the cotyledons of these specimens is 0.6 mm at the most. The dimensions of the lentils from Hienheim correspond to those of carbonized lentils from other LBK settlements. These are Aldenhoven Ldkr. Jülich (BRD), Lamersdorf Ldkr. Düren (BRD), Rödingen Ldkr. Jülich (BRD) and Langweiler-2 Ldkr. Düren (BRD) (Knörzer 1967a, Knörzer 1973). Knörzer gives the dimensions 2.49 (1.9–3.0) × 1.7 (1.3–2.0) for the lentils from Aldenhoven and Lamersdorf. In Langweiler-2 a fragment of a cotyledon was found with a diameter of ~ 2.4 mm and a thickness of 0.7 mm. We do not mention the lentils from Eisenberg, Heilbronn and Böckingen, because we do not know for sure whether these finds are of uncontested linearbandkeramik age. From Nerkewitz Kr Jena (DDR) the impression of a lentil is known. The diameter of this specimen is 4.3 mm and thus much larger than the diameter of the carbonized speciments (Tempir & Gall 1972). We think that this lentil had absorbed water.

The lentil has never been found in large concentrations so far and apparently does not belong to the usual finds.

Linum usitatissimum L. (fig. 28, fig. 34)

Linseed was observed in three find numbers, each with one damaged specimen. The characteristic beak is absent in all three cases. The keeled edge is clearly visible. The surface of the seeds is smooth with a clear cellular structure. This structure corresponds entirely to that of Linum usitatissimum. The surface of L. austriacum and L. flavum, which look like our Linum, has larger cells. The final determination, however, only followed after we had compared the fragments from Hienheim with Linum usitatissimum from Lamersdorf Ldkr Düren (BRD). The length of the seeds from Hienheim was originally slightly over 2.8 mm. The breadth of the specimens is 1.6, 1.4 and 1.3 mm; the thickness is 0.6, 1.0 and 0.3 mm respectively. In Lamersdorf these dimensions are 3.10 (2.8–3.3) × 1.56 (1.2–2.0) × 0.64 (0.5–0.9) mm. Further parallels are Langweiler-2 Ldkr Düren (BRD) with seeds of ~ 2.3–3.2 × 1.37 (1.2–1.5) × ~ 0.8–1.05 mm and Garsdorf Ldkr Bergheim/Erft (BRD) with seeds of 2.84 (2.6–3.0) × 1.50 (1.4–1.6) × 0.74 (0.7–0.8) mm (Knörzer 1967a, 1973 and 1974). Large concentrations of linseed have been found in above-mentioned Lamersdorf, in Köln-Lindenthal Stkr Köln (BRD) and in Morken-Harff Ldkr Bergheim/Erft (BRD) (Buttler & Haberey 1936, Hinz 1969). No dimensions are known from the latter two find sites.

Apart from the above-described find in Hienheim, the presence of linseed has been restricted so far to the Rheinland, at least when we leave Eisenberg and Heilbronn out of consideration. The dates of the latter finds are not mentioned exactly.

OTHER PLANTS

Betulaceae, Corylus avellana L.

Two very small fragments of a hazelnut from a single find number are the only traces of the presence of hazelnuts. The fragments could come from one and the same nut, which is why the table mentions only one specimen.

Caryophyllaceae, Silene cucubalus Wib. (fig. 31, fig. 34)

The two kidney-shaped seeds from 1211/2 are respectively 1.1 and 0.9 mm long, have a breadth of 1.0 and 0.7 mm, whereas the most intact specimen is 0.7 mm thick. The "dorsal side" opposite the hilum is convex, the sides are almost entirely flat. The seed-coat is covered with blunt conical spines of 0.08 mm in length, which are arranged in rows. The hilum has fine stripes. The seeds bear a close resemblance to recent seeds of Silene cucubalus from the surroundings of Hienheim. The seeds of Lychnis flos-cuculi are smaller. The seeds of Melandrium album and M. rubrum look like those of Silene cucubalus, but the spines have a different shape.

Chenopodiaceae, Atriplex sp.

There is only one fragment of Atriplex sp.: a piece of a seed with protruding radicle tip. The seed-coat is smooth, except on the radicle tip where it shows small lengthwise furrows. The fragment was identified by means of the size, the shape of the radicle tip and the sculpture of the surface. It is identical to the corresponding part of seeds of Atriplex patula L. and Atriplex hastata L. from our collection.

Chenopodiaceae, Chenopodium album L.

Seeds of Chenopodium album are found frequently. They completely answer the description which is given of this oft mentioned species. The dimensions of the specimens from Hienheim are 1.11 (1.0–1.3) × 0.64 (0.4–0.8) mm (N = 14). Chenopodium album seeds belong to the most common components of seed assemblages from LBK pits.

Chenopodiaceae, Chenopodium hybridum L. (fig. 31, fig. 34)

In as far as we know, Chenopodium hybridum has not been found before in a LBK context. Apparently the specimen from find number 325 was not ripe yet when it was carbonized. The seed-coat shows folds and the seed is too flat for a fully grown specimen: it measures 1.3 × 0.4 mm. The specimen from find number 1259/1 is also on the smallish side: it measures 1.4 × 0.8 mm. The seeds have pits at both sides. They are distinguished from other Chenopodium species of the same size by this sculpture.

Compositae, Lapsana communis L. (fig. 28, fig. 32)

The three specimens of 1211/2 are heavily damaged. The dimensions of the two still measurable achenes are 2.7 × 0.7 × 0.7 and 2.3 × 0.8 × 0.2 mm. The ribs have disappeared almost completely. The achenes show a good similarity with achenes from LBK sites in the Rheinland.

Cruciferae, Sinapis sp. or Brassica sp. (fig. 34)

A fragment of a seed-coat which comes from a spherical seed with a diameter of circa 1.6 mm, is attributed to Sinapis or Brassica. The coat has a reticulum with meshes of 0.04 mm in diameter. The fragment looks most like Sinapis arvensis, but given the problems encountered in distinguishing between species of the genera Sinapis and Brassica, we consider it impossible to attribute a single fragment.

Equisetaceae, Equisetum sp.

A 3 mm-long fragment of an Equisetum stem cannot be identified to the species-level.

Gramineae, Bromus sp., Bromus cf arvensis L., Bromus secalinus L. or Br. mollis L., Bromus tectorum L. or Br. sterilis L. (fig. 29 fig. 33).

Fragments of Bromus caryopses are the most frequently found, after those of Polygonum convolvulus. The fragments can be recognized by their characteristic longitudinal stripes (see photographs). Undamaged grains are not to be found. Of most fragments it can no longer be determined to which species they belong. On the ground of the shape of loose apices and of the breadth of the fragments, we assume that at least three species are represented in the material. Find no. 1211/2 contains at least 17 fragments which belonged to caryopses with a maximum breadth of 1.10 (0.7–1.3) mm. The apices of these caryopses are more or less round. The edges are rolled inwards in most specimens, so that the grains have a boat-like aspect. They show a great similarity with Bromus arvensis. A second type of caryopses also has rounded-off apices, but the grains are plumper and much broader, namely circa 1.6 mm. We consider these caryopses as Bromus secalinus or Bromus mollis. In find no. 1211/2 three fragments with a pointed apex were found besides the caryopses of Bromus cf arvensis. The breadth of two specimens can be determined: it is 1.0 and 1.2 mm respectively. The apices correspond with the apices of Bromus tectorum and Bromus sterilis. The material of 1280 contains a similar apex.

Gramineae, Echinochloa crus-galli (L.) P.B. (fig. 29)

Three find numbers each contain a single caryopsis of a grass species that could be identified as Echinochloa crus-galli. The grains are plump with a L/B ratio of 1.1, 1.3 and 1.3, the apex is round. The scutellum has disappeared in all three specimens, but the scar can still be seen. It reaches until 2/3 of the length of the seed and has more or less parallel sides. These features make it possible to exclude comparable species. Panicum miliaceum has a shape that is very close to our finds, but the scutellum-scar of Panicum has clearly diverging sides and never reaches further, at least in the samples which we studied, than half the length of the caryopsis. The dimensions of the caryopses are 1.2 × 1.1 × 0.5, 1.0 × 0.8 × 0.5 and 0.9 × 0.7 × 0.5 mm. The dimensions of parallel finds are 1.15 (1.0–1.25) × 0.94 (0.8–1.1) × 0.63 (0.5–0.7) mm for 8 specimens from Lamersdorf Ldkr Düren (BRD), 1.3 × 1.05 × 0.7 mm for a specimen from Langweiler-2 Ldkr Düren (BRD) and 1.15 (1.1–1.2) × 0.88 (0.8–0.9) × 0.59 (0.5–0.7) mm for 10 caryopses from Garsdorf Ldkr Bergheim/Erft (BRD) (Knörzer 1967a, 1973 and 1974).

Gramineae, Setaria viridis (L.) P.B. or Setaria verticillata (L.) P.B. (fig. 29).

In the pit filling of no. 921 we found 22 seeds which on the one hand have a strong similarity with the (L/B index 1.64 (1.5–1.8)). Similar caryopses appeared in four other samples. To some specimens adhere remains of the palea on which cross rows of papillae can be seen. The scutellum scar covers adhere remains of the palea on which cross rows of papillae can be seen. The scutellum scar covers 2/3 to 2/5 of the length of the grain. A hilum can no longer be observed. The features indicate that the caryopses came from a Setaria species. Because of the dimensions, 1.20 (1.1–1.3) × 0.74 (0.6–0.8) × 0.52 (0.4–0.6) mm, this Setaria can only be Setaria viridis or Setaria verticillata. In as far as we know, this is the first Setaria found in a LBK context.

Papaveraceae, Papaver dubium L. or Papaver rhoeas L. (fig. 31)

The kidney-shaped poppy seed measures 0.7 × 0.6 × 0.5 mm. The surface shows a network of isodiametric fields. The fields are arranged in rows. The number of fields per side is circa 40. This gives the seed the features of Papaver dubium or P. rhoeas. We are not able to demonstrate differences between both species. We do not know of parallel finds.

Papilionaceae, Lathyrus tuberosus L. (fig. 28)

Of the two specimens which were found together, one is completely intact. The other one lacks the seed-coat. The seeds have an ellipsoid shape. Their dimensions are 4.0 × 2.9 × 2.5 mm and 3.6 × 2.2 × 2.2 mm respectively. The hilum measures 1.3 × 0.6 mm; it covers approximately 1/8 of the circumference. The seed-coat is smooth. We compared the seeds with all the Lathyrus species that, according to Oberdorfer, are present in Southern Germany (Oberdorfer 1970) and that have a hilum covering less than 1/3 of the circumference. The size and the shape of the seeds and the size and the shape of the hilum appeared to correspond very well with Lathyrus tuberosus. We know of no other find of this species.

Papilionaceae, cf Trifolium sp. (fig. 28, fig. 32)

One seed with a protruding radicle measures 1.1 × 0.6 × 0.5 mm (breadth without radicle). It has a hilum of 0.24 × 0.16 mm. The radicle reaches half the length of the seed. The specimen is slightly deformed at the narrow side opposite of the hilum and the radicle. We can find no identical recent seeds. The seed corresponds best with a Trifolium such as Trifolium dubium, but the radicle is slightly too short. Perhaps it shrunk more than the cotyledons during the carbonization.

Polygonaceae, Polygonum convolvulus L. (fig. 30, fig. 32)

In many assemblages there are fruits or fruit fragments of Polygonum convolvulus. Most fruits are heavily damaged. We could measure only eight specimens. The dimensions of the fruits are 2.21 (2.1–2.6) × 1.67 (1.5–1.9) mm. The carbonized fruits of Polygonum convolvulus are found very frequently in LBK settlements.

Polygonaceae, Rumex acetosella L. (fig. 30)

Sample number 1082/1 contains an undamaged and a heavily damaged specimen of a triangular fruit with rounded edges. The dimensions of the intact specimen are 1.3 × 1.0 mm. A very closely related species, Rumex tenuifolius (Wallr.) Löve, was found by Knörzer in Lamersdorf Ldkr. Düren (BRD), Langweiler-2 Ldkr. Düren (BRD) and Langweiler-6 Ldkr. Düren (BRD) (Knörzer 1967a), 1973 and 1972). The fruits of Rumex tenuifolius are slightly smaller than those of R. acetosella.

Polygonaceae, Rumex sp. (fig. 30, fig. 32)

A triangular fruit of a Rumex species from number 1211/2 has sharp edges. Upper and lower end are distinctly pointed. Its dimensions are 1.9 × 1.2 mm. In our opinion it is impossible to identify a single Rumex fruit of these dimensions.

Rubiaceae, Galium spurium L. (fig. 30, fig. 34)

Galium spurium has been noticed in six find numbers. The half fruits measure 1.34 (1.0–2.1) × 1.16 (0.8–2.0) × 1.10 (0.7–2.0) mm (N = 10). The cavity which indicates the place of the hilum, is round in all specimens and relatively small. A number of specimens show two lengthwise furrows (see photograph and drawing). The outer fruit wall has disappeared, the inner fruit wall shows a pattern of ladder-shaped rows of rectangular cells. Galium spurium (or Galium aparine) is found frequently in LBK settlements. We mention the settlements in the Rheinland, Göttingen-Hagenberg Ldkr Göttingen (BRD), Opava-Katerinky (ČSSR) and Sittard (Netherlands) (Knörzer 1971b, Meyer & Willerding 1961, Tempír 1968, Bakels in this publication). In comparison with other finds, the half fruits from Hienheim are on the smallish side.

Scrophulariaceae, Veronica sp. (fig. 31)

One seed of a Veronica sp. has the dimensions 0.9 × 0.7 × 0.4 mm. It is shield-shaped and has a smooth surface. Before the carbonization, it was perhaps flatter. It shows a similarity with seeds of Veronica species such as V. arvensis and V. serpyllifolia.

Solanaceae, Solanum nigrum L. (fig. 31, fig. 34)

Seeds of a Solanum species were found in five pits. One of the find numbers, 1180, contained 34 of these seeds. Considering the find circumstances, these must have come from the same species and perhaps from one and the same plant. Of the 34 seeds 27 specimens could be measured. The dimensions are: 1.75 (1.5–2.0) × 1.41 (1.3–1.6) × 0.85 (0.8–1.0) mm. The contours are shown in figure 27. Some look like the round seeds of Solanum dulcamara, others are more like the seeds of Solanum nigrum. The latter have one round and one more or less pointed end. We consider all seeds as Solanum nigrum. The relatively great thickness indicates that the shape of the seeds can have been modified by the carbonization. This could explain the somewhat round shape of the Solanum dulcamara-like specimens. Besides, recent Solanum nigrum seeds also sometimes have rounded contours. Solanum (cf) nigrum has been found, besides in Hienheim, in Göttingen-Hagenberg (Meyer & Willerding 1961).

Indeterminatae

This group comprises fragments of fruits and seeds, which could no longer be determined.

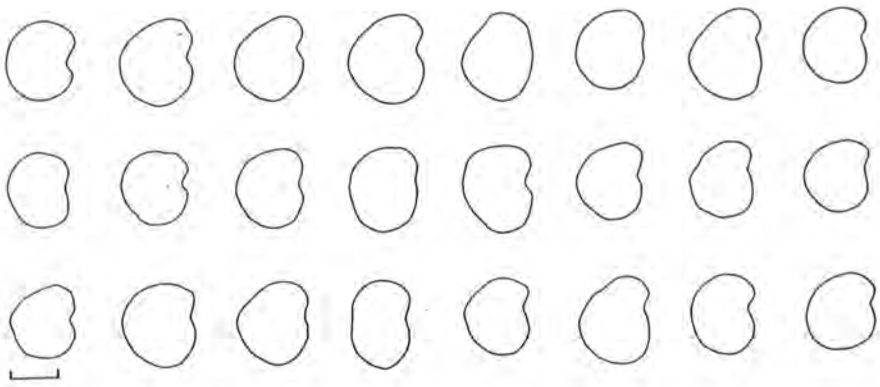


Fig. 27 Contours of Solanum nigrum seeds from Hienheim 1180. scale unit 1 mm

Table 15. Plant remains from the LBK settlement at Hienheim.

Sample number	*sample size, dm³*	*Triticum monococcum*	*Triticum cf monococcum*	*Triticum dicoccum*	*Triticum cf dicoccum*	*Unidentified cereal grains*	*Spikelet forks + glume bases*	*Pisum sativum*	*Lens culinaris*	*Linum usitatissimum*	*Wild fruits and seeds*	*Total number of fruits and seeds*	*Fruits and seeds/dm³*	*Plants remains/dm³*
325	15	120	4	30	5	125	372–238	–	1	–	7	292	19.5	44.3
414	30	76	6	57	26	85	–	2450	–	–	5	2705	90.2	90.2
415	0.25	–	–	2	1	4	–	4	–	–	6	17	68.0	68.0
593	5	–	–	–	–	2	3–2	5	–	–	3	10	2.0	2.6
598	5	–	–	3	–	–	–	–	–	–	3	6	1.2	1.2
701	5	10	–	3	–	62	37–24	723	–	–	5	803	160.6	168.0
764	1.5	23	–	19	3	86	60–37	–	–	–	–	131	87.3	127.3
921	22	9	1	2	–	1	5	–	–	–	24	37	1.7	1.9
1082/1	5	–	–	–	–	3	14–7	–	–	–	6	9	1.8	4.6
1082/2	5	1	–	1	–	17	36–18	–	–	–	4	23	4.6	11.8
1082/3	5	–	–	–	1	16	4	–	–	1	8	26	5.2	6.0
1086/1	2	–	–	1	–	9	3	1	–	–	2	13	6.5	8.0
1086/2	2	–	–	1	4	–	5–3	–	–	–	3	8	4.0	6.5
1086/3	2	–	–	–	–	4	2	–	–	–	–	6	3.0	4.0
1089	5	–	–	–	–	1	7–4	50	–	–	5	56	11.2	12.6
1101	1.5	–	–	5	–	7	22–16	–	–	–	9	21	14.0	28.7
1140	10	16	–	29	–	110	149–76	2	–	–	7	164	16.4	31.3
1143	5	–	–	–	–	6	10–5	–	–	–	4	10	2.0	4.0
1157	2	–	–	–	–	–	1	–	–	–	2	2	1.0	1.5
1180	3	–	–	–	–	4	13–7	–	–	–	40	44	14.7	19.0
1211/1	2	–	–	–	–	–	1	–	–	–	–	–	–	0.5
1211/2	5	15	–	1	–	–	229–121	–	3	–	67	86	17.2	63.0
1212	2	–	–	–	–	3	1	1	–	1	4	9	4.5	5.0
1222	2	–	–	–	–	2	5–4	–	–	–	3	5	2.5	5.0
1228	2	–	–	–	–	3	1	–	–	–	2	5	2.5	3.0
1259/1	2	–	–	–	–	2	2	–	–	–	3	5	2.5	3.5
1259/2	2	–	–	–	–	3	1	–	–	–	–	3	1.5	2.0
1261	2	–	–	–	–	2	–	–	–	–	–	2	1.0	1.0
1269	2	–	–	–	–	3	4	1	–	–	1	5	2.5	4.5
1280	2	–	–	–	–	2	7	–	–	–	9	11	5.5	9.0
1380	2	–	–	–	–	1	2	–	1	–	4	6	3.0	4.0
1384	2	–	–	–	–	–	1	–	–	–	–	–	–	0.5
1387	2	–	–	–	–	–	2	–	–	–	1	1	0.5	1.5
1396	0.2	–	–	–	–	–	1	–	–	–	1	1	5.0	10.0
1397	2	–	–	–	–	3	3–2	–	1	1	6	11	5.5	7.0
1405	2	3	–	3	–	21	27–14	–	–	–	1	28	14.0	27.5
1420	0.2	7	–	4	–	70	42–22	–	–	–	2	83	415.0	625.0

Table 16. Remains of wild plants from the LBK settlement at Hienheim.

Sample number	*Corylus avellana*	*Silene cucubalus*	*Atriplex sp.*	*Chenopodium album*	*Chenopodium hybridum*	*Lapsana communis*	*Sinapis/Brassica sp.*	*Equisetum sp.*	*Bromus sp.*	*Bromus cf arvensis*	*Bromus secalinus/mollis*	*Bromus tectorum/sterilis*	*Echinochloa crus-galli*	*Setaria viridis/verticillata*	*Papaver dubium/rhoeas*	*Lathyrus tuberosus*	*cf Trifolium sp.*	*Polygonum convolvulus*	*Rumex acetosella*	*Rumex sp.*	*Galium spurium*	*Veronica sp.*	*Solanum nigrum*	*Indeterminatae*
325	–	–	–	–	1	–	–	1	1	–	–													
414	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	3	–	–	–	–	–	2
415	–	–	–	4	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	1	–	–	1
593	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–
598	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
701	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	1	–	–	2	–	–	–
921	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	1	–	–	1
1082/1	–	–	–	–	–	–	–	–	1	–	–	–	1	22	1	–	–	–	–	–	–	–	–	–
1082/2	–	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	1	2	2	–	–	–	–	–
1082/3	–	–	1	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	1	–	–	–
1086/1	–	–	–	–	–	–	–	–	1	–	–	–	–	4	–	–	–	1	–	–	–	–	–	1
1086/2	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
1089	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
1101	–	–	–	–	–	–	–	–	4	–	–	–	–	–	–	–	–	1	–	–	–	–	1	1
1140	–	–	–	1	–	–	–	–	3	–	–	–	1	–	–	–	–	1	–	–	1	–	1	1
1143	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	2	–	–	–	–	1	–
1157	–	–	–	2	–	–	–	–	–	–	–	–	–	–	–	–	–	2	–	–	–	1	–	–
1180	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1211/2	–	2	–	–	–	3	–	–	25	17	–	–	1	–	–	–	–	2	–	–	–	–	34	3
1212	–	–	–	3	–	–	–	–	–	–	–	3	–	–	–	–	–	8	–	1	6	–	2	–
1222	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
1228	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	1	–	–	–	–	–	–
1259/1	–	–	–	2	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	1
1269	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1280	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1380	–	–	–	2	–	–	–	–	1	–	–	1	–	5	–	–	–	2	–	–	–	–	–	–
1387	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
1396	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1397	–	–	–	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1405	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
1420	–	–	–	1	–	–	–	–	1	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–
												–	–	–	–	–	–	–	–	–	–	–	–	–

Table 17. Wood remains from the LBK settlement at Hienheim.

Sample number	*Quercus*	*Pinus*	*cf Prunus avium*	*Pomoideae*	*Alnus*	*Identification by*
166	15	–	–	–	–	Baas
324	15	–	–	–	–	Baas
325	16	2	2	–	1	Schweingruber
333	15	–	–	–	–	Baas
414	76	–	–	–	–	Baas
593	60	14	1	1	–	Schweingruber
598	26	4	–	2	–	Schweingruber
714	100	–	–	–	–	Baas
911	25	–	–	–	–	Schweingruber
921	15	–	–	–	–	Baas
1086/3	60	2	–	–	–	Schweingruber
1222	2	–	–	–	–	Schweingruber

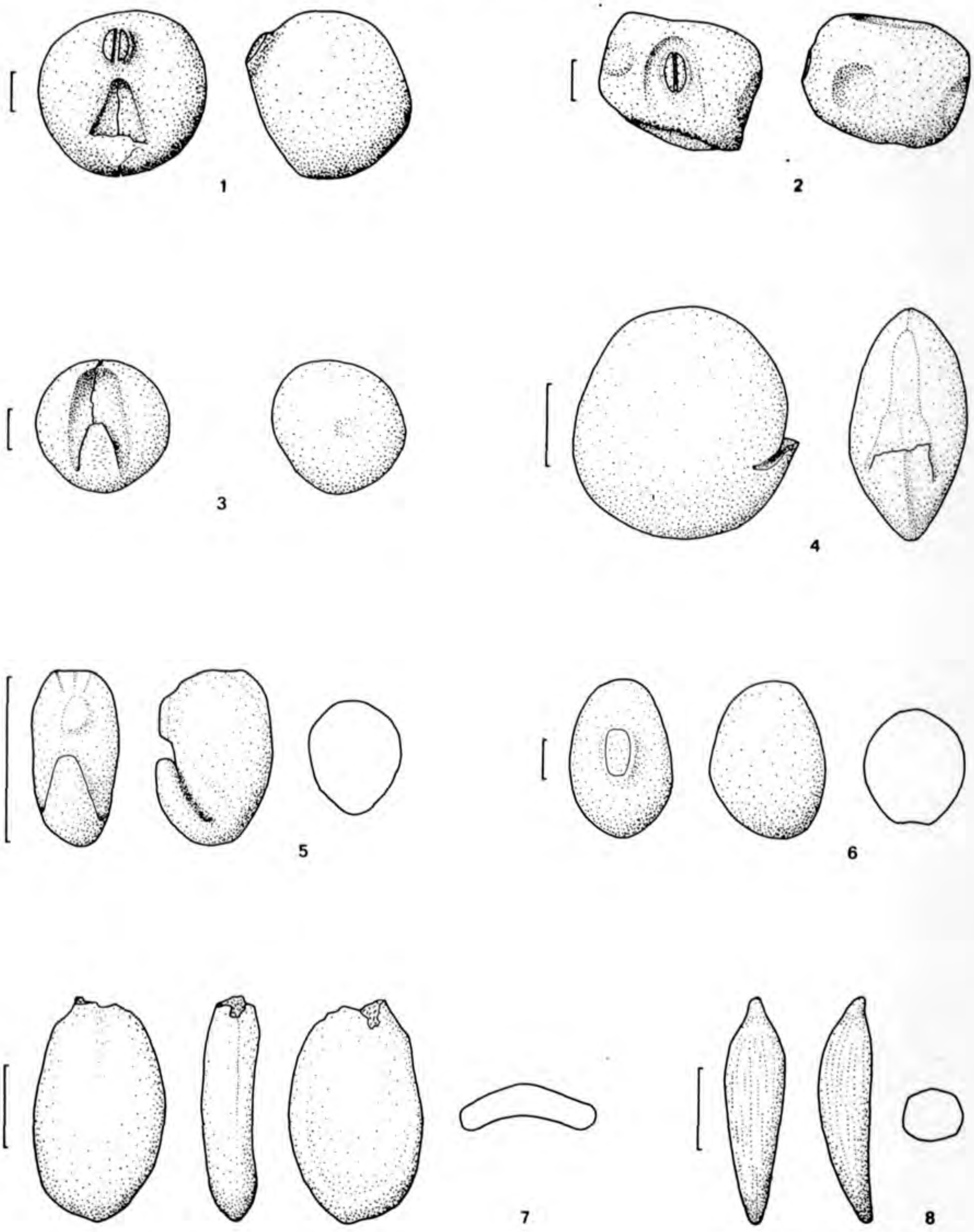


Fig. 28. Carbonized fruits and seeds from Hienheim; scale unit 1 mm. 1, 2 and 3: Pisum sativum 4: Lens culinaris 5: cf Trifolium sp. 6: Lathyrus tuverosus 7: Lnum usitatissimum 8: Lapsana communis.

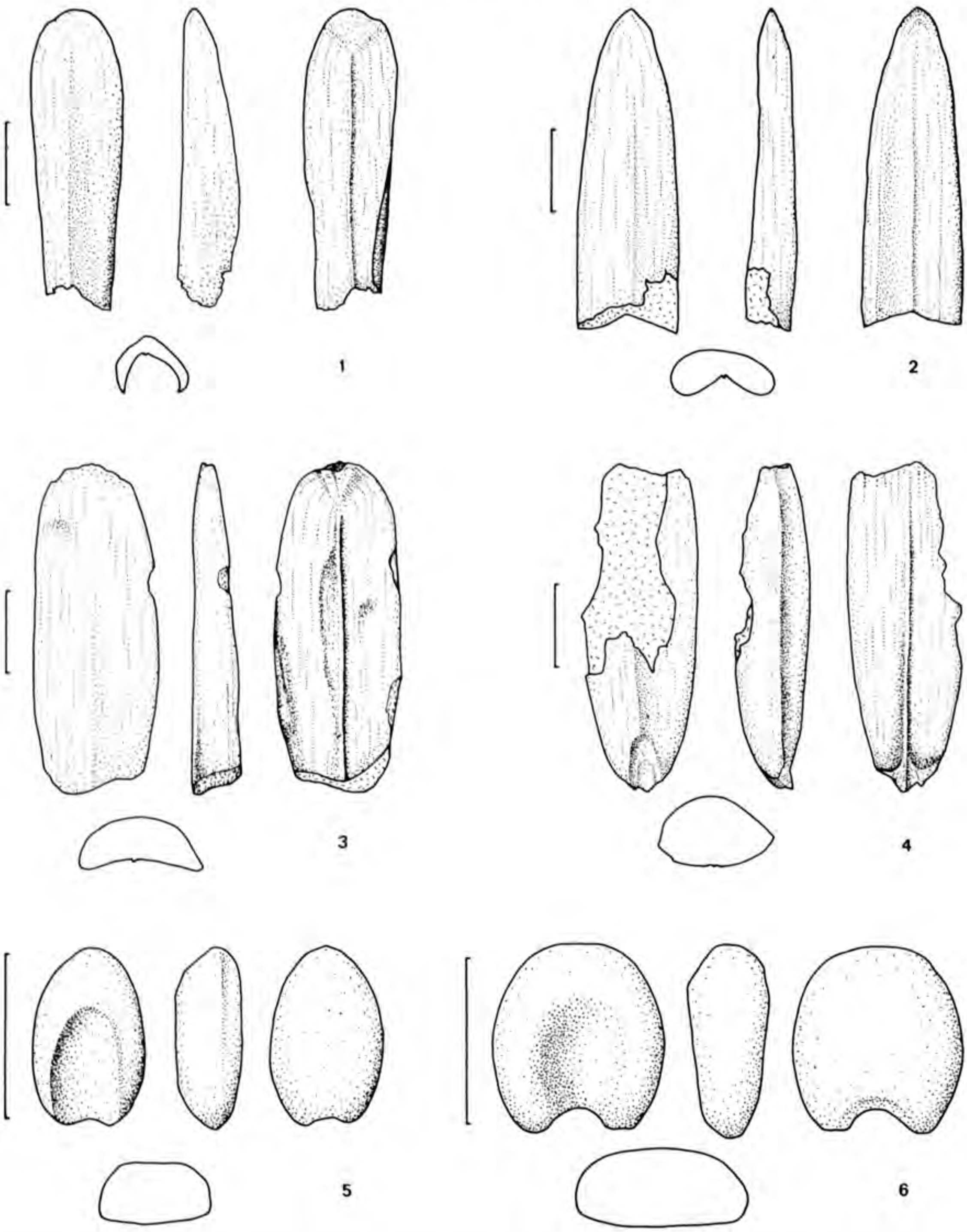


Fig. 29. Carbonized fruits and seeds from Hienheim; scale unit 1 mm. 1: Bromus cf arvensis 2: Bromus tectorum/sterilis 3 and 4: Bromus secalinus/mollis 5: Setaria viridis/verticillata 6: Echinochloa crus-galli.

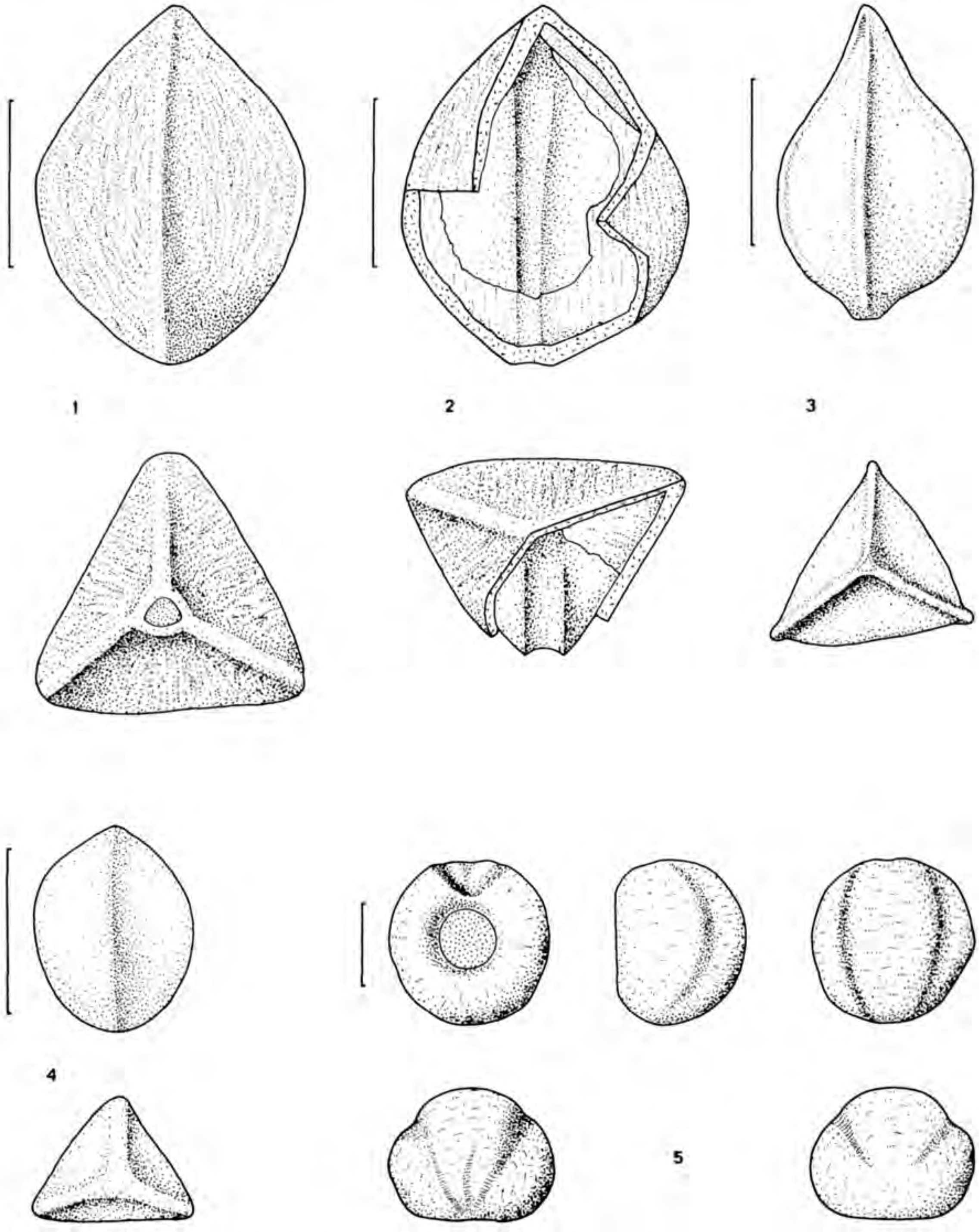


Fig. 30. Carbonized fruits and seeds from Hienheim; scale unit 1 mm. 1: Polygonum convolvulus 2: Polygonum convolvulus, damaged, true seed visible 3: Rumex sp. 4: Rumex acetosella 5: Galium spurium.

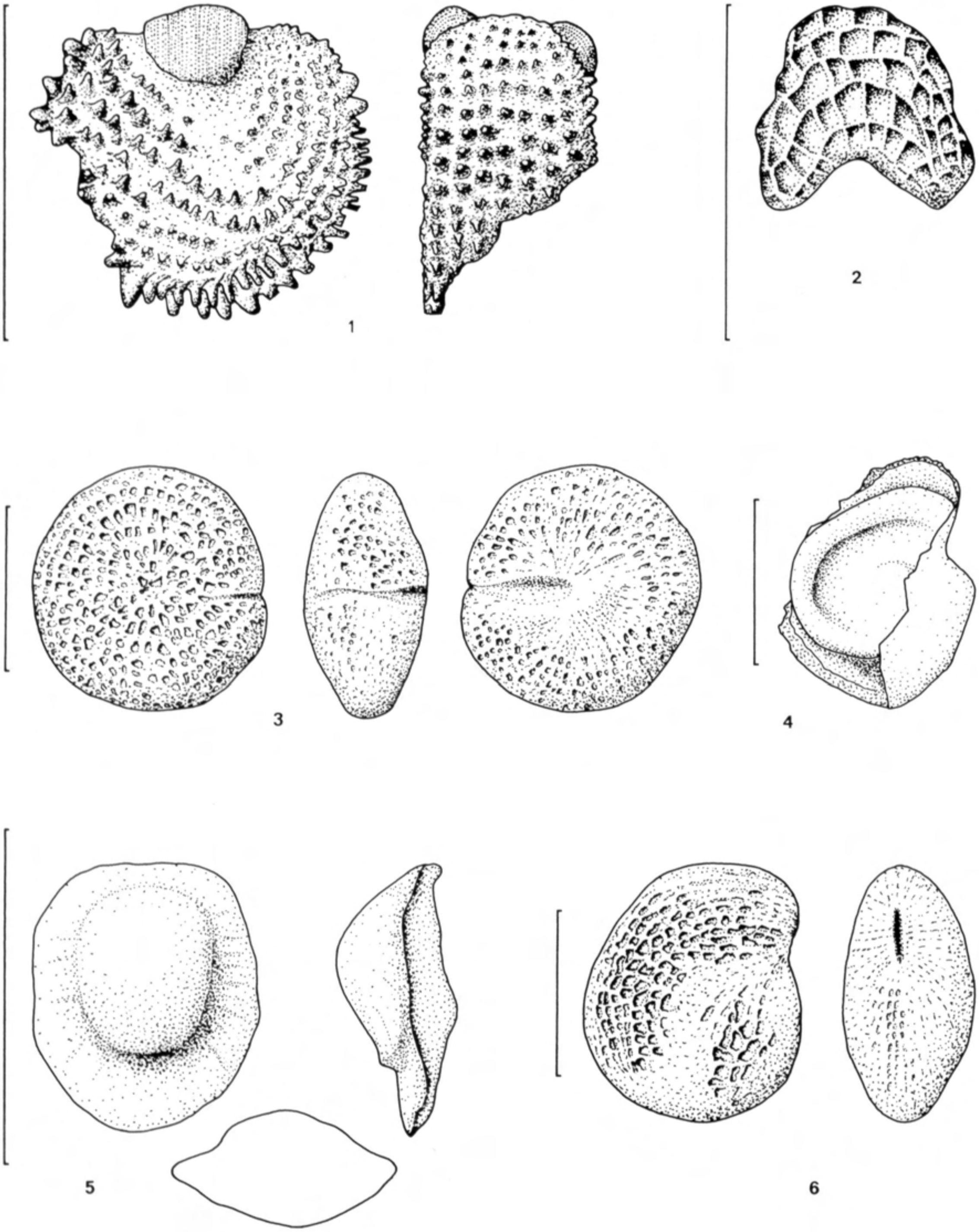


Fig. 31. Carbonized fruits and seeds from Hienheim; scale unit 1 mm. 1: Silene cucubalus 2: Papaver dubium/rhoeas 3: Chenopodium hybridum 5: Veronica sp. 4 and 6: Solanum nigrum, in 4 coiled embryo visible.

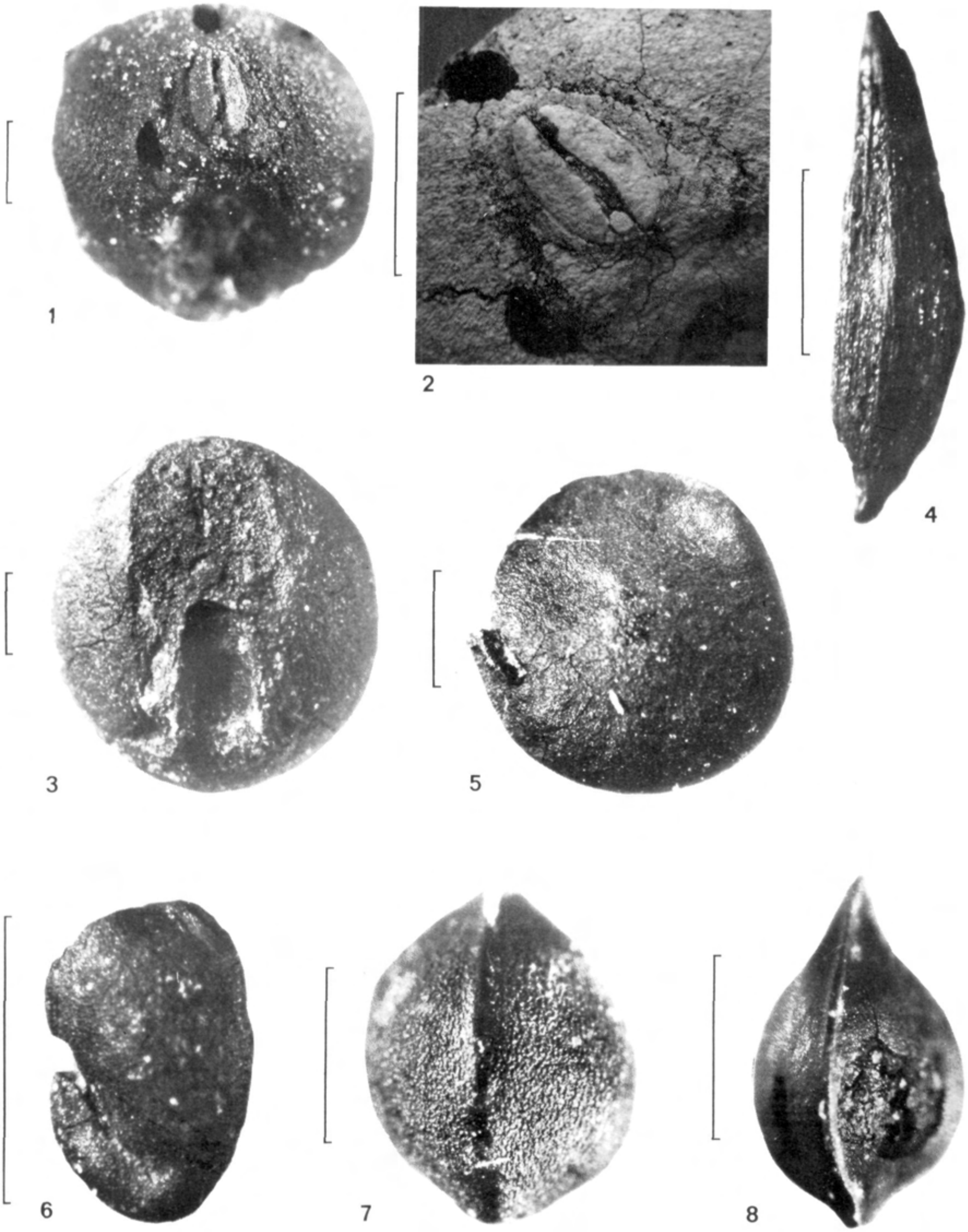


Fig. 32. Carbonized fruits and seeds from Hienheim; scale unit 1 mm. 1 and 3: Pisum sativum 2: hilum of Pisum sativum 4: Lapsana communis 5: Lens culinaris 6: cf Trifolium sp. 7: Polygonum convolvulus 8: Rumex sp.

Fig. 33. Carbonized fruits and seeds from Hienheim; scale unit 1 mm. 1 and 2: Bromus secalinus/mollis 3: Bromus tectorum/sterilis.

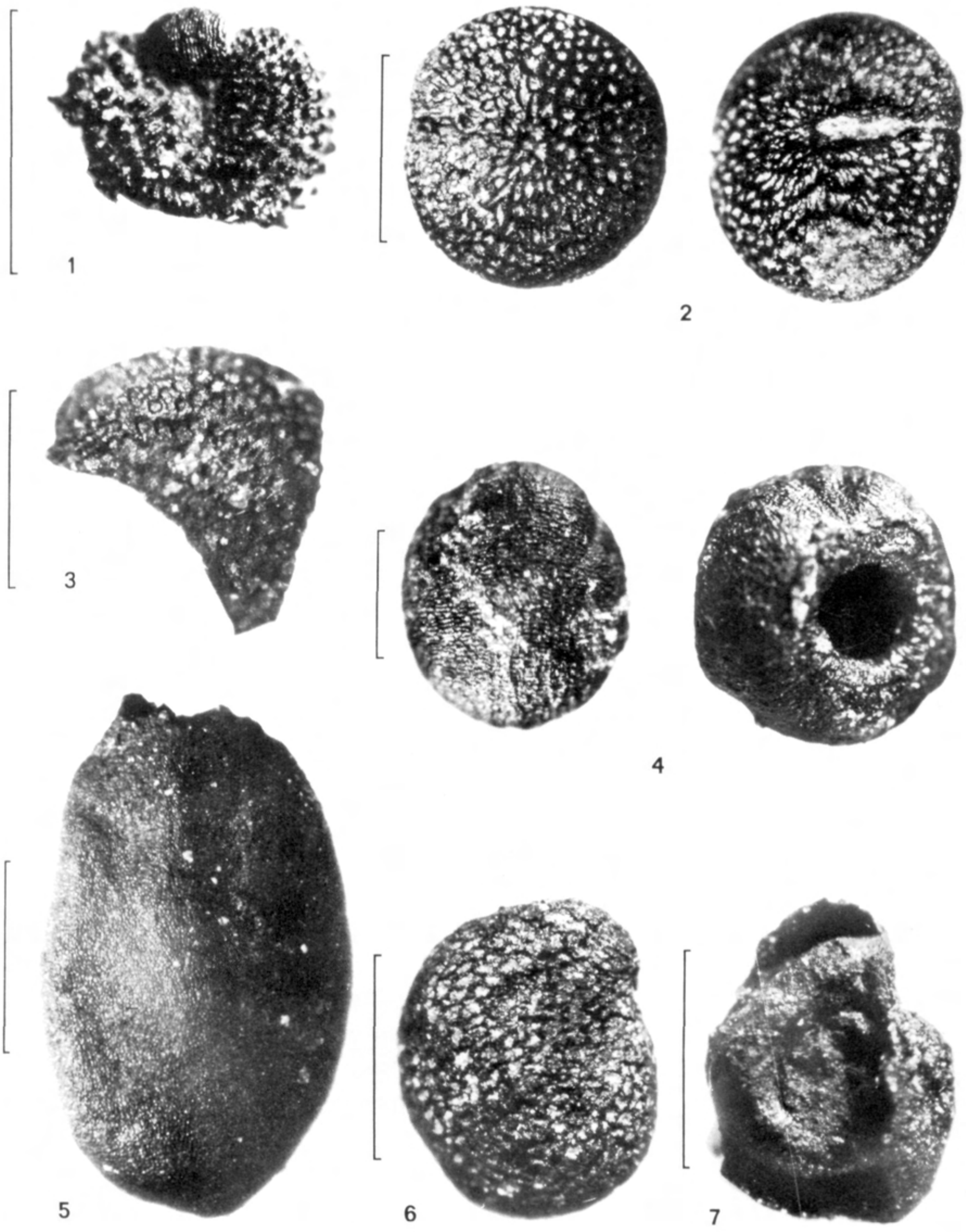


Fig. 34. Carbonized fruits and seeds from Hienheim; scale unit 1 mm. 1: Silene cucubalus 2: Chenopodium hybridum 3: Sinapsis/Brassica sp. 4: Galium spurium 5: Linum usitatissimum 6 and 7: Solanum nigrum, in 7 coiled embryo visible.

APPENDIX III
EXAMINATION OF LBK POTSHERDS FROM HIENHEIM

S. SLAGER, L. VAN DER PLAS, J.D.J. VAN DOESBURG*

INTRODUCTION

The examination relates to four LBK potsherds from the excavation "am Weinberg" near Hienheim, Ldkr Kelheim, Bayern. The excavation was carried out by a team of the Institute of Prehistory of the University of Leiden, under the direction of Prof. Dr. P.J.R. Modderman. The four potsherds come from a pit which is filled with dirty loess. The finds from this pit bear the number 325.

The description of the potsherds, according to the system used by the Institute of Prehistory, is given in table 18. It is by J.J. Assendorp. The description demonstrates that the potsherds are tempered with sand and pottery fragments; number WR 75/45 has a comparatively coarse temper with particle sizes up to 2 mm.

METHODS

A thin section was taken from the potsherds for microscopic analysis. A piece of the potsherd was ground. A part of this powder was used for chemical analysis, another part for X-ray diffraction analysis, and a third part for thermal analysis. Besides, test briquettes were fired of four clay samples from the direct vicinity of the excavation, which seemed to have good properties for the freehand forming of pottery. These clays are: loam from the decalcified illuviation zone in the loess (B2t), loam from the calcareous horizon in the loess (C2), a river loam from the valley of the Donau, and a white loam from the Hienheimer Forst. The test briquettes were fired with the purpose to verify whether the clays are suitable for making pottery. The first and the third clay indeed appeared to be suitable at temperatures up to circa 1000° C. Higher temperatures were not considered. At low temperatures, the calcareous loess gives a ceramic product that crumbles and cracks when moistened. The white loam shows so much shrinkage that this material must be considered unfit.

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Table 18. Description of the sherds.

find number	*analysis number*	*temper*				*thick-ness*	*colour and decoration*	
		sand grains size in mm		*pottery fragments size in mm*				
		< 1	1–2	< 1	1–2			
325–1	WR 75–42	x	–	X	–	4 mm	ext. surface	dark non oxidized
							core	light non oxidized
							int. surface	dark non oxidized
							decorated	
325–6	WR 75–43	X	x	–	–	6–7 mm	ext. surface	dark non oxidized
							core	dark non oxidized
							int. surface	dark non oxidized
							decorated	
325–11	WR 75–44	x	–	x	–	10 mm	ext. surface	light uncertain
							core	dark non oxidized
							int. surface	dark non oxidized
325–14	WR 75–45	X	X	x	X	8 mm	ext. surface	dark non oxidized
							core	dark uncertain
							int. surface	dark non oxidized

temper: X = main component
x = accessory material

colours based on the Munsell system
light = values 6–8
dark = values 2–5
non oxidized = chroma 1
uncertain = chroma 2–5, hue yellower than 2.5 YR

RESULTS OF THE ANALYSIS OF THIN SECTIONS

The results of the analysis of thin sections make it plausible that for the temper of the four potsherds, use was made of the same type of sand, namely a sand with a felspar content of circa 20%. An attempt to determine the degree of temper by means of microscopic analysis with the point counter provided the four figures of table 19.

Table 19. Temper of the potsherd in % of weight.

	WR 75/42	*WR 75/43*	*WR 75/44*	*WR 75/45*
quartz	17	16	23	24
felspar	4	3	5	6

The values mentioned in the table must be regarded with some reserve, because the thin sections of the potsherds have numerous small pores and it is not quite certain whether these were present from the outset or whether part of them originated as a result of the grinding off of quartz and felspar grains. The latter may occur in spite of the fact that the potsherds were impregnated with a synthetic resin before the grinding.

The temper is more clearly visible in the coarse potsherds than in the finer ones; use was made of a sand fraction with grains of up to 0.2 mm. In the finer material of potsherd WR 75/42, a very fine temper occurs with particles between 0.02 and 0.04 mm. This does not mean that the potsherds do not contain coarser grains now and then. The limits given here apply to the greater part of the grains observed in the thin section.

In addition to felspar, the sands used contain a small amount of chert fragments. It can further be said about the temper that the grains are sharp and angular. This could indicate that man obtained the tempering material by pulverizing or calcinating a solid rock.

The temper with pottery fragments mentioned in table 18 can also be observed in the thin sections. As far as temper is concerned, the fragments do not distinguish themselves from the fabric in which they were used.

Finally must be mentioned that one potsherd, namely WR 75/42, is different from the others in that its mass is microscopically rich in coarser micas (0.03 mm). It is not clear whether these belong to the body clay or to the temper.

RESULTS OF THE CHEMICAL ANALYSIS

The chemical analyses are XRF (X-ray fluorescence spectrometry) analyses. The results are given in table 20a.

As far as the results regarding the potsherds are concerned, it may be observed that the values stated want some correction, for it has been proved that the potsherds, during the long period that they were buried in the soil, absorbed clay minerals in their pores because of illuviation by soil development. This can be observed in the thin sections. However, the analysis results were not corrected for this illuviation, because no quantitative methods have been developed yet to do so in an acceptable way. But it appears from the X-ray diffraction analysis that the clay illuviation is about equally important in the four potsherds.

In one respect, the chemical composition of the four potsherds is notably different from the three clay samples (the white loam was left out of consideration), in that the P_2O_5 contents of the potsherds were much higher than those of the clay samples. This might be attributed to the fact that the potsherds come from an environment of dirty loess. The loess filling of the LBK pits has indeed a higher P_2O_5 content than the undisturbed loess. The P_2O_5 content of the latter (fertilized arable) lies between 0.13 and 0.21% with an average of 0.15 (based on 5 measurements by H. v.d. Wetering). The pit fillings have a P_2O_5 content of 0.16–0.27% with an average of 0.23%. The contents in the potsherds are thus even higher.

Furthermore it is notable that the potsherds have a much lower CaO content than the calcareous loess (C2). This makes it improbable that the calcareous loess was used as material for making pottery.

The oxides, as given in table 20a, were converted into a best-fitting mineral composition: a "norm". The calculating procedure is defined generally as a "petrochemical calculating method based on the use of equivalents" (Burri 1959). Table 20b includes the first step from the procedure followed. Table 20c gives a ceramic variant of the norm, which is applicable to coarse ceramic products which are fired at temperatures between 900° C and 1030° C. For the calculating method we refer to v.d. Plas and v. Schuylenborg 1970. The variant starts from the following phases: felspars, wollastonite, hematite, mullite, cordierite, forsterite and quartz. A composition on the basis of these phases offers a better possibility of comparison than one on the basis of oxides. To illustrate this, one may compare the quartz contents from table 20c with the SiO_2 contents from table 20a.

The figures in table 20c show that the quartz contents of the four potsherds are different. The highest

Table 20a. Chemical analyses of the four sherds, three clay samples and loam from a pit, filled with settlement waste, % of weight.

	WR 75/42	*WR 75/43*	*WR 75/44*	*Wr 75/45*	*B2t*	*C2*	*pit*	*river loam*
SiO_2	60.29	64.87	59.60	74.12	70.59	64.42	68.44	72.48
Al_2O_3	15.75	14.51	16.75	10.52	13.48	9.24	10.69	12.73
Fe_2O_3	5.84	4.87	6.17	4.73	5.40	3.63	4.20	5.02
MnO	0.03	–	0.04	0.01	0.09	0.08	0.12	0.12
MgO	0.79	1.04	1.50	0.82	1.88	1.74	0.99	1.66
CaO	2.22	1.62	2.44	1.15	1.16	5.12	1.50	1.01
Na_2O	0.44	0.03	0.18	0.11	–	–	–	–
K_2O	2.40	1.98	2.27	1.44	2.64	1.92	2.39	2.23
H_2O*	5.09	6.24	4.06	4.05	4.13	11.10	10.53	4.51
TiO_2	0.91	0.79	0.86	0.69	0.75	0.56	0.67	0.87
P_2O_5	6.28	2.32	3.88	1.54	0.16	0.18	0.26	0.27
	100.04	98.27	97.92	99.18	100.28	97.99	99.79	100.90

* loss on ignition

Table 20b. Basic composition.

Cp or P	5.50	2.09	3.92	1.35	0.35	0.42	0.60	0.68
Ru	0.71	0.63	0.67	0.54	0.57	0.47	0.55	0.66
Kp	9.48	8.07	9.06	5.73	10.23	8.25	10.05	8.64
Ne	2.64	0.18	1.08	0.66	–	–	–	–
Cal	7.38	5.55	8.16	3.84	1.58	14.16	4.20	2.07
Sp	3.66	4.95	6.99	3.81	8.52	–	4.86	7.53
Cs	–	–	–	–	–	1.77	–	–
Fo	–	–	–	–	–	4.35	–	–
Fa	–	–	–	–	–	0.12	–	–
Fs	6.86	5.85	7.31	5.55	6.30	4.59	5.37	5.90
C	7.78	8.43	7.08	5.63	6.47	–	4.43	5.93
Q	55.99	64.26	56.24	72.90	65.99	65.33	69.94	68.62

Cp = apatite
Ru = rutile
Kp = kaliophilite
Ne = nepheline
Cal = calciumaluminate
Sp = spinel
Ca = larnite
Fo = forsterite
Fa = fayalite
Fs = ferrisilicate
C = corundum
Q = quartz
P = phosphorus

Table 20c. Ceramic variant of the "norm," valid for 900° C; calculations based on the chemical analysis.

Q	40.29	50.36	38.78	62.87	50.96	51.33	55.23	55.38
Or	15.80	13.45	15.10	9.55	17.05	13.75	16.75	14.40
Plag	9.27	5.38	8.00	7.50	2.63	23.60	7.00	3.00
Mull	14.24	13.45	13.39	7.51	8.63	0.00	7.38	7.91
Cord	6.71	9.08	12.81	6.99	15.62	Fo 4.47	8.91	13.80
Woll	2.90	1.67	2.96	0.00	0.00	2.36	–	–
Hm	4.58	3.90	4.87	3.70	4.20	3.06	3.58	3.93
Ru	0.71	0.63	0.67	0.54	0.57	0.47	0.55	0.66
(Felsp)	(25.07)	(18.83)	(23.10)	(17.05)	(19.68)	(37.35)	(23.75)	(17.40)
P	5.50	2.09	3.42	1.35	Cp 0.35	Cp 0.42	Cp 0.60	Cp. 0.68

Q = quartz
Or = orthoclase
Plag = plagioclase
Mull = mullite
Cord = cordierite
Woll = wollastonite
Hm = hematite
Ru = rutile
(Felsp) = felspars, orthoclase + plagioclase
P = phosphorus
Fo = forsterite
Cp = apatite

calculated quartz content is 62.87% and the lowest is 39.56%. The contents become lower if the somewhat arbitrary wollastonite is left out and calcium aluminate (Cal) is converted entirely into anorthite. To allow comparisons the Cal values have also been included (table 20b). These Cal values show that definitely less calcium felspars can occur in WR 75/45. It is to be noticed that with respect to the measured quartz contents, the data from the X-ray diffraction analysis differ partly from the contents calculated on the basis of the norm. The quartz contents, registered in the arbitrary unit of counts per time unit, are 29, 33, 35 and 40 for WR 75/42, WR 75/43, WR 75/44 and WR 75/45 respectively. The diffractograms confirm that the potsherd WR 75/45 contains significantly less felspar than the other three.

Conspicuous is also the rather constant content of normative mullite in the potsherds WR 75/42, WR 75/43 and WR 75/44, and its low content in WR 75/45. One may assume that the content of normative mullite gives information about the quantity of kaolinite which was originally present in the clay. Apparently the material of which WR 75/45 was made, contained both less felspar and less kaolinite, whereas the content of quartz must have been higher. One wonders whether this conclusion will hold after a correction for the temper, as it is obvious that the contents of felspar and quartz in the potsherd are the result of an addition of the quartz and felspar contents of the clay and of the temper material. However, the results of the microscopic analysis with the point counter indicate that the differences cannot be attributed to the temper material. Another way to study the effect for WR 75/45 is to lower the normative quartz content to the average value of the four potsherds: 48.08. When the sum of the normative phases is then brought back to 100%, the mullite content and the felspar content are still too low in comparison with the values found for the other potsherds. The mullite content then becomes 8.8 and the felspar content 20.0.

RESULTS OF THE X-RAY DIFFRACTION ANALYSIS

After grinding, diffractograms were made of these potsherds with a Guinier de Wolff Camera. The powders were also calcinated at 600° C and at 1000° C and then photographed again. Finally, diffractograms were made of the clay fractions and of the sand fractions of the three earlier mentioned clay samples and of test briquettes fired at circa 1000° C in an oxidizing atmosphere. Diffractograms of the powders of the potsherds and of the clay samples give an insight in the semi-quantitive mineralogical composition of the potsherds and of the clay. In the untreated potsherd samples, the mineral quartz, plagioclase, microcline, wollastonite and diopside are found besides the illuviated illite.

Conspicuous is the absence of both hematite and spinel (which originates by burning kaolin). Also mullite, cordierite and magnesium-containing phase were not found. Because of the high phosphorus content, a thorough search was made for possible phosphates. Crystalline phosphates are apparently absent in the analyzed potsherds. Finally, the large quantity of calcium suggests the presence of gehlenite, which was not found.

After calcination, the potsherd samples no longer show lines of micas, or illite. But mica is clearly visible in the thin sections, so that it might be expected that at this low temperature the mica which has come with the coarse sandy temper, would still be visible. Since this is not the case, it can be suggested that because of the termal treatment in the past and the subsequent chemical influence of the soil development, the still-visible mica has lowered heat-resistance. Muscovite does not normally disintegrate until 800 to 900° C.

The diffraction pattern contains no crystalline iron minerals such as goethite, magnetite or hematite. Also heating to 600° C does not let these phases develop, although goethite, when present in the amorphous state (in which it is, as appears from the microscopic analysis), converts into hematite at circa 330° C. Only after heating to 1000° C do lines of hematite occur in the pattern. Weak lines of hematite occur in the test briquettes fired of clay.

The above indicates that the pottery must have originated in a partially reducing environment at temperatures higher than circa 550° C but lower than circa 900° C, the temperatures at which gehlenite and cordierite develop. The absence of hematite and crystalline goethite does not necessarily point to low temperatures, because the hematite, which was present in the test briquettes and which developed at high temperatures, can very well have been reconverted into non crystalline goethite because of its long stay in the soil.

The results regarding the quartz and felspar contents have been given already on p. 197.

The X-ray diffraction analysis of the B2t and the C2 of the loess, and of the river loam, shows that both loess samples are characterized by a relatively high kaolinite content besides considerable amounts of montmorillonite and illite. The river loam has less clay fraction than the other samples, but the composition of the clay fraction is not different from the rest. A table of the peak areas shows the shares of the three clay minerals in the three samples (table 21). No quantitative ratio of the clay minerals should be concluded from these peak areas. They only give an indication of the relative increase and decrease.

Table 21. Relative ratio of the peak areas of the clay fraction of the three clay samples.

	Kaolinite	*Illite*	*Montmorillonite*
C2	14	10	76
B2t	8	16	76
river loam	12	14	74

A diffractogram of the fraction larger than 50 μm of the clay samples shows that they contain almost no felspar. Many felspars are found, however, in the fraction smaller than 50 μm of the loess. These felspars are the same as those found in the potsherd powders. The felspar assemblage of the river loam is clearly different.

RESULTS OF THE THERMAL ANALYSIS

TG and DTA analyses were made of the ground potsherd samples. The results are given in figure 35 and figure 36. The TG analyses show that the heating to 1000° C causes the following losses of weight:

WR 75/42 – 9.6%, WR 75/43 – 6.8%, WR 75/44 – 4.5% and WR 75/45 – 4.7%. At a heating of 20°/min, the loss of weight has disappeared at circa 500° C. Part of the loss of weight must be attributed to the loss of the water which the potsherd has absorbed in the soil in the course of time, some of which is rather firmly bound. Further, the dehydration of the illuviated clay minerals and of the possible present amorphous goethite plays a part. The disappearance of carbon must also be taken into account.

The DTA analysis shows a loss of moisture between 100° C and 170° C, followed by a more or less pronounced exothermic reaction. Especially WR 75/43, a thoroughly dark-coloured, almost black potsherd, shows this exothermic reaction very pronouncedly. The reaction is attributed to the disappearance of carbon. WR 75/43 must have been a sample rich in carbon. The carbon-content and thus the black colour can have been caused by the smothering of the pottery. It is known that pottery which is

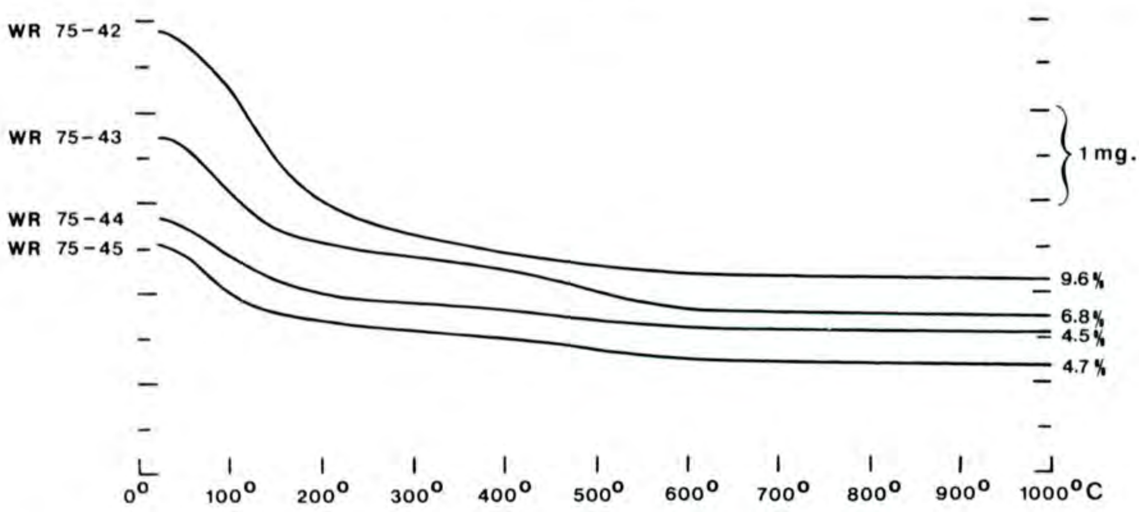

Fig. 35. Results of the TG analysis of four LBK sherds from Hienheim.

reduced at a lower temperature, e.g. in hay or saw-dust, immediately turns thoroughly black because of the reduction of the iron to FeO, wüstite, and as a result of absorption of carbon by the potsherd. This carbon can be removed again by burning.

Reactions of clay minerals or carbonate have not been found in the thermal analyses and are not to be expected either, in view of the results of the X-ray analysis.

An X-ray diffractogram at rising temperature was taken of one sample, WR 75/42. The result of this analysis provided no new information, so that this method has been left out, for the time being, for the other samples.

DISCUSSION AND REMARKS

On the basis of the mentioned methods, the question which materials were used for making the four LBK potsherds can be answered partly. The white loam from the Hienheimer Forst does not qualify because of its poor firing behaviour. It is rather certain that the calcareous C2 loess was not used either. The Ca content of this material is too high and besides, the ceramic product made of the C2 loess is of poor quality. The analyzed river loam contains other felspars than those found in the potsherds, and perhaps it also has a too small clay fraction to be the raw material. The B2t loess has the best qualities. The felspar content of this loam corresponds in many respects to that of the potsherds. However, the clay which was used, must have been slightly more calcareous than the present B2t. As we do not know yet which treatment the occupants of the excavated settlement used to make their clay suitable for the manufacture of pottery, it cannot be said with absolute certainty that the local loess was used. What is certain is, that the loess must have undergone a special treatment to reach the composition as found in the sherds. This can be concluded from the high P_2O_5 content of the potsherds. A temper with bone was thought of in the first place.

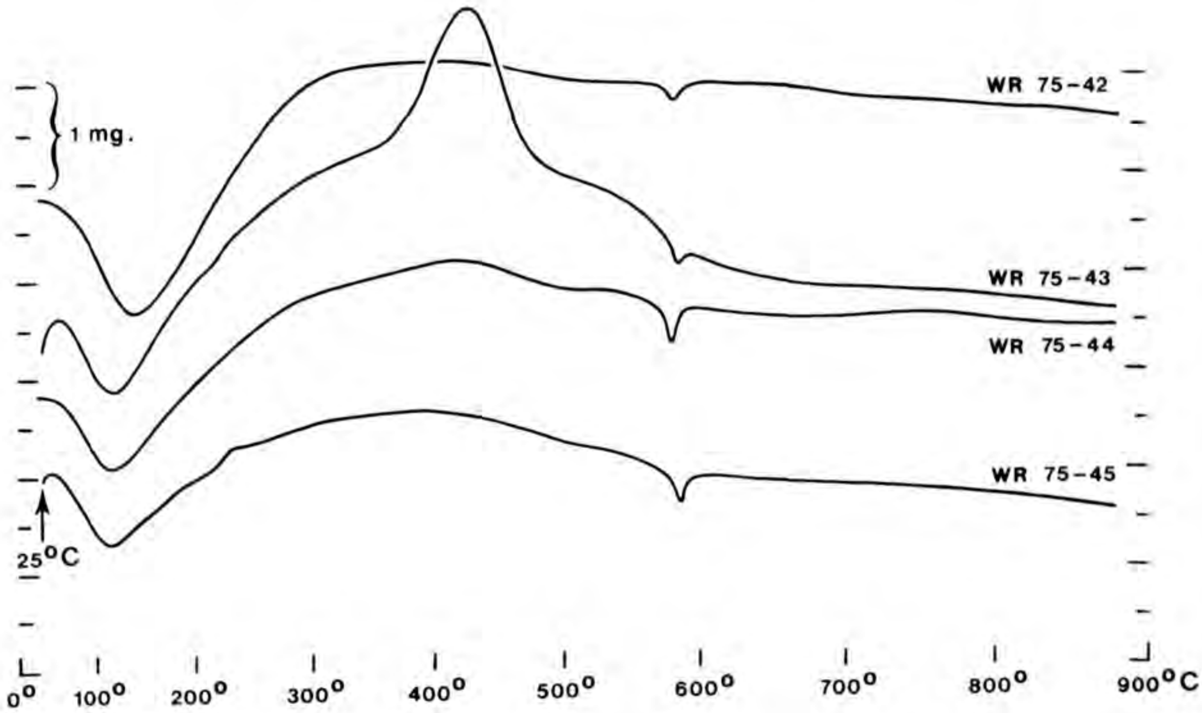

Fig. 36. Results of the DTA analysis of four LBK sherds from Hienheim.

If a temper with bone is assumed to explain the high phosphorus content and if $Ca_{10}(PO_4)_6(OH)_2$ is taken as average bone composition, then one introduces 10 calcium ions with each 6 phosphorus ions, or, to stay within the terms of the calculation, each cation per cent phosphorus means 1.7 cation per cent calcium. This subsequently means 5.1% Cal. and finally 8.5% calcium felspar or anorthite and the necessary decrease of the calculated quartz content and demonstrates that a B2t loess with a temper additive of ground bone must have received a considerable enrichment in calcium. That calcium content is amply sufficient to explain the difference in calcium content between the present B2t and the found potsherds. In general, it can even be said that the calcium contents of the potsherds are too low to assume that the high phosphorus content can be attributed exclusively to the addition of fresh bone meal. In this connection, it must be noticed that it is possible that a part of the lime was converted into CaO and subsequently dissolved when the pots were used. It is conspicuous, however, that the pots were not cracked by the hydrolysis of this CaO.

Finally it is also possible that calcinated bones were used as temper material. Calcination followed by leaching with water, before the material is added to the clay, can lead to an enrichment in phosphorus without all calcium contained originally in the bones ending up in the pottery.

The results also provide some information about the firing process. The potsherds must have developed in a reducing environment at temperatures between 550° C and 900° C. Such an environment can be created with a fire which is laid in a hole in the ground and covered later with straw or sods. A test-firing of pots, made according to this method with loess from Hienheim, showed that the pottery made in this way was not very different from the excavated potsherds.

As the examination was restricted to four potsherds from one single pit, the conclusion should not be drawn that these results are generally valid. It is necessary to submit large numbers of potsherds from as many pits as possible to a comparable examination. This work has been started in the meantime. Moreover it is desirable to carry out certain firing tests.

APPENDIX IV

PETROGRAPHY AND POSSIBLE ORIGIN OF ADZES AND OTHER ARTEFACTS FROM PREHISTORIC SITES NEAR HIENHEIM (BAVARIA, GERMANY) AND ELSLOO, SITTARD AND STEIN (SOUTHERN LIMBURG, THE NETHERLANDS)

C.E.S. ARPS*

INTRODUCTION

The main objective of the present study is to correlate prehistoric artefacts with a possible geological source. Petrologically artefacts are rock fragments and before discussing their origin, two important aspects should be mentioned. Firstly the term "source" or "origin" may be interpreted differently by geologists and by prehistorians. Secondly the prehistoric artefacts investigated are in fact always selected samples.

What may have happened to rock material of archeological importance between its geological formation and the moment that certain parts are found as artefacts?

Prehistoric artefacts are generally made of carefully selected rock types, which are exceptional varieties of igneous, metamorphic or sedimentary rocks. The commonly selected rock types may have been quarried at the sites where they were originally formed by the rock-forming processes in the earth's crust (referred to as geologically primary sources; fig. 37) or may have been found as boulders or pebbles transported by exogenous geological processes, such as flowing water or ice, (far) away from the original place of formation. These rock fragments (boulders, cobbles, pebbles) in sediments (referred to as secondary sources) offered prehistoric man a natural choice of hard and tough materials that appeared to be very resistant to weathering and wearing by erosion and transport.

With the exception of the finds in prehistoric quarries the selected samples may have been transported by man ("trade") over considerable distances. It is also possible that the material passed through more than one prehistoric site before it reached its ultimate owner, i.e. the place where it was ultimately found. From the above it is obvious that the "source" of the investigated artefacts is often highly speculative.

Most artefacts from the sites investigated are made of chert, quartzitic rock, basalt and amphibolite. Chert, quartzite and quartz arenite or "sandstone" occur in almost all European countries as primary and/or as constituents in secondary deposits (sedimentary deposits). Primary basaltic and especially amphibolitic rocks occur geologically in more restricted areas (see later). The rock components of sedimentary deposits were transported by glacial ice (Pleistocene) and/or rivers in different directions. Glacial deposits in the northern part of Central Europe are northern in origin (Scandinavia; enclosures 6 and 7) and include all the above-mentioned rock types.

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	origin of the rock	*aspect of the rock*	*processes*
A	geologically primary source: crystalline basement	more or less fresh outcrops	rock forming processes in the earth's crust
B	geologically secondary source: sedimentary deposits	selected boulders, cobbles, pebbles	selection by geological process, i.e. weathering, erosion, transport
	.... (human interference)		
AX/BX	sampling site or quarry	i.e. rock fragments	human selection
			human transportation (further selection)
Y	workshop	waste, rough-outs, implements	
			human transportation (further selection)
Z_1	place of use (e.g. settlements)	implements, reworked implements, waste	
			human transportation (further selection)
Z_2	second place of use	implements, reworked implements, waste	
	etc.	etc.	

Fig. 37. Complications in the search for "the source" of prehistoric artefacts.

It appears, however, that the artefacts found in the prehistoric sites mentioned in this article are Central European in origin as will be discussed in later paragraphs.

AVAILABLE PREHISTORIC ARTEFACTS

HIENHEIM

All the adzes, adze fragments, rough-outs and waste material excavated at the Hienheim prehistoric site and classified as belonging to the Linearbandkeramik culture (LBK) were made from amphibolitic rocks. Adzes of basaltic rock or black siliceous shaly rock were not encountered, although some of the known outcrops of basaltic rock lie only 115 km NNE of Hienheim (encl. 7; Strunz 1975). The quern fragments consist of unmetamorphosed quartz arenites and quartzite.

ELSLOO, SITTARD AND STEIN

In contrast to the Hienheim prehistoric site, the implements found at the LBK sites in the southeastern part of the Netherlands were made not only from amphibolitic rock but also from basaltic and siliciclastic rocks, i.e. (meta)quartzites and black siliceous shales including lydite.

Fragments of querns and grinding-stones consist of unmetamorphosed quartz arenites and quartzites.

PETROLOGICAL INVESTIGATIONS

The available prehistoric artefacts were investigated with the aid of a low-magnifying binocular microscope; only a few thin sections were cut for further analysis.

When possible the thin sections from amphibolites were made by cutting the rock fragments perpendicular or oblique to the foliation plane (lineation), an important prerequisite when such rocks are compared in any detail.

All the relevant information concerning the amphibolitic and basaltic artefacts was grouped according to the properties of the constituent minerals, the rock structures and other properties; see tables 22 and 23 (enclosures 8 and 9). A selection of photo(micro)graphs of surface textures and internal features have been added as important sources of information for correlation.

To obtain conclusive evidence of the correlations, more extensive methods (mainly geochemical) seem inevitable for future investigations. Trace element analysis and pattern recognition (de Bruin et al. 1972) might possibly be applied successfully for correlation of basaltic and amphibolitic material. A serious objection to most investigations is that the methods are generally destructive, although it is always possible to limit the "damage".

Finally it must be emphasized that a broad reference collection of archeologically "proper" source rocks is of primary importance for any effective correlation.

The investigations carried out for this study included only the more conventional methods; moreover the relevant proper reference collections are still small. The conclusions made here must to a certain extent be regarded as preliminary.

AMPHIBOLITES FROM CENTRAL EUROPEAN SOURCES

Amphibolites are dark-coloured metamorphic rocks generally displaying a schistose structure, i.e. parallel orientation of the dark minerals (amphiboles, biotites).

Calcareous sediments and basic rocks of plutonic origin, like gabbros, or of volcanic origin, like basic tuffs, basalts, etc. and basic dikes or dolerites, may change progressively (metamorphism) into amphibolites due to increasing pressure and temperature. It is also possible that the amphibolites are the result of a retrogressive metamorphism of rocks of a higher metamorphic grade (granulites, eclogites). Metamorphic processes occur on a regional scale in crustal areas of mountain-building. The ultimate metamorphic product may be isochemical with respect to the parent rocks, but it is also possible that the chemical composition has changed (metasomatism). It should be stressed that the above-mentioned genetic aspects of the metamorphic rocks, e.g. amphibolites, play an important role in the evaluation of the geological source and history of the material investigated.

As amphibolites may occur in all metamorphic terrains, the level of crustal erosion will determine whether amphibolites are encountered or not. Both the Alps and the Carpathians are part of a geologically young mountain range (Alpine Orogen); the originally deeper parts now cropping out on the Earth's surface often contain amphibolitic rock. But nearer to the prehistoric sites of the present study the remnants of an older mountain range crop out, i.e. the Variscan or Hercynian Orogen of Central Europe (encl. 6). Amphibolites from the Variscan have also been found in many localities and, as can be seen from the map, they occur most frequently in the southeast and are absent in the northwest.

THE VARISCAN OROGEN IN CENTRAL EUROPE

This old mountain range can be divided geotectonically into several zones (Lotze 1971); parts of these zones crop out and are known to us under regional names. They are indicated on the map (encl. 6).

To the northwest the Rhenohercynian Zone includes the Ardennes-Rhine Massif, the Hunsrück-Taunus Massif and the Harz. Deformation structures trend NE-SW and only the southeastern rims of the Hunsrück, Taunus and Harz display a low-grade metamorphism.

Adjacent to the former zone is the Saxothüringen zone which contains crystalline basement rocks of low to medium-grade metamorphism with NE-SW structures. The Vosges, Black Forest, Odenwald, Spessart and the northwestern part of the Bohemian Massif belong to this zone while the Sudeten Range and Silesicum can be explained as a NW-SE trending continuation (Vejnar 1971). The Münchberger Mass and the Granulitgebirge are basement cores of a higher metamorphic grade. Farther to the southeast the Moldanubian Zone, structurally heterogeneous, consists of basement units with different orogenic and metamorphic histories. To the west the Oberpfalz Forest, Bavarian Forest and Bohemian Forest have NW-SE structures and show a medium to high-grade metamorphism.

From the above it is apparent that the deepest parts of the Variscan are exposed in the southeastern part of the range. Age determinations and structural-petrological data indicate that parts of the basement are polymetamorphic, i.e. underwent earlier (Pre-Variscan) phases of deformation and metamorphism (Vejnar 1971; Stettner 1975).

BASALTIC ROCKS IN CENTRAL EUROPE

The volcanic rocks of Central Europe, which grade from acid to (ultra) basic types, were extruded roughly during two main periods of volcanic activity.

The older volcanic activity was connected with the Variscan Orogeny. It started with initial magmatism (basic rocks) in zones of geosynclinal sedimentation lasting from the Lower Devonian to the Lower Carboniferous – e.g. in Sauerland, Harz, Schiefergebirge, Vosges, Thüringen, etc. – and continued mainly in the Permian with magmatism as a result of block movement in the already rigid Variscan Orogen (Knetsch 1963); locally this caused large-scale extrusions of quartz porphyries, basalts, etc., e.g. in the Saar-Nahe area.

The younger period of volcanic activity, lasting from the Upper Cretaceous to the Quaternary, is again closely connected with large-scale crustal dislocations in a zone west and north of the Alpine Orogen. The centres of volcanism were restricted mainly to areas near or within graben(-like) structures, e.g. the French Central Massif, the Rhine Graben and Hessian Depression, and the Northwestern Bohemian Massif (encl. 7). These volcanic rocks can be found not only as extrusions near the graben but also at the junctions of cross-cutting fault systems. The main Central European Tertiary volcanic districts are the Hocheifel - Nordeifel - Siebengebirge area, Vogelsberg, Westerwald, Rhön - Lower Hessen area, Kaiserstuhl, Doupovké Horý, České Středohoři and the Lausitz-Silesian area. Volcanism in the Laacher See area and the Western Eifel is of Quaternary origin.

Petrologically the European neovolcanic rocks are alkaline rocks whereby alkali olivine basalts form the major rock type. They occur in specific associations, e.g. olivine basalt – tephrite – phonolite, which are representative of relatively stable crustal areas with major faulting (Wimmenauer 1972, 1974). Many basalts were intruded (sub-volcanic) as dikes and dike swarms, while basaltic volcanic plugs as well as basaltic lavas and tuffs also occur.

HIENHEIM

AMPHIBOLITIC MATERIAL

A total of sixty-six amphibolite samples, sixty of which were classified as LBK, was available for examination. Thin sections were made from twenty fragments.

Description of the samples

On the basis of grain size, structure, polish and colour of the patina,[1] this population has been tentatively subdivided into two main groups of 21 (including 7 thin sections) and 45 (including 13 thin sections) specimens, respectively.

Macroscopically the members of the first group are very fine grained with thin and often irregular layering. Leucocratic more coarser grained layers and cross-cutting veinlets are common. Due to these properties the artefacts display a fine polish and a splintery fracture (fig. 38). On the basis of the colour of the patina a further subdivision was made. The implements vary from light brownish green (Ia) and brownish green (Ib) to dark grey (Ic).

[1] The use of surface polish and patina colour for the classification of artefacts is hazardous due to differences in weathering conditions at different places and levels of the site.

Group Hienheim I consists of the following samples:

I a: 1140–2, 1140–3, 511, 344 t.s.[1], 550, 183–1 t.s., 359* t.s. and 728

I b: 1063–1, 699 t.s., 183–3, 183–2 and 265,
721–1, 764–1 t.s. and 530* t.s.

I c: 726–1 and 1089,
349, 380 and 266 t.s.

A subdivision of the implements of the second group was based upon the grain size. They vary from very fine grained (IIa), a slightly coarser grain (IIb) to more coarser grained (IIc). The individual differences in grain size of the mineral constituents may be pronounced, especially within the more coarser grained samples. Individual minerals and mineral clusters may be visible with the naked eye (fig. 38). The implements of the second group also vary in colour from light green and brownish green to dark green. The surface polish is not as smooth as that seen in the first group.

Group Hienheim II consists of the following samples:

II a: 307–1, 545, 1083 t.s., 182–2 t.s., 715*, 737, 607, 720, 602, 292–1 t.s., 1063–3 and 593

II b: 206* t.s., 526, 182–1, 729, 726–2, 929 t.s., 1062 t.s., 1063–2 t.s., 271, 764–2, 292–2, 489, 401,
617 and 1082–2

II c: 307–3, 477, 412, 721–2 t.s., 476, 685* t.s., 701, 703,
1140–1 t.s., 1082–1 t.s., 12, 325 and 307–2

II d: 718* t.s., 919 t.s., 748, 343 and 921

The samples of subgroup IId are rather irregular with respect to grain size, structure and colour. Sample 748 is a rough-out that contains relatively large porphyroblastic hornblende clusters and brown hornblende is the main constituent of adze 343.

Thin section analysis

The mineral composition and other petrographic properties of the amphibolites are listed in table 22 (enclosure 8). A sharp demarcation between the two implement groups with respect to mineral composition and properties is not present, although each group displays certain characteristics.

The most important constituent in all the amphibolites is an almost colourless to light bluish-green *hornblende*. The almost colourless (*actinolitic*) hornblende is especially abundant in the amphibolites of the first group, while bluish-green hornblende is more abundant in the second group, especially in the more coarsely grained varieties. The textural pattern of the hornblende is highly characteristic. It may occur firstly as individual needles or sheafs oriented parallel to the foliation or (more often) at random, secondly as microcrystalline crystal aggregates with bushy outlines (fig. 42), and thirdly as an irregularly shaped coarser variety (fig. 43).

Amphibolites rich in radial or sheaf-like hornblende clusters (fig. 44) are known in German literature as "Strahlsteinschiefer" (Bauberger et al. 1973). The larger crystals or sheafs are particularly well-developed when they occur together with recrystallized quartz and albite (fig. 45). Sometimes relatively larger hornblende porphyroblasts have developed (fig. 46).

[1] t.s. = thin section

* not LBK

The larger hornblende grains display a deeper blue-green colour. In a few cases traces of an older brownish hornblende are visible.

After hornblende the main constituents are ore minerals, quartz and/or plagioclase (albite). A typical aspect of almost all the amphibolitic implements is the presence of numerous *ore mineral* grains or clusters. Ore minerals in Central European amphibolites were identified by Scholz (1968) as mainly ilmenite, with some magnetite and pyrite, and by Štelcl et al. (1970) as arsenopyrite. *Quartz* is either fine grained or recrystallized. A polygonal or mosaic fabric of recrystallized quartz in layers or lenses is often characteristic.

Plagioclase (albite), seldom twinned, may also occur as small grains throughout the rock or concentrated with quartz in layers and lenses. An initial porphyroblastic recrystallization may be observed.

Epidote is generally present in variable amounts but seems more frequent in the first group. In addition to saussuritic masses relatively large crystals occur. Other constituents are *biotite*, *chlorite*, *muscovite* and *titanite*, the latter sometimes as numerous small rounded grains concentrated in quartz and feldspar.

In thin sections layering or foliation is generally clearly visible and sometimes pronounced (fig. 47). The layering of some of the implements of the first group may reflect an original depositional layering (tuffs). Strings of ore minerals are oriented parallel to the layering. Small-scale faults with crenulation effects acted upon some of the amphibolites, before as well as after metamorphism.

Possible provenance of the amphibolites

Most of the amphibolites from Hienheim are characterized by the low-grade metamorphic mineral assemblage actinolitic hornblende ± biotite ± chlorite ± epidote ± plagioclase (albite) ± quartz (greenschist facies). Relics of a higher grade of metamorphism have not been encountered.

The coarse-grained varieties have reached higher stages of low-grade metamorphism with larger amphiboles (porphyroblasts) and a deeper blue-green colour.

The sheaf or garven-like pattern of the amphibole needles, which is the cause of the toughness of the "Strahlsteinschiefer" amphibolites, indicates that the originally mafic rocks crystallized under relatively low pressure and high temperature metamorphic conditions. Stress-fabrics were rarely encountered and after metamorphism no penetrative deformation affected the amphibolites.

The presence of a well-developed thin "sedimentary" layering, sometimes weakly folded, in combination with a large quantity of ore minerals might indicate that these rocks were originally mafic volcanic rocks (Bauberger et al. 1973).

Three geological possibilities may be mentioned with regard to the source of the amphibolitic artefacts: firstly the quaternary glacial deposits derived mainly from Scandinavian (primary) sources, secondly the Alpine Orogen (Alps and Carpathians; Štelcl et al. 1970) and thirdly the Variscan basement of Central Europe.

Hermann & Schüller (1951) in a study of artefacts from Southern Saxonian prehistoric sites found that only in exceptional cases were implements made from northern erratics. No artefacts of amphibolitic composition were described and according to Scholz (1968) this rock type is a rare constituent of the glaciogenic deposits.

On the basis of the geological and (scarce) petro-archeological literature it is most likely that the source of most of the amphibolitic artefacts from Central European prehistoric sites is Variscan. The same applies for Hienheim, and a choice of sources seems to be nearby.

In the first place the western margin of the Moldanubian zone should be considered. Here medium to high-grade polymetamorphic rocks crop out that underwent Late-Precambrian to Variscan phases of deformation and metamorphism. Rather small amphibolites and other metabasites (serpentinites, marbles, lime-silicate rocks) occur scattered throughout the Bavarian and Regensburger Forst (Troll & Bauberger 1968; Troll 1975; Stettner 1975). The main mafic constituent of the amphibolites is often brown hornblende, e.g. Steinbügel near Wörth 50 km ENE of Hienheim. The majority of the amphibolites, however, are metagabbros. All the amphibolites contain blue-green hornblende as a rim around brown hornblende and/or pyroxene or replacing these minerals completely. In some metagabbros a blue-green hornblende rim encloses a lighter blue-green or colourless hornblende, both secondary to pyroxene. The blue-green hornblendes are Variscan and the corresponding metamorphism has been described as a low-pressure and high- temperature ("Abukuma") type of metamorphism (Vejnar 1971). The presence of brown hornblende, however, might possibly be connected with progressively higher grade elements of the same facies series (Schreyer & Blümel 1974).

Twenty-one amphibolite outcrops were sampled in the Western Moldanubicum but no amphibolitic rocks similar to the majority of the Hienheim artefacts were encountered. Only in one case does a Western Moldanubian provenance seem evident, that is the brown hornblende-bearing amphibolite 343.

Metagabbros which crop out near the prehistoric sites of Knöbling and Thierling (Regensburger Forest) are weakly amphibolitized. In rock fractures in particular blue-green hornblende is present, sometimes as rosettes (fig. 48). Bauberger et al. 1973, who investigated similar rocks in that area, suggested that more markedly deformed parts of the metagabbro might have been the source of some of the implements excavated nearby.

East of the Oberpfalz, and continuing into Czechoslovakia, a large partly amphibolitized gabbroic intrusion crops out (Schreyer & Blümel 1974) and within the Oberpfalz farther to the northwest, the more common amphibolites and serpentinites occur together with eclogite-amphibolites and garnet amphibolites indicating high-grade metamorphic conditions (high-pressure "Barrovian" type) prior to Variscan metamorphism (Stettner 1975). Serpentinites and amphibolites are often closely related (Klinkhammer & Rost 1975).

Contact metamorphism in the serpentinites due to Variscan intrusion of granite resulted in the growth of amphibole rosettes and occasionally narrow (20–30 cm) tremolite "Strahlstein" layers.

The northwestern to northern peripheral zone of the Bohemian Massif, i.e. the Saxothüringicum, consisting of Precambrian and Lower Palaeozoic rocks, is a second, possibly more promising area to be considered as the provenance of the artefacts. The rocks in this area are generally characterized by a low-grade (epizonal) metamorphism, in which progressive and retrogressive metamorphism is evident (Mielke & Schreyer 1969; Stettner 1974). Geotectonically aberrant complexes are the Münchberger Mass ca. 150 km north of Hienheim, and the Granulitgebirge farther to the northeast. They contain high-grade metamorphic rocks such as eclogites and granulites. Among the mafic Palaeozoic rocks of the Münchberger Mass lower-grade epidote-albite amphibolites and chlorite amphibolites occur.

Locally the Late-Precambrian basement rocks of the Fichtelgebirge include mafic (sub)volcanic rocks. Their mineral assemblage is characterized by chlorite + actinolite + epidote + albite + biotite. In places a subsequent contact metamorphism, due to the intrusion of Variscan granites, affected the basement rocks. A sheaf-like recrystallization of hornblende or the growth of large porphyroblasts has been observed in some amphibolites (Dimroth 1960).

Amphibolites have also been reported from the Thüringen Forest and Thüringen Schiefergebirge, the Erzgebirge and the Sächsische Zwischengebirge (Pietzsch 1962). Recently Scholz suggested sources in

Thüringen and Münchberg for some of the Hienheim implements (Scholz, written comm.). With respect to the amphibolitic artefacts found in Southern Saxonian prehistoric sites, Herrmann & Schüller (1951) favour the nearby Frankenberg-Hainichener Zwischengebirge (250 km NNE of Hienheim) as the source area. In this area amphibole-epidote schists (greenschist facies) occur which are regarded as retrogressive products due to strong mylonitization. These rocks, also called prasinites, are fine grained and either massive or schistose.

The metamorphic mineral assemblage comprises hornblende, chlorite, epidote, albite, quartz, titanite and calcite.

Along the northeastern margin of the Bohemian Massif (Sudetic zone) a few amphibolite-bearing areas have been indicated as potential provenances of artefacts. In a study of Neolithic amphibolitic implements found in Central Czechoslovakia, Štelcl et al. (1970) have suggested the Rychlebské Hills and Hrubý Jesenik Mountains as possible source areas. Frechen has often referred to the Sobótka (Zobten) area in Southwestern Poland as the provenance of amphibolitic artefacts (Frechen 1965; Frechen, written comm.). A series of reference samples from Mount Kósciusko (Zobten area), which was kindly placed at our disposal by Dr. A. Majerowicz, was investigated. These rocks are amphibolites with varying grain sizes; deep blue-green hornblende pophyroblasts forming well-crystallized sheafs (fig. 49), porphyroblastic plagioclase and dispersed ore minerals are the main constituents with some biotite and very little secondary epidote, chlorite and titanite. In spite of the sheaf-like pattern of the hornblende, these rocks do not resemble the typical Strahlsteinschiefer amphibolites.

Five thin sections made from amphibolites belonging to the University of Bonn could be examined through the kindness of Prof. Dr. J. Frechen. The geological source was identified as the Zobten area although the exact localities are unknown. Two samples were typical finely banded Strahlsteinschiefer amphibolites and one a nephritic rock (no. 220); the other two were metagabbros (no 215). The amphibolites from the Sobótka (Zobten) area are partly surrounded by gabbros and serpentinites which contain a few small nephrite outcrops (Geschwendt 1976). These nephrite deposits may possibly have a Variscan origin similar to that of the tremolite bands in the Oberpfalz serpentinites (Klinkhammer & Rost 1975). Nephrite has also been found in serpentinites close to the Czechoslovakian border (Rychlebské Hory or Reichensteiner Hills).

Though not enough reference material is available to establish the source of the Hienheim artefacts, one is inclined to conclude that the Fichtelgebirge, Thüringen and the Frankenwalder Zwischengebirge are the most probable areas of provenance and possibly but less likely, the Oberpfalz Forest as well as Southwestern Poland (Sobótka).

SILICICLASTIC MATERIAL

description of the samples

Fragments of eight querns and grinding-stones excavated at Hienheim were investigated in more detail. From seven samples a thin section was made. The majority of the artefacts were made from yellowish to light brownish-yellow quartz arenites that owe their colour to the matrix. The samples are listed in order of increasing grain size: 489 t.s. (medium grain size ca. 0.3 mm), 317 t.s., 414 t.s., 613 t.s. (ca. 0.5 mm), 307, 593 t.s. and 300 t.s. One sample (227 t.s.) is a very different greyish-white banded quartzite with a violet hue.

The properties which appear to differ among the various sedimentary rock samples are the grain size, grain shape and roundness of the grains as well as sorting, matrix content, packing, porosity and mineral constituents. They will be discussed in the next paragraph because only some of these properties can be determined macroscopically or with the aid of a binocular microscope.

Thin section analysis

Those mineral constituents which can be discerned are almost all quartz grains, sometimes with accessory micas, ore minerals, tourmaline and zircon. The quartz arenites are weakly porous and loosely packed; the grains are embedded in a very finely grained to cryptocrystalline (dark)greyish or brownish matrix. Interstitial flow structures are characteristic (fig. 50).

Roundness and sorting of the particles vary from sample to sample. Artefacts 489, 317, 414 and 613 represent sediments with good to moderate sorting; the roundness of the grains varies from sub-angular to angular (fig. 50); the matrix is dark greyish. Samples 300 and 593, poorly sorted sediments with a high matrix content, also include large grains up to 2 mm across. The larger grains are well-rounded to rounded, while the smaller grains become increasingly angular with decreasing grain size. The brownish matrix contains a large quantity of very finely grained quartz (fig. 51).

The quartz particles are monocrystalline or polycrystalline; extinction under crossed nicols is variably undulose. Some of the polycrystalline grains clearly derive from metamorphic rocks (fig. 52).

Sample 227 is a weakly porous (here due to disintegration of certain mineral constituents) quartzite, the undulose particles being closely packed. Where the originally well-rounded grains are in contact, the effects of recrystallization are clearly visible (fig. 53). The resulting fabric is weakly polygonal (mosaic). Parts of the diagenetically recrystallized microcrystalline matrix are still present.

Possible provenance

When the rock types of the quern and grinding-stone fragments are compared with similar rocks cropping out in the area, a striking resemblance is found with the silicified Schutzfels-Schichten (Schmidt-Kaler 1968). These fluviatile kaoline-bearing quartz sands are of Lower Cretaceous origin, the material derives from the Variscan mountain range in the northeast. This deposit is only locally silicified into a compact "quartzitic sandstone", e.g. near Bad Gögging and Sandharlanden, ca. 5 km southeast of Hienheim, and Hagenhill, ca. 7 km to the northwest.

Samples (from C.C. Bakels) of these outcrops were investigated (11 thin sections). Like the artefacts they are quite similar in general appearance but being variable in detail (grain size and shape, matrix, sorting and roundness). The reference material also shows interstitial flow structures in the matrix, moreover the accessory mineral spectra of the artefacts and the reference collection show a close resemblance.

The Hienheim artefacts 489, 317 and 414 in particular turned out to be very similar to the reference samples from Bad Gögging and to a lesser extent Sandharlanden. Artefact 613 is almost identical to one of the Bad Gögging samples, both also have typical lenses of more markedly silicified quartz arenite (fig. 39). The provenance of artefacts 593 and 300 is less certain, although they are still typical of Schutzfels. Possibly the source may have been just northwest of Sandharlanden or near Hagenhill, but the latter deposit is more porous and the intermediate-size grains show better rounding.

The source of artefact 227 has not been found and a former constituent of nearby Tertiary or Quarternary deposits is unlikely.

ELSLOO, SITTARD AND STEIN

AMPHIBOLITIC MATERIAL

Forty-three amphibolitic samples consisting of adzes, adze fragments and rough-outs from Elsloo, Sittard and Stein were investigated macroscopically. Only a few fragments from Elsloo (4) and Stein (4) were available for thin sections. They represent only some of the wide range of variations mentioned in the text below.

Description of the samples

The individual amphibolitic adzes differ in the first place as a result of their structure and grain size (fig 40). Differences in the colour of the patina may be pronounced, but this is also due to the degree of weathering. The relatively fresh implements display a typical dark olive-green colour, the strongly weathered samples are light greenish-grey.

Differences in structure are more pronounced in comparison with the somewhat doubtful significance of the colour so that the amphibolites were divided macroscopically into six structurally different groups. On the basis of the grain size a further subdivision was made. The groups are composed of the following samples, listed in order of increasing grain size:

I: Si* 163, E* 153, St* 115–1 t.s., E 444 t.s., E 334–1 t.s., Si 98, St 115–2 and E 200
II: St 157, Si 105–1, Si 26, Si 305 (=) Si 307, St 233, Si 198, E 116, E 111 t.s. and E 154 t.s.
III: E 482, Si 64, Si 106, E 388–1, St 52, St 163 t.s.,
E 325, St 48 t.s., Si 105–2, E 452, St 168 t.s., E 337, Si 141 and E 330
IV: E 56, Si 127, Si 97, St 220, E 214, E 210, Si 105–3.
V: E 129 and E 454
VI: E 388–2, E 422 and Si 188

The structural criteria used as the basis for this tentative division are a weakly oriented fabric (I) to a more gneissic structure (II and III), a weak to pronounced layering (III, IV and V) and a weak to pronounced porphyroblastic fabric of relatively larger hornblende and feldspar grains or clusters (II and III). The members of the sixth group are more or less exceptional amphibolites (fig. 40). It should be mentioned that amphibolites resembling the implements of the first Hienheim group were not encountered at the Dutch sites.

Thin section analysis

The mineral composition and petrographic properties of the amphibolites are listed in table 22 (enclosure 8).

Main constituents are *blue-green hornblende*, *quartz*, *feldspar* and *ore minerals*. *Biotite*, *chlorite* and *epidote* occur in variable amounts.

Amphibolites with almost colourless hornblende have not been encountered. Traces of *brown hornblende* may be enclosed in bluish-green hornblende (fig. 54). The textural pattern of hornblende varies between fine-grained clusters with bushy outlines and radial or sheaf-like crystal aggregates (figs. 55 and 57) to

* E = Elsloo, Si = Sittard and St = Stein.

coarser varieties (fig. 56). A less pronounced "Strahlsteinschiefer" pattern is visible in the fine-grained amphibolites. A layering is often pronounced (fig. 59).

Hornblende and also biotite and plagioclase may have developed into porphyroblastic crystals. The orientation of the porphyroblasts is generally at random with respect to the foliation plane (figs. 58 and 59).

Quartz occurs generally as polygonal aggregates, sometimes together with plagioclase.

Possible provenance of the amphibolites

Macroscopically as well as in the thin sections, one may observe some important differences between the Southern Limburg amphibolitic artefacts and those from Hienheim. The very fine grained thinly layered Strahlsteinschiefer amphibolites with irregular cross-cutting veinlets are absent at the Dutch sites. Instead one may encounter porphyroblastic amphibolites which show better crystallization and sometimes well-defined layers (fig. 40).

To decide upon the provenance of these implements is, compared with Hienheim, a more difficult task. No amphibolitic rocks occur within a distance of at least 200 km from the Southern Limburg sites. Van Straaten reports (1946) that only very few and small amphibolite pebbles were encountered in the gravels of the Maas River.

Scholz (written comm.) suggests that some of the Limburg material possibly derives from sources in the Thüringen Forest. Frechen investigated amphibolitic implements from Müddersheim (ca. 65 km southeast of Sittard) and concluded that a Sobótka (Zobten) provenance was in his opinion most likely (Frechen 1965). Later he also suggested the same provenance for amphibolitic artefacts from Elsloo and Stein (Frechen, pers. comm.).

From a geological point of view, in addition to sources along the periphery of the Bohemian Massif, other areas must also be taken into consideration. In the first place the narrow southern strip of the Taunus range and a similar strip in the southeastern part of the Harz, both belonging to the Rhenohercynian zone, should be mentioned. Here very low-grade greenschist facies metavolcanics occur. The basic greenschists of the Southern Taunus may contain the mineral assemblage quartz + albite + actinolite + chlorite + sericite + epidote (Anderle & Meisl 1974); the massive varieties may have been suitable for the production of implements. Low-grade amphibolitic rocks also occur in the Southern Harz; they were quarried in Prehistoric times (Scholz, written comm.). Furthermore nephrite fels and fibrous nephrite, which most probably were used by early man, appear as secondary lenses and veins in close connection with ultramafic harzburgites in the Oberharz (Kluge 1967).

Amphibolites, hornblende gneisses and related rocks are also known to occur in the crystalline basements of the Spessart and the Odenwald. In the Spessart they are found either as scattered relatively small intercalations within the metamorphic basement or concentrated in larger numbers or as larger masses in the northern and southern parts of the complex.

The majority of the amphibolites of the Spessart are of magmatic origin, mafic metavolcanics as well as metagabbros, and consist of (garnet bearing) epidote amphibolites, amphibolite- facies metadolerites (with relics of an ophitic fabric), blastomylonitic amphibolites, chlorite amphibolites (metagabbros) and chlorite-hornblende felses (retrograded peridotites). The metamorphic mineral assemblage of the metabasites consists of blue-green hornblende + plagioclase (20–50%An) ± quartz ± epidote ± pyroxene ± garnet (Matthes & Okrusch 1974).

At the northwestern edge of the complex the most compact parts of a relatively large amphibolite lens were sampled for reference purposes. The main constituents of this amphibolite are a well-crystallized blue-green hornblende showing predominantly parallel orientation and metablastic plagioclase, containing many small inclusions; the latter often show parallel orientation (Si), but are inclined with respect to the general foliation (Se) of the rock (fig. 60). Other constituents of the amphibolite are zoisite, epidote, biotite, titanite, rutile and some ore minerals. The inclusions are mainly small grains of blue-green hornblende and quartz droplets as well as some garnet, epidote, zoisite, titanite and rutile. This amphibolite does not resemble any of the (microscopically) investigated implements from Southern Limburg.

In the Odenwald the metamorphic basement rocks, Precambrian or Lower Palaeozoic, include amphibolites, mainly of (sub)volcanic origin, which are generally concentrated in SW-NE trending zones. The temperature-pressure conditions during the main Variscan metamorphism in the Spessart and the Odenwald are very similar. Metamorphism in the Odenwald also took place under amphibolite facies conditions and the metamorphic mineral assemblage of the amphibolites consists of blue-green hornblende + plagioclase (25–55% An) ± biotite ± pyroxene ± epidote ± quartz (Okrusch et al. 1975). Garnet-bearing amphibolites are restricted to the northeastern part of the region. Effects of contact metamorphism and Late-Variscan retrogradation are present.

From the above it is clear that the majority of the amphibolites in the Spessart and the Odenwald were not suitable for the production of implements.

Finally the Vosges and Black Forest may be taken into consideration. Geologically both areas belong to one complex, divided in the N-S direction by the Rhine graben. In both areas, however, amphibolites are comparatively scarce. There are at present no indications that the Limburg implements came from these source areas.

BASALTIC MATERIAL

The adzes and adze fragments of the second largest group were made from basaltic rock. Twenty-seven samples were available for investigation, 14 from Elsloo (11 thin sections), 6 from Sittard and 7 from Stein (5 thin sections).

Description of the samples

Macroscopically and with the aid of a binocular microscope, the basaltic adzes were subdivided according to structure and grain size. The term structure is used here for the porphyritic habit of the basalts as well as the presence of parallel orientation of the mineral constituents due to flow. Three larger groups, a few smaller ones and several additional individual types can be distinguished. For some groups the subdivision corresponds well with the colour of the patina.

The largest group of basalt consists of samples Si 231, Si 199 (=) Si 354, St 239 t.s., E 185 t.s., Si 251, E 481, E 127 and Si 66 in order of increasing grain size and/or porphyritic habit. These basalts are characterized by a strong porphyritic structure in which well-developed idiomorphic black pyroxenes, sometimes in clusters, are clearly visible together with a hypidiomorphic brownish olivine, always surrounded by a serpentine rim, and ovaloid relics of basaltic hornblende (fig. 41). There are relatively more pyroxene than olivine phenocrysts. A parallel orientation resulting from flow may be pronounced. The colour of the patina varies from light silvery-grey to brownish-grey.

The second group includes in order of increasing grain size and porphyritic habit St 164–1 t.s., E 102 t.s., E 366 t.s., E 63, E 608 t.s. and St 115–3 t.s. These basalts are finer grained, especially the phenocrysts.

A flow structure is only visible with the aid of the microscope. The percentage of phenocrysts varies, and also the relative abundance of pyroxene with respect to olivine. The colour of the patina is more or less brownish grey (black spotted).

The third large group consists of fine-grained basalts with a brownish-grey to greyish-brown colour. At first sight these rocks have a "sandstone-like" appearance. Phenocrysts are hardly visible. Only with the aid of a binocular microscope can one observe a predominance (sometimes marked) of olivine over pyroxene. Flow banding is occasionally visible. The samples in this group are St 129, E 354 t.s., St 164–2 t.s., E 600–1 t.s., E 344 t.s.(=) E 600–2 t.s. and Si 465.

The other basaltic adzes differ slightly to markedly from the three above-mentioned groups in grain size, structure and also colour. These samples are E 389 t.s., a very finely grained basalt with relatively large phenocrysts, St 27, E 398 t.s., St 135 t.s. and E 334–2 t.s.

Thin section analysis

The mineral composition and the petrographic properties of the basalts are listed in table 23 (enclosure 9).

When comparing phenocrysts and groundmass of the basaltic adzes one observes that the differences in grain size are generally distinct, and only in a few of the basaltic adzes is the transition more gradual.

The groundmass consists mainly of the same primary mineral constituents as the phenocrysts, although the relative abundances may vary markedly, e.g. plagioclase.

The main constituents of the basaltic adzes are *(titano)magnetite, olivine, titanaugite, brown basaltic hornblende, biotite, plagioclase, leucite, nepheline*, and some secondary minerals.

(Titano)magnetite commonly displays a well-developed idiomorphism, both the larger crystals and the smaller ones in the groundmass. Size differences are generally gradual (fig. 61).

Colourless olivine phenocrysts may be present as equidimensional crystals or as prisms. This mineral is partly to completely serpentinized (figs. 61 and 63).

Titanaugite, pleochroic in violet and brown, often displays well-developed zoning and twinning. It may occur as individual crystals or in clusters, sometimes together with olivine and/or titanomagnetite (figs. 62 and 63).

Highly pleochroic brown basaltic hornblende occurs in a few adzes (E 185, St 239) as lenticular-shaped bodies that have changed partly or completely into plagioclase, augite, rhönite and titanomagnetite (Frechen 1965; fig. 64).

Biotite only occurs in adze E 389 as rims around around olivine (fig. 66).

Plagioclase is a main constituent in the groundmass of almost all the adzes. It occurs as small laths often in more of less parallel orientation, thus indicating magmatic flow (fig. 65). The small crystals are generally twinned. Only in a few cases are large phenocrysts of plagioclase present. Basalts rich in plagioclase are also known as plagioclase basalts (Frechen 1965).

A few adzes seem to have nepheline as a minor constituent in the groundmass, but two adzes were found to be foid-rich, i.e. the basanites E 334–2 with nepheline together with plagioclase and E 389 with leucite and nepheline (fig. 66).

Possible provenance of the basalts

All the basaltic adzes investigated were made from olivine basalt; almost all contain variable amounts of titanomagnetite, olivine and titanaugite as main mafic constituents and plagioclase usually as the only, sometimes abundant felsic constituent. Foid-rich basaltic rocks were encountered in only two cases (basanites), which possibly may suggest that these rocks were less attractive for use as adzes. The most suitable varieties seem to be the fine grained, moderately porphyritic, compact and plagioclase-rich basalts.

From the map (enclosure 7) it appears that the source rocks are close at hand. Earlier provenance determinations carried out by Frechen using some of the basaltic adzes from the sites in Southern Limburg indicated, in his opinion, outcrops in the Siebengebirge and in one case the Western Eifel (Frechen, written comm.). It is obvious that the most probable source rocks for these basaltic implements are located in the Siebengebirge, Northern Eifel, High Eifel and Western Eifel areas, while the Laacher See and Westerwald areas cannot be excluded entirely.

The presence of (partly altered) basaltic hornblende as a typical mineral constituent in the basalts of the first group is a strong indication that these adzes were quarried near Bad Godesberg on the western side of the Rhine (Lyngsberg, Caeciliënhöhe).

The adzes of the second and third groups and possibly also a few others probably all derive from basaltic rocks from the Siebengebirge area (Oberkassel, Papelsberg, Dollendorf). They may have been quarried from the geologically primary rocks or found as boulders in the (older) Rhine terraces. Only very recently a basaltic boulder resembling the Lyngsberg material was encountered in a Rhine terrace about 12 km north of Sittard.

Sample E 334–2, a basanite with nepheline, shows some resemblance to the Tomberg basanite, 17 km south west of Bad Godesberg. Foid-rich basaltic rocks are not as abundant in the Siebengebirge area as the more silica-saturated plagioclase-rich basalts.

In one case an adze of rather aberrant macroscopical appearance turned out to be a biotite-bearing basanite rich in leucite and nepheline (E 389). It was recognized by Frechen as coming from Gossberg in the Western Eifel, northeast of Gerolstein.

Among the implements from Southern Limburg was one artefact (E 218) made from a doleritic rock with a well-developed ophitic structure. Titanaugite, olivine and plagioclase are the main primary constituents and calcite and chlorite are secondary minerals.

It is not unlikely that the original dolerite was found in the terrace deposits of the Maas River. Dolerites in these deposits originate from the Southern Ardennes (Waterlot & Beugnies 1973).

SILICICLASTIC MATERIAL

Description of the samples

The investigated siliciclastic artefacts from the LBK-sites Elsloo, Sittard and Stein consist of a group of sixteen adze fragments, three quern fragments and several fragments of extensively weathered grinding-stones.

The majority of the adzes were made from weakly metamorphic compact quartzitic rocks, generally displaying a weak schistosity or layering. This group includes three greyish metaquartzites (E 685 t.s., E 684 t.s. and St 153 t.s.), six dark grey to almost black quartzitic phyllites (E 49 t.s., E 71 t.s., E 677, St 167, E 644 t.s. and E 492 t.s.), one black siliceous shale or lydite with a characteristic conchoidal fracture (E 75 t.s.), two dark brown quartz arenites (E 61 and E 477 t.s.), a dark brown siliceous shale (Si L.V.) with an imperfect conchoidal fracture, a quartzitic schist (Si 75), a quartzitic greenschist (St LV) and a strongly weathered biotite gneiss (Si 167).

The three yellowish quern fragments (E 3 t.s., E 40 t.s. and E 57 t.s.) are slightly porous quartzites. The grinding-stone fragments are all quartz arenites which differ in colour and compaction. Three samples were taken for thin sections. Some are reddish-brown due to pronounced limonitization (samples E 11 and E 37); the others are brown to yellowish (samples E 70).

Thin section analysis

Microscopically the adzes differ from each other in the structure and the degree of metamorphic recrystallization, the sizes, shapes and relative amounts of the main constituents quartz, sericite, muscovite, biotite, chlorite, as well as the accessory minerals tourmaline, zircon, rutile and ore minerals, the presence and relative amounts of rock particles and matrix, and the presence of a dispersed dark-brown to black pigment.

The six dark grey-coloured implements owe their colour to a pigment, dispersed throughout the rock but more intensively concentrated in finer-grained bands. The quartz particles (up to 0.1 mm) in the very finely grained matrix are angular. These weakly metamorphic (muscovite and chlorite) rocks were originally banded carbonaceous arenites with a high clay content (fig. 67).

The four lighter grey implements have a higher quartzite content.

The recrystallized quartz particles of E 685 lie in close contact with one another and have irregular (lobate) rims (fig. 72). The matrix of E 685 forms brownish crypto-crystalline siliceous patches. Samples E 684 and St 153 are more schistose with muscovite and chlorite-bearing sinusoidal strings around the quartz particles.

Samples E 492 and E 75 have in common that both rocks are heavily pigmented and very fine and even grained, but they differ in that E 75 is a non-metamorphic black siliceous shale (lydite) with lenses of crypto-crystalline quartz enclosing many small rutile crystals and E 492 is a dark-coloured chloritoid-bearing phyllite (figs. 68 and 69). The prismatic chloritoid metablasts developed prior to the latest deformation.

The dark brown quartz arenites, E 61 and E 477, are layered arenites with coarser grains embedded in a silicified matrix (fig. 70). They seem hardly affected by metamorphism. The majority of the particles (diam. 0.08–0.4 mm) are angular to sub-rounded quartz grains; in addition these rocks contain many rock fragments and newly formed ore minerals (pyrite crystals). Sample Si L.V. possibly represents a similar rock type with a finer average grain size.

The greenish adze fragment, St LV, is a quartzitic schist, consisting of quartz with a variable grain size (up to 0.8 mm), well crystallized chlorite, muscovite and some albite, and accessory tourmaline and ore minerals (fig. 71).

The monocrystalline and polycrystalline quartz constituents of the quartzitic to quartz arenitic querns are closely packed. The contacts are slightly indented and partly straight (mosaic) with only weak traces of recrystallization around the original grain boundaries. The average grain sizes vary between 0.2–0.5 mm.

The majority of the angular (E 37) to sub-rounded (E 70) quartz grains (average grain size 0.2 mm) of the grinding-stones is monocrystalline. Effects of diagenetic recrystallization are incipient and only visible when limonitization is weak.

Possible provenance

The Quaternary terrace deposits of the Maas River contain abundant rock material (boulders, cobbles, etc.) similar to the rock types that were used to make artefacts. Thus a local provenance for at least part of the material is probable and this seems to apply especially for the light-greyish (meta)quartzitic implements and the non-metamorphic quern fragments.

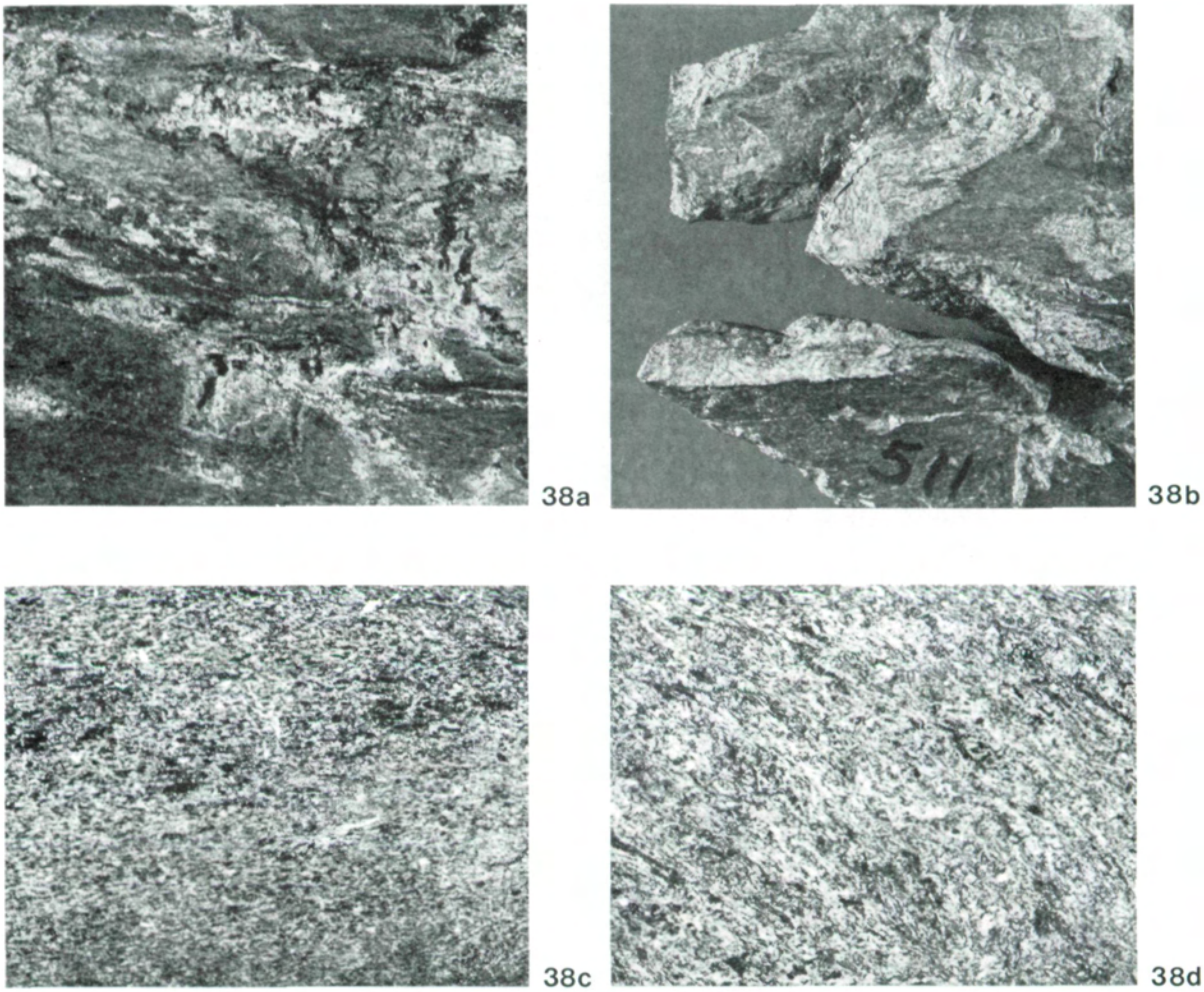
To assume a local source for the dark grey to black coloured adzes, however, is more doubtful since these rocks are quite scarce in the terrace deposits (van Straaten 1946). Moreover, the few small lydite stones encountered in the deposits are devoid of the typical rutile crystal inclusions which were found in the lydite of adze E 75. In the opinion of van Straaten the lydites of the Maas River terraces derive from the Ardennes Massif.

Two specimens, E 71 and E 644 which belong to the group of dark grey implements, were found to compare quite favourably with a similar (reference) rock-type from Horion-Hozémont in Eastern Belgium, where in prehistoric times a workshop was located (Dradon 1967). Although of lighter colour, sample E 49 may have the same provenance.

The chloritoid-bearing phyllite (E 492) must have its primary source in the low-grade metamorphic cores in the Ardennes, south of Stavelot or between Rocroi and Bastogne, respectively (Waterlot & Beugnies 1973).

With regard to the weakly metamorphic quartzitic schists and quartzites an exact geologically primary source is much more difficult to indicate. Greyish to greenish quartzites and grey to dark grey quartzites are known from the lower Palaeozoic of the Ardennes (Waterlot & Beugnies 1973).

The limonitized quartz arenites used for the grinding stones, are derived from locally cemented sands of the Maas River terrace deposits (P.W. Bosch, oral comm.).



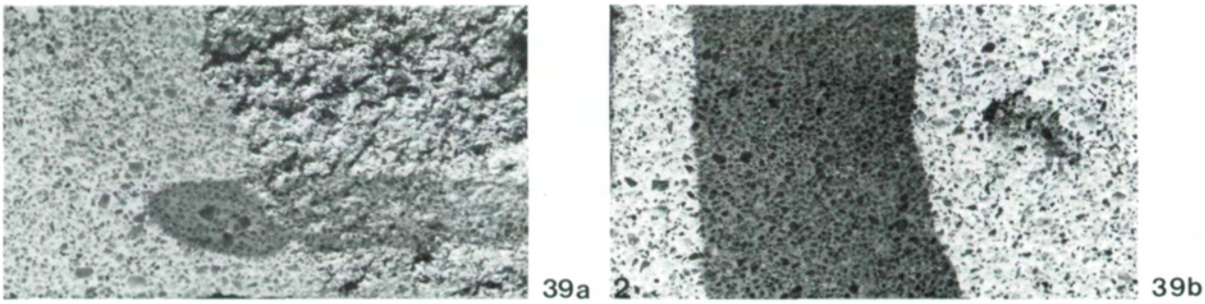
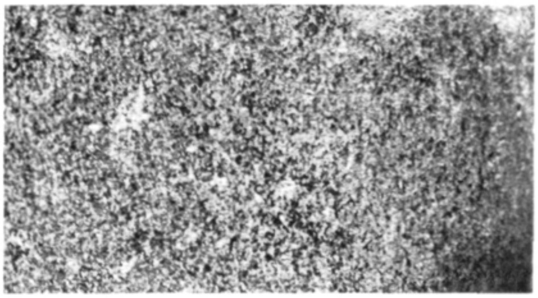


Fig. 38. Macroscopic appearance of four amphibolitic adzes from Hienheim: (a) irregularly banded and a fine polish (H 1089), (b) a splintery fracture (H 511), (c) a linear fabric (H 307-3) and (d) an irregular foliation (H 919). ca 2.5 ×.

Fig. 39. Quern fragment (H 613) and reference material (Bad Gögging) with light brownish coloured lenses. ca 2.5 ×.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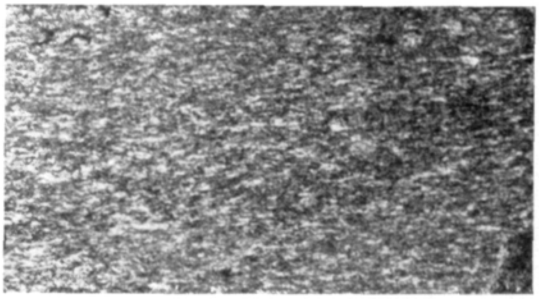
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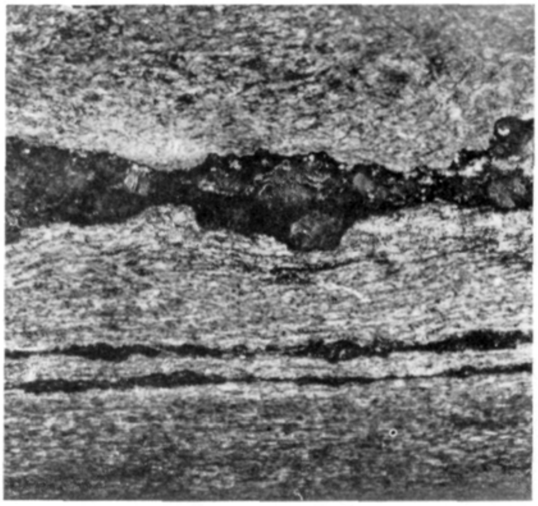
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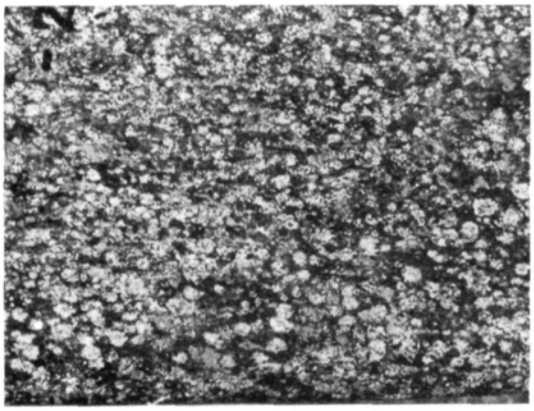
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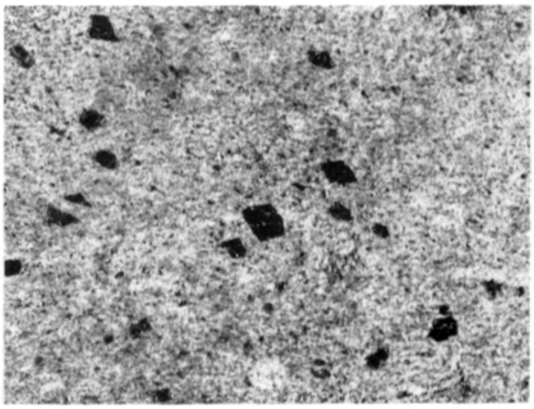
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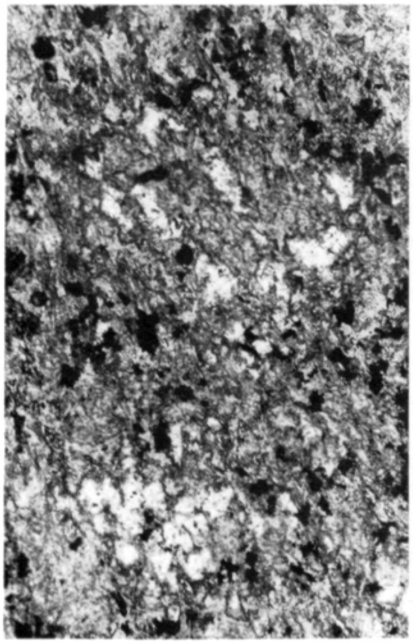
Fig. 40. Macroscopic appearance of four amphibolitic adzes from Southern Limburg: (a) very fine-grained (E 444), (b) a linear fabric (E 116), (c) linear patches (E 452), (d) strongly layered (E 752) and (e) relatively coarse porphyroblastic plagioclase and hornblende (E 388-2). ca 2.5 ×.

Fig. 41. Characteristic surface texture of a basaltic adze from Southern Limburg (Si 66), possible provenance near Bad Godesberg. ca 2.5 ×.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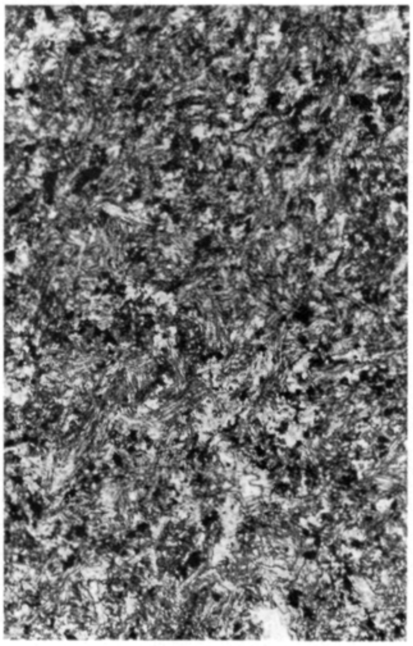
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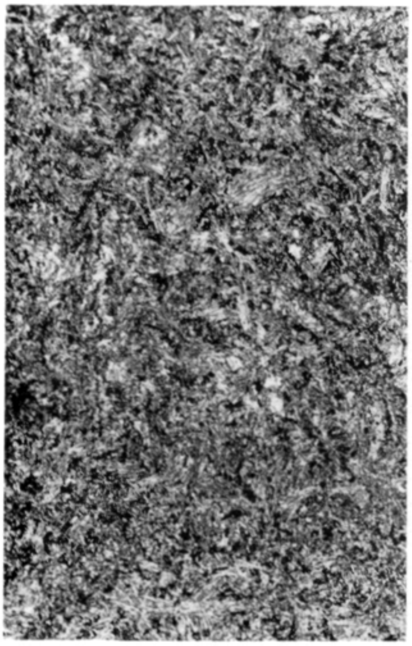
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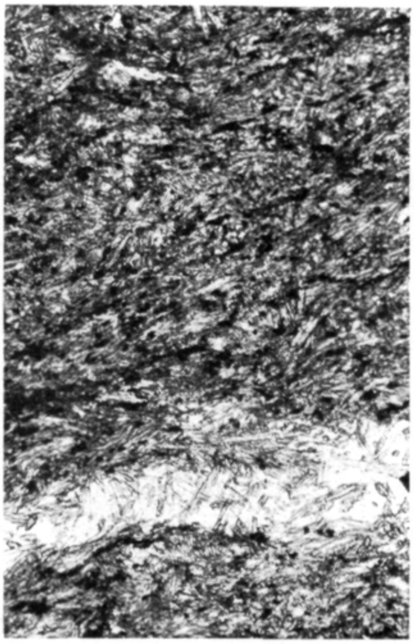
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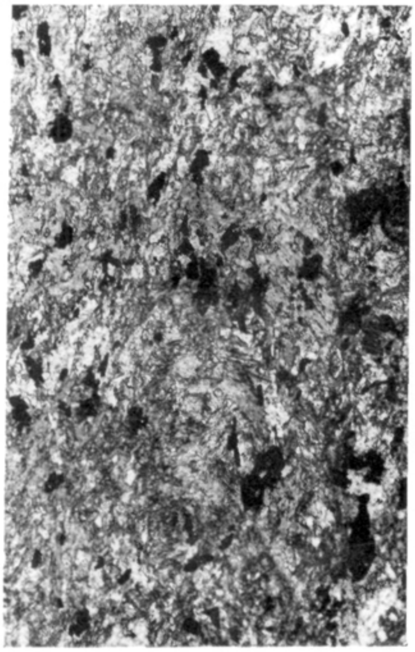
Fig. 42. Amphibolite with microcrystalline bluish green hornblende aggregates with bushy outlines (Hienheim 1083), 40 ×.

Fig. 43. Amphibolite with relatively coarser blue green hornblende clusters (Hienheim 359). 40 ×.

Fig. 44. Very fine grained amphibolite with typical "Strahlsteinschiefer" habit (Hienheim 699). 40 ×.

Fig. 45. Needles of bluish green hornblende penetrating radially in a quartz veinlet of an amphibolite (Hienheim 530). 50 ×.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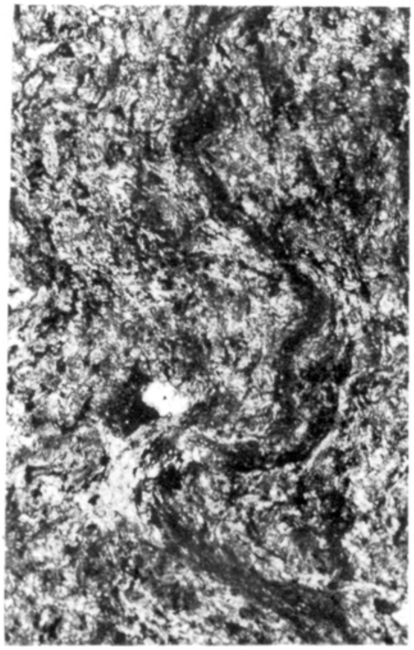
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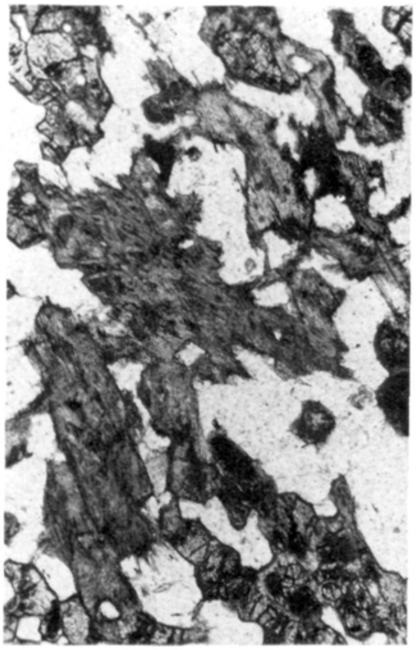
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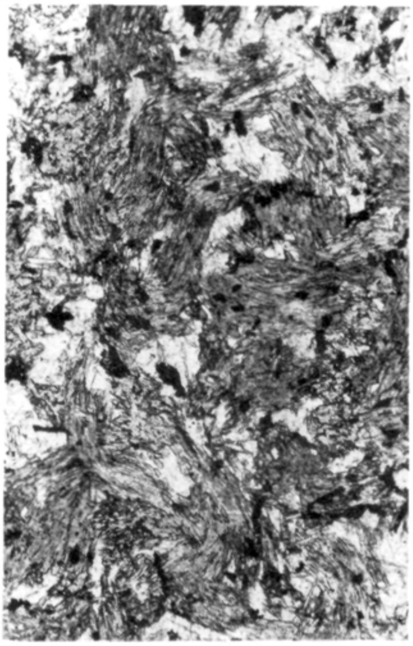
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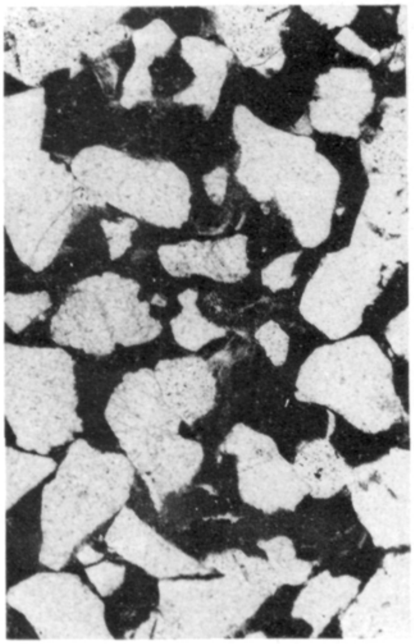
Fig. 46. Porphyroblastic hornblende in amphibolite (Hienheim 1140). 40 ×.

Fig. 47. Finely layered amphibolite (Hienheim 183–1). 40 ×.

Fig. 48. Amphibolitization of gabbro along fractures. Thierling, Regensburger Forest. 40 ×.

Fig. 49. Sheaf-like clusters of coarse grained hornblende oriented at random in amphibolite from Mount Kościusko (Zobten area), Southwestern Poland. 40 ×.



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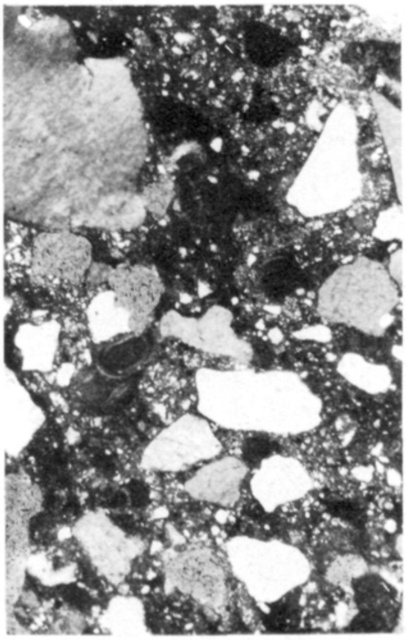

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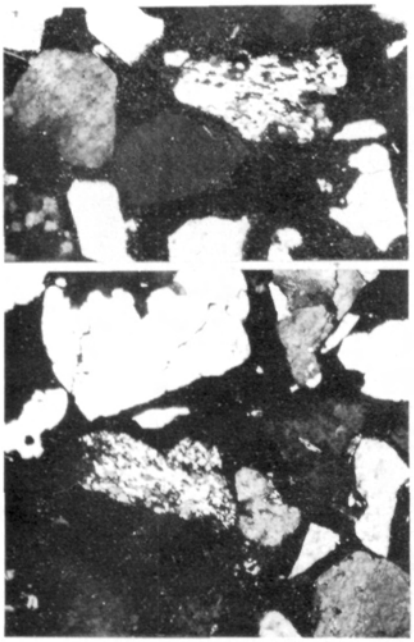

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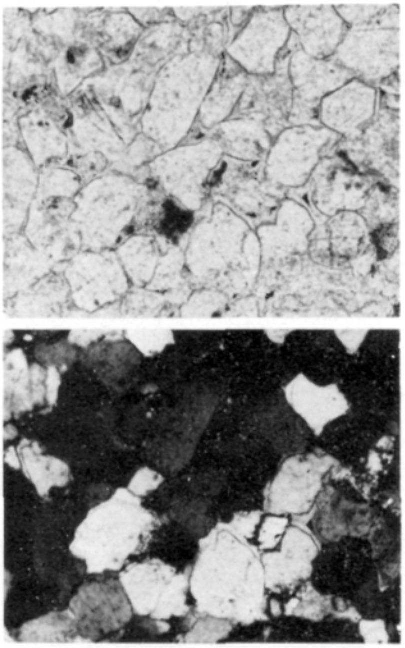

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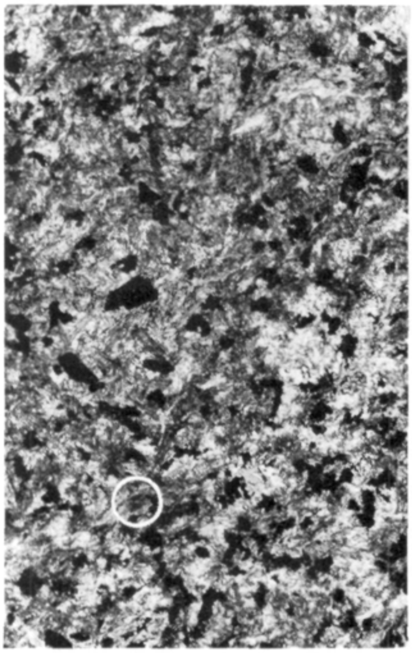
Fig. 50. Moderately sorted, sub-angular quartz grains embedded in cryptocrystalline dark matrix with interstitial flow structures (quartz arenite, Hienheim 317). 40×.

Fig. 51. Badly sorted quartz arenite (Hienheim 300) with microcrystalline angular quartz particles in the matrix. Crossed nicols. 40×.

Fig. 52. Polycrystalline quartz grains in quartz arenite derived from Variscan metamorphic rocks (Hienheim 613). Crossed nicols. 40×.

Fig. 53. Diagenetic recrystallization of a quartzite (Hienheim 227); the contours of the originally sub-rounded particles are still visible. Lower part crossed nicols. 40×.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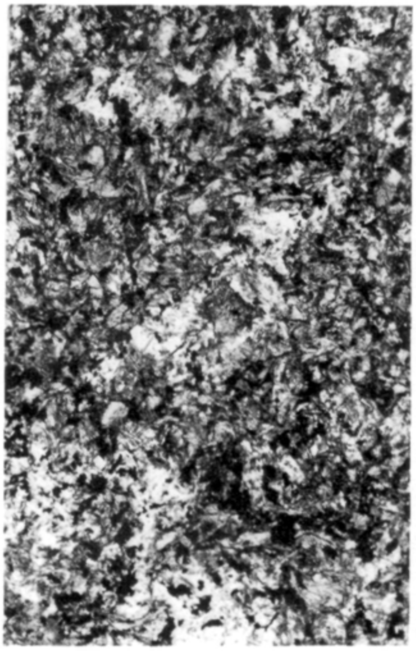
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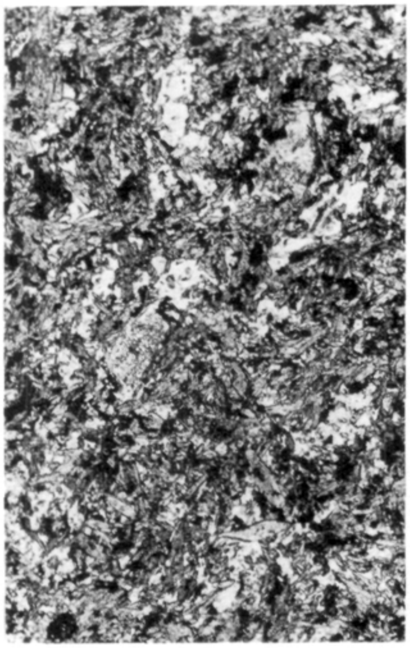
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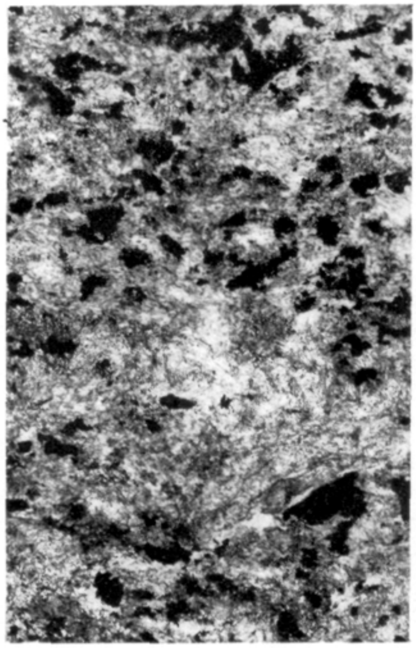
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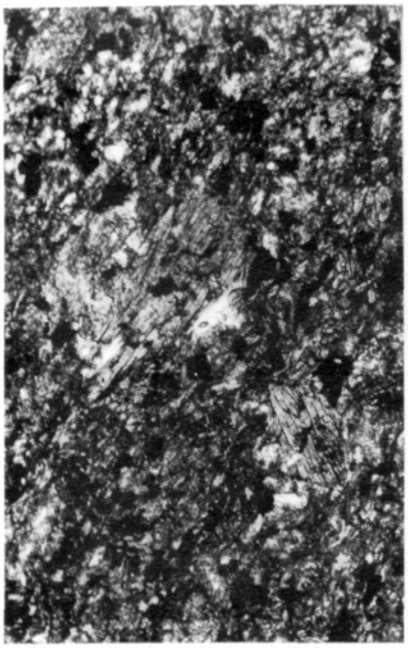
Fig. 54. Amphibolite from Elsloo (E 344–1) with traces of brown hornblende, encircled, within blue-green hornblende. 40×.

Fig. 55. Amphibolite with hornblende clusters and sheafs (Elsloo 163). 40×.

Fig. 56. Relatively coarsely crystallized hornblende and plagioclase porphyroblasts in amphibolite (Elsloo 111). 40×.

Fig. 57. Fine-grained randomly oriented bluish green hornblende needles and sheafs in amphibolite (Stein 168). 40×.



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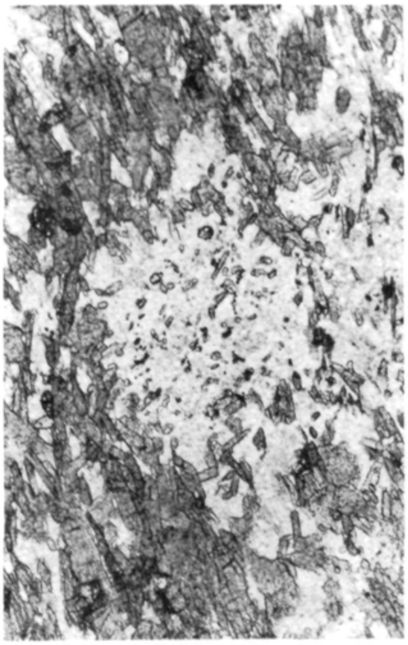

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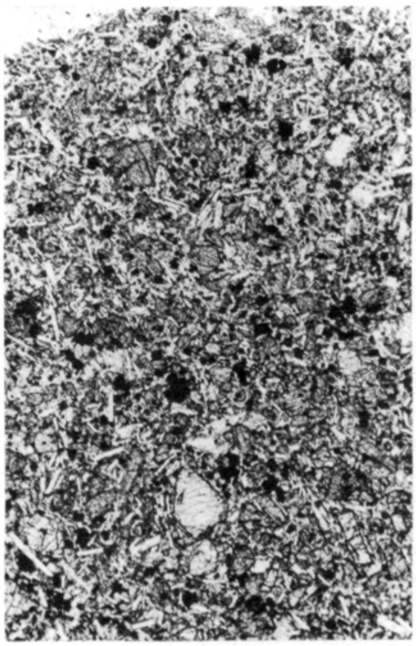

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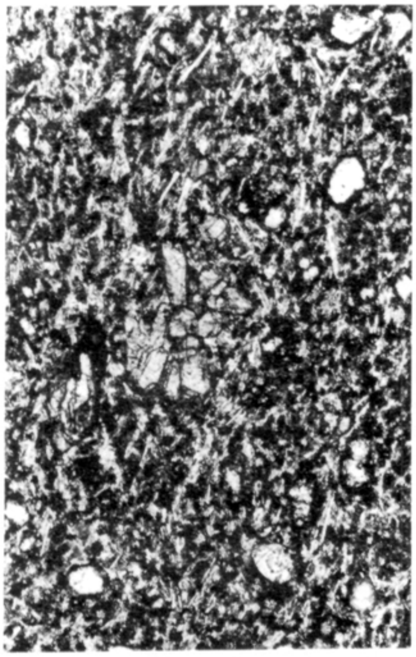
Fig. 58. Amphibolite with relatively large blue green hornblende porphyroblasts (Stein 48). 40 ×.

Fig. 59. Layered amphibolite with relatively large biotite crystals associated with quartz; some biotites are oriented perpendicular with respect to the foliation (Elsloo 334–1) 40 ×.

Fig. 60. Reference amphibolite (Northwestern Spessart) with plagioclase porphyroblast containing inclusions (a.o. garnet). Internal orientation (Si) of inclusions is oblique with regard to external foliation (Sc), 40 ×.

Fig. 61. Olivine basalt with phenocrysts of titanomagnetite in variable sizes, olivine and titanaugite (Elsloo 608), 40 ×.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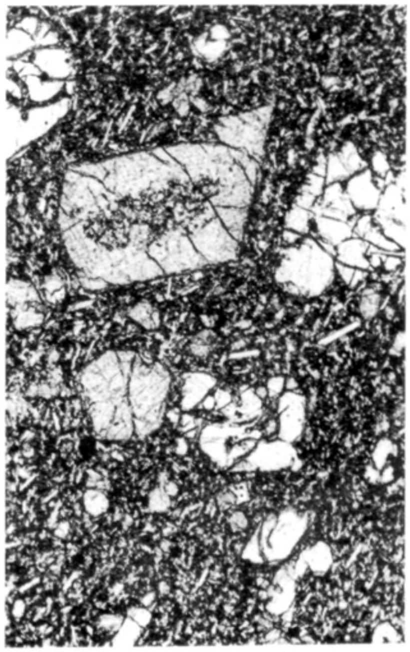
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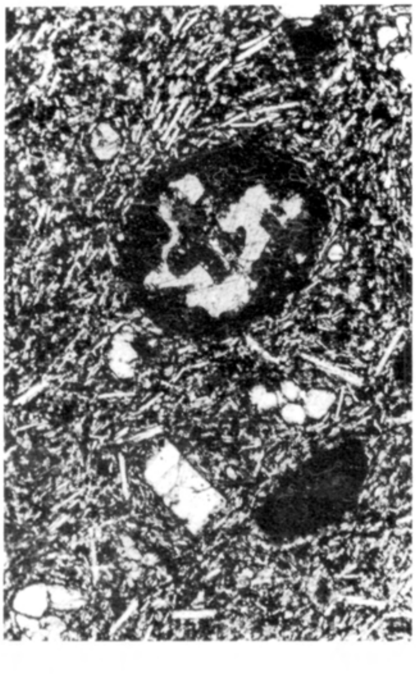
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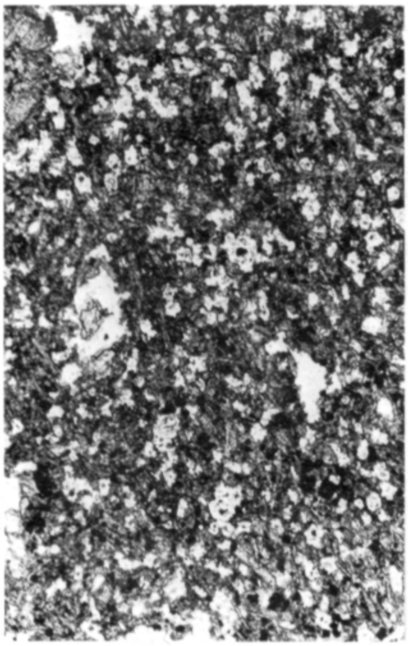
Fig. 62. Olivine basalt with titanaugite cluster (Elsloo 600–1). 40 ×.

Fig. 63. Relatively large phenocrysts of olivine and titanaugite in olivine basalt (Stein 135). 40 ×.

Fig. 64. Olivine basalt with partly and completely altered basaltic hornblende, titanaugite and olivine (Elsloo 239), 40 ×.

Fig. 65. Plagioclase basalt with olivine and numerous relative large plagioclase laths displaying a flow orientation (Elsloo 366), 40 ×.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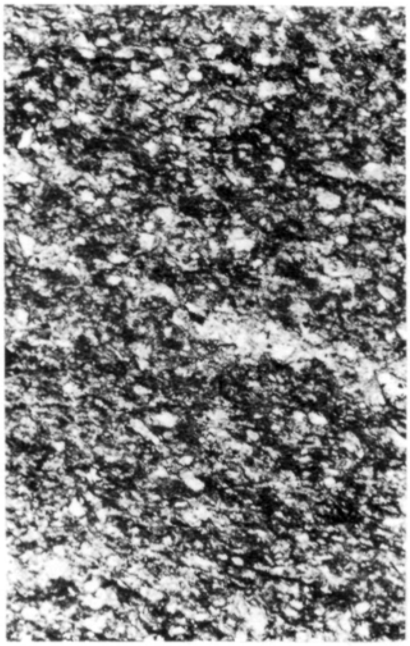
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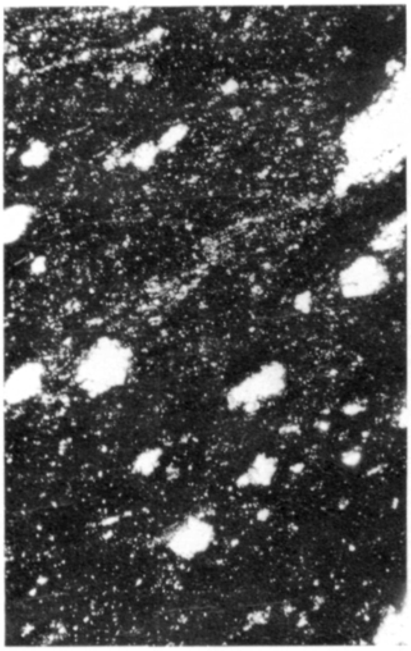
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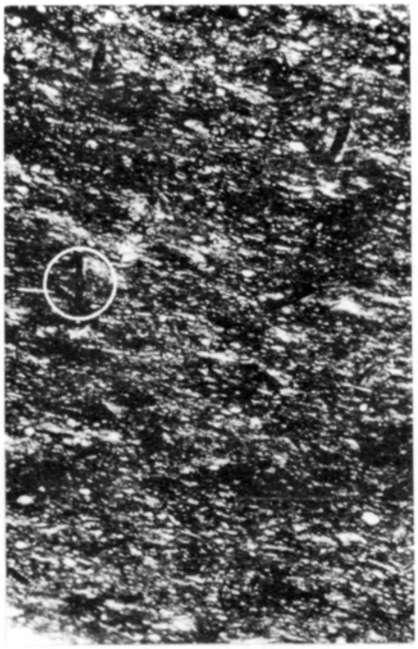
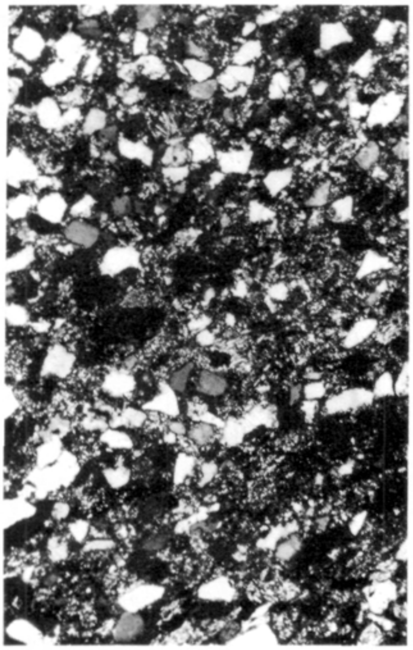

69

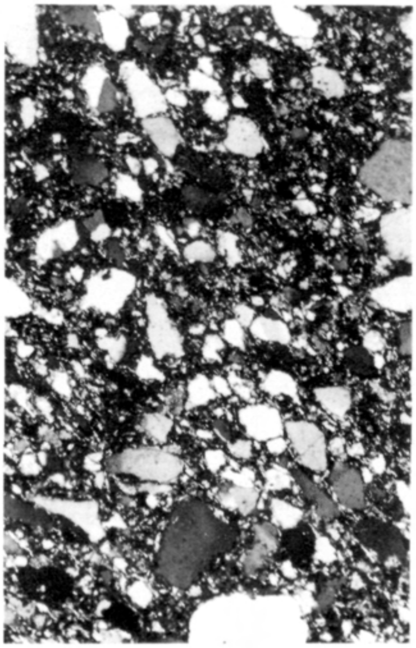
Fig. 66. Basanite, possible origin Western Eifel, with biotite-rimmed olivine phenocrysts and within the groundmass nepheline and equidimensional leucite with a typical inclusion pattern (Elsloo 389), 40×.

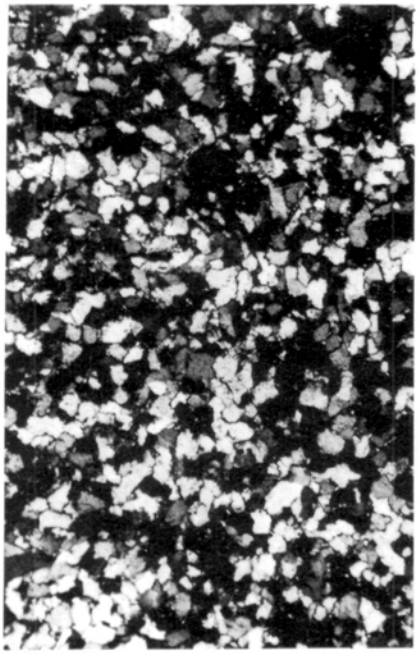
Fig. 67. Weakly layered dark brown pigmented compact phyllite, possible origin Horizon Hozémont (Elsloo 644), 40×.

Fig. 68. Typical lydite with microcrystalline quartz clusters (Elsloo 75), 40×.

Fig. 69. Darkly pigmented chloritoid-bearing phyllite (Elsloo 492). Chloritoid is encircled. 40×.


70


71


72

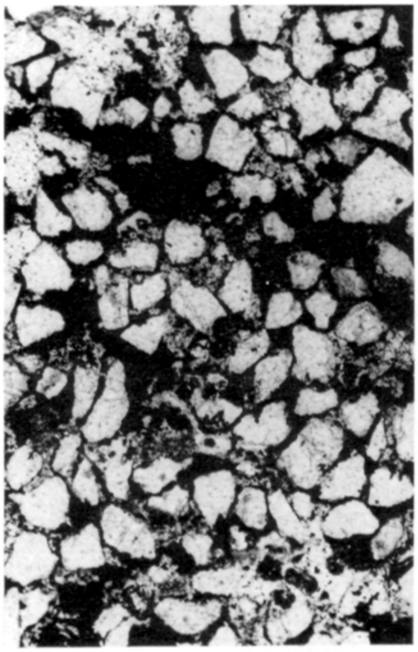

73

Fig. 70. Dark brown arenite with a high matrix content (Elsloo 477). Crossed nicols. 40×.

Fig. 71. Muscovite, chlorite and albite bearing quartzitic "greenschist" (Stein LV). Crossed nicols. 40×.

Fig. 72. Fine-grained quartzite with irregular grain-boundaries (Elsloo 685). Crossed nicols. 40×.

Fig. 73. Quartz arenite grinding-stone fragment with limonitic cement (Elsloo 37). Possible source: Maas River terrace. 40×.

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LIST OF FIGURES

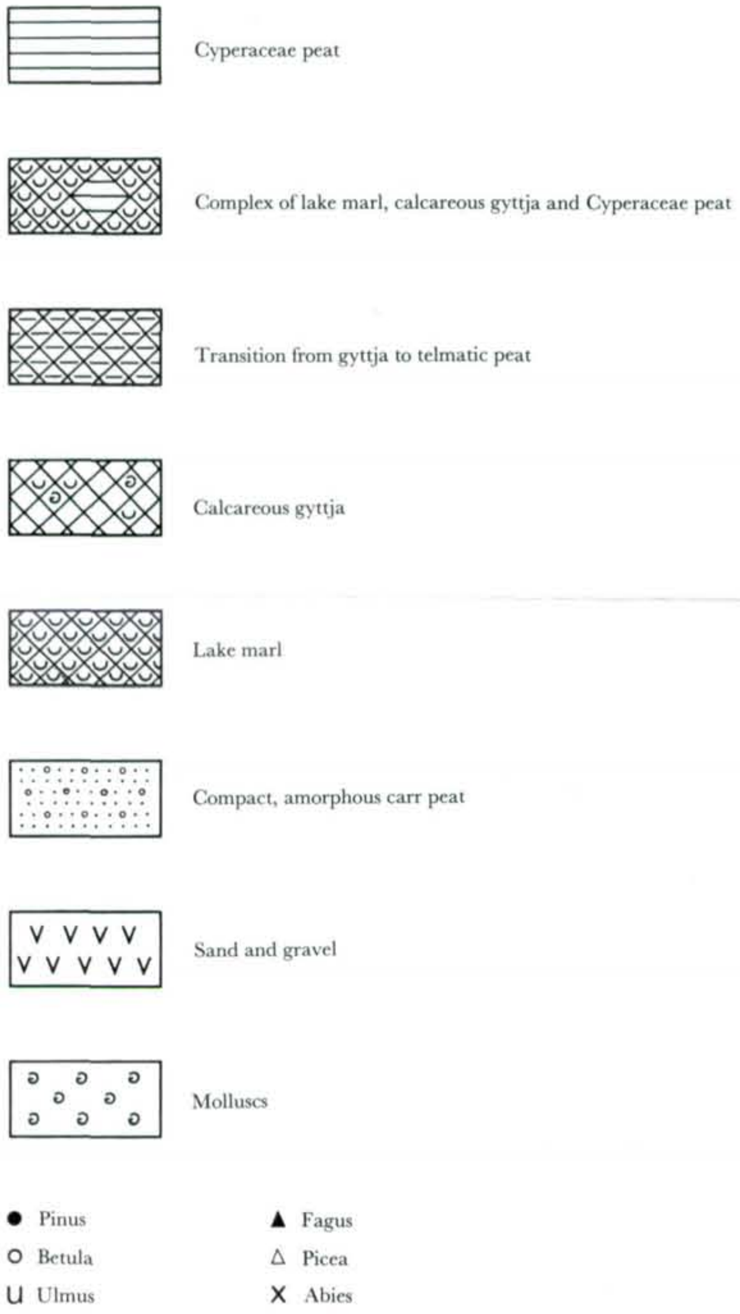
LIST OF TABLES

ENCLOSURES

ANALECTA PRAEHISTORICA LEIDENSIA

1978

XI

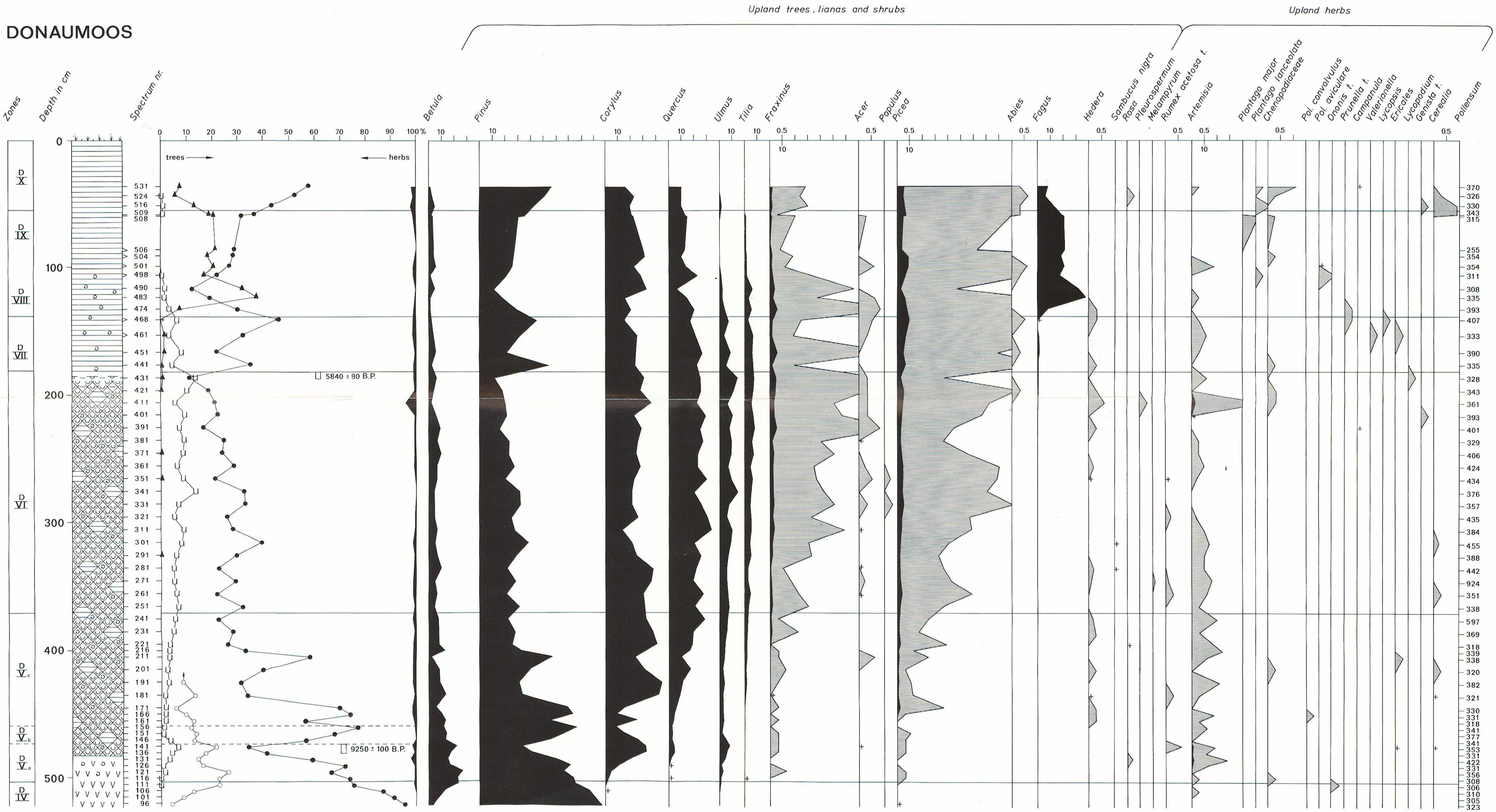


Enclosure 1. Legend to the pollen diagrams.

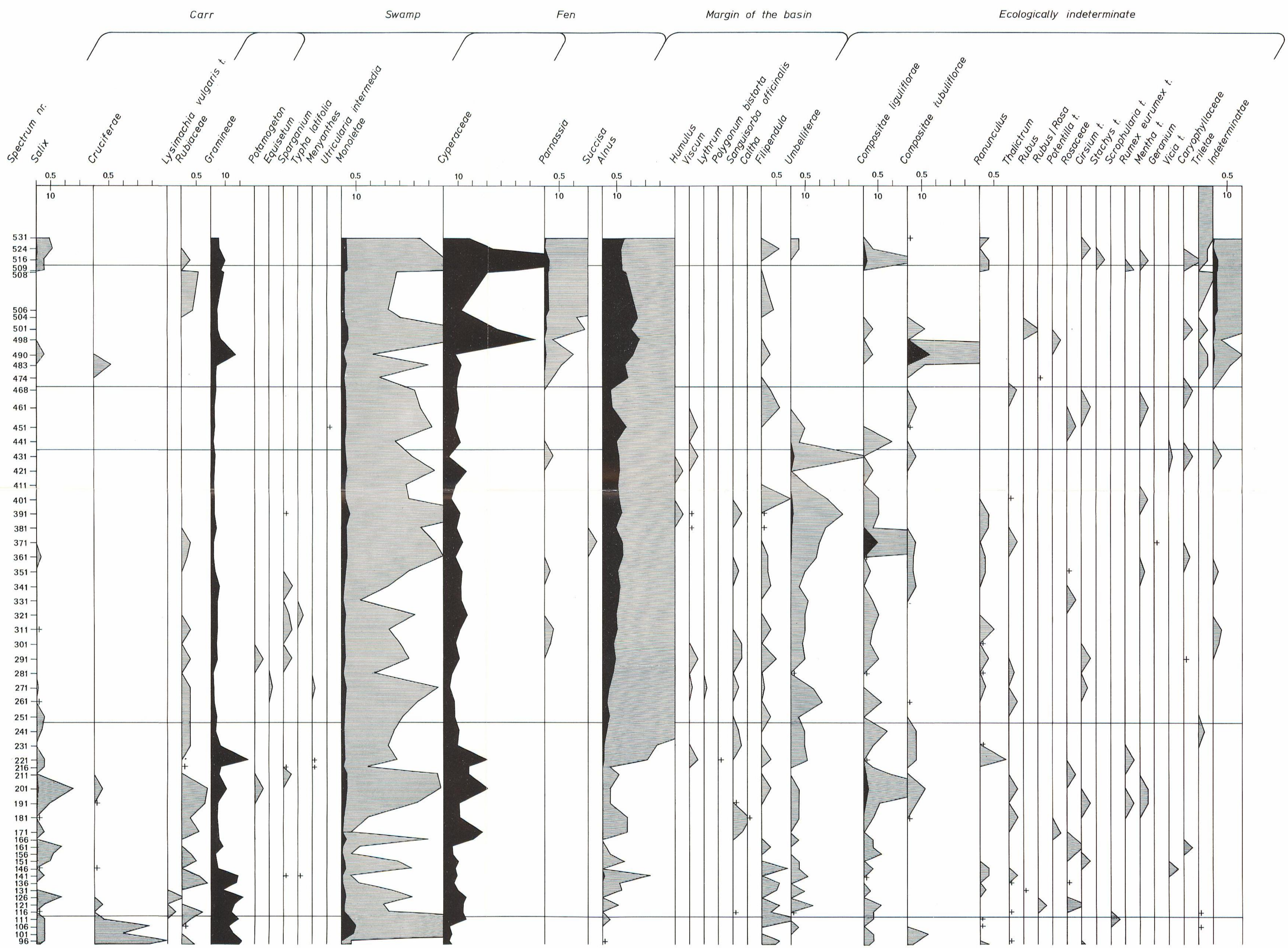
Enclosure 2. The Heiligenstädter Moos, diagram of pollen types included in the pollensum.

Enclosure 3. The Heiligenstädter Moos, diagram of pollen types excluded from the pollensum.

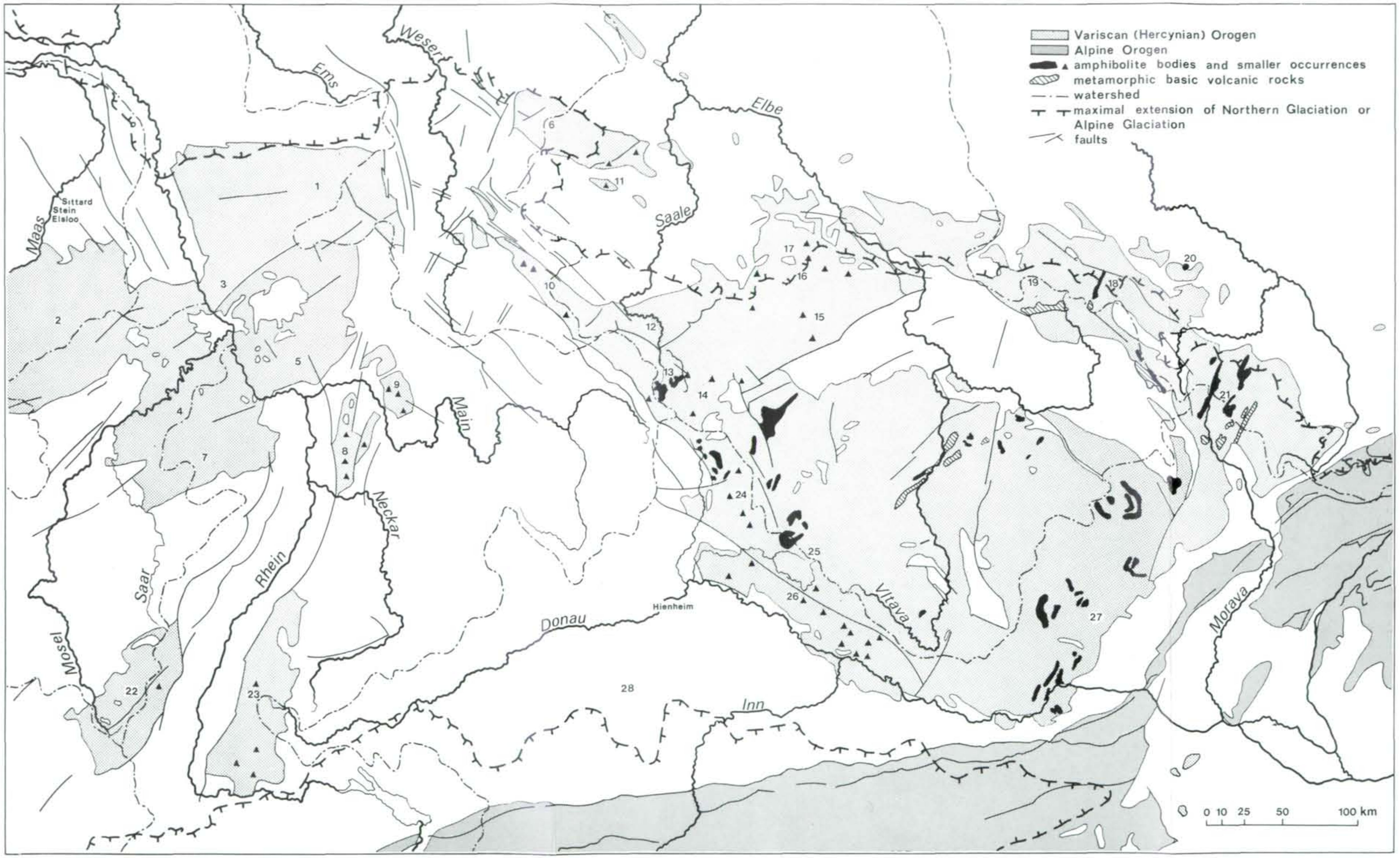
DONAUMOOS



Enclosure 4. The Donaumoos, diagram of pollen types included in the pollensum.

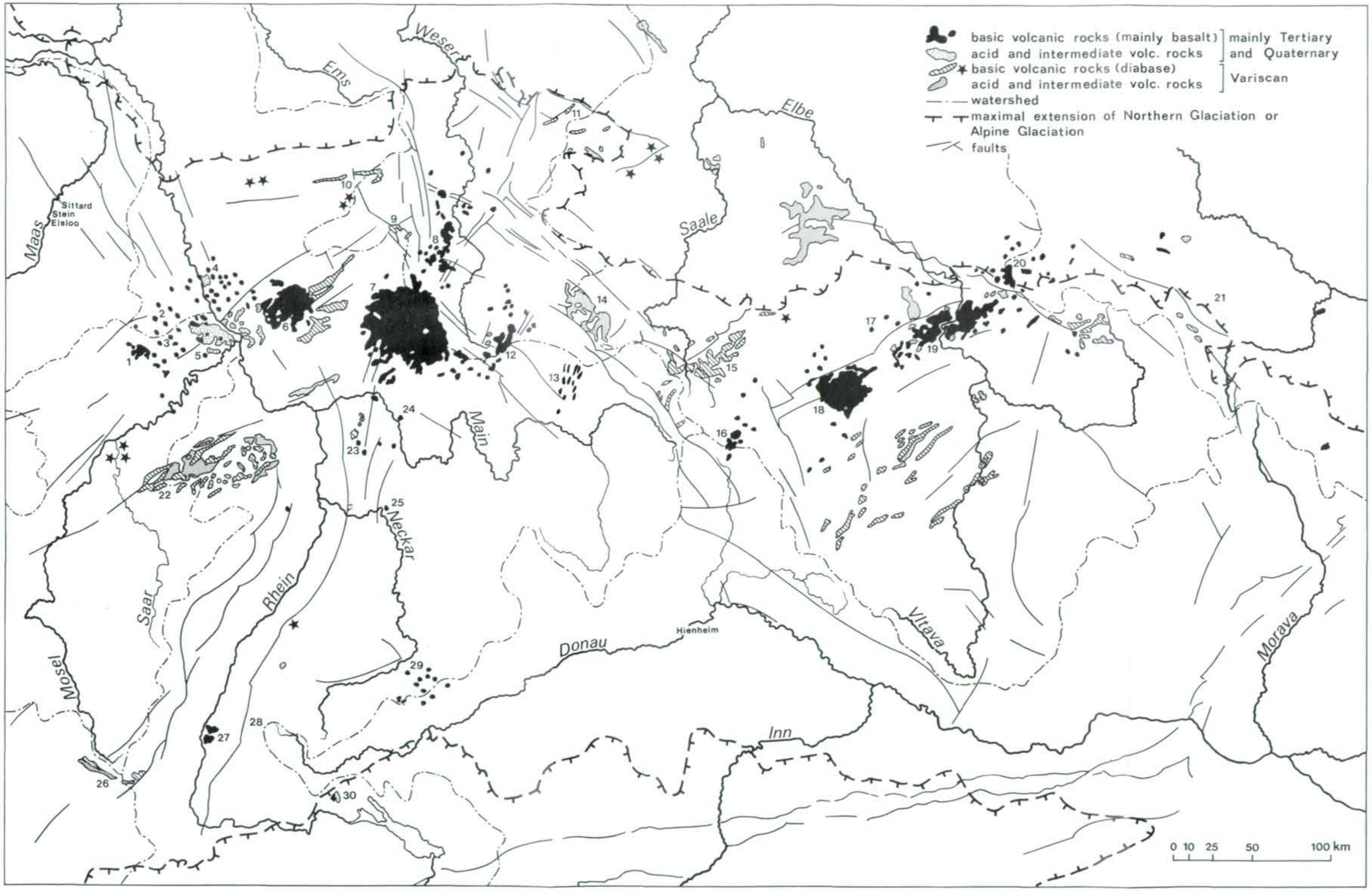


Enclosure 5. The Donaumoos, diagram of pollentypes excluded from the pollensum.



1. Sauerland
2. Ardennes
3. Rheinisches Schiefergebirge
4. Hunsrück
5. Taunus
6. Harz
7. Saar-Nahe
8. Odenwald
9. Spessart
10. Thüringer Wald
11. Kyffhäuser
12. Thüringer Schiefergebirge
13. Münchberger Mass
14. Fichtelgebirge
15. Erzgebirge (Krušné Hory)
16. Frankenwalder Zwischengebirge
17. (Sachsische) Granulitgebirge
18. Sudeten Range
19. Krkonoše, Karkonosze (Riesengebirge)
20. Sobótka (Zobten)
21. Rychlebske Hory (Reichensteiner Gebirge) and Hruby Jesenik (Altvater Gebirge)
22. Vosges
23. Schwarzwald (Black Forest)
24. Oberpfälzer Wald
25. Český Les (Böhmerwald or Bohemian Forest)
26. Bayerischer Wald (Bavarian Forest)
27. Moravia

Enclosure 6. Amphibolites from Central European sources.



1. Westeifel
2. Nordeifel
3. Hohe Eifel
4. Siebengebirge
5. Laacher See
6. Westerwald
7. Vogelsberg
8. Nordhessen (Northern Hessen)
9. Kellerwald
10. Sauerland
11. Harz
12. Rhön
13. Heldburger Schar
14. Thüringer Wald
15. Thüringer Schiefergebirge
16. Reichsfort
17. Erzgebirge (Krušne Hory)
18. Doupovské Hory (Duppauer Gebirge)
19. České Středohoří (Böhmisches Mittelgebirge)
20. Lausitz
21. Silezia
22. Saar-Nahe
23. Odenwald
24. Spessart
25. Katzenbückel
26. Vosges
27. Kaiserstuhl
28. Schwarzwald
29. Uracher Vulkangebiet
30. Hegau

Enclosure 7. Basaltic rocks in Central Europe.

Table 22: Qualitative mineralogical composition and other petrographic properties of amphibolitic artefacts from Hienheim (Bavaria, Germany) and Elsloo and Stein (Southeastern Netherlands).

petrographic properties / findnr.	mineral constituents: opaque/ore mineral	titanite	brown hornblende	blue-green hornblende	epidote/clinozoisite	biotite	chlorite	muscovite/sericite	quartz	plagioclase	mineral and rock properties – opaque: concentrations	opaque: dispersed	opaque: strings ∥ foliation or crenulation	hornblende: colourless to weakly blue-green	hornblende: blue-green	hornblende: oriented∥foliation	hornblende: sheaf-like arrangement	hornblende: aggregates with bushy outlines	hornblende: relatively coarse-grained	hornblende: porphyroblasts (often at random)	plagioclase: dispersed (and fine-grained)	plagioclase: layers, patches	plagioclase: porphyroblastic	quartz: dispersed	quartz: layers, patches	quartz: mosaic pattern	fabric: foliated (generally very weak)	fabric: layered	fabric: folded	fabric: cross-cutting veinlets	fabric: fractures, crenulation	average grain size (without porphyroblasts, veins, etc.)	photomicrograph (fig. nr. in text)	find numbers
H 344	‡			‡	—	+				+	○	●	○	●		○	●	○	○		●	○	○				○	○	○	○	●	f		H 344
H 183–1	+			‡	‡		+		—	+			●	●	○	●	●	○	○			●			?		●	●	●	○	●	f	47	H 183–1
H 359*	‡	—		‡	+				‡	‡	●	●	○	○	●	○	●	○	○	○	●	○	○		●	●	●	●	●	●	○	m	43	H 359*
H 699	‡			‡	—					‡	○	●	○	●			●				●	○	○					○	○		○	mf	44	H 699
H 764–1	‡			‡	‡		+		‡	+	○	○	●	●	○	○	●		○		○	●			●	●	○	●	○	●	○	f		H 764–1
H 530*	‡	—		‡	—	—			?	‡	○	○	●	○	●	●	●		○	○	○	●					●	●	○	●	○	mf	45	H 530*
H 266	‡	—		‡	—				?	‡	○	●	○	●	○	○	●		○	○	●	●	○				○	●	○	○	○	f		H 266
H 1083	‡	—		‡	—	—			‡	‡	○	●	○	○	●		●	●		○	○	●	○	●	○	○		○				mf	42	H 1083
H 182–2	‡	—		‡	—	—			‡	‡		●	○	○	●	○	●	●		○	○	●		●	○	○	○	○				mf		H 182–2
H 292–1	‡			‡		+			+	‡		●		●	○		●	●			●		●	●	●	●				●		m		H 292–1
H 206*	‡			‡					+	‡	○		●	○	●	●	●	○	○	●	●	○	○	○	●		●	●				mc		H 206*
H 929	‡	—		‡					+	‡		●			●		●	●			●			●			○	○		○		m		H 929
H 1062	‡			‡	—		—		—	‡		●			●	○	○	○	●	●	●	○	○	○			○					mc		H 1062
H 1063–2	‡			‡		—			—	‡		●			●	●	○	●		○	●			○			●					m		H 1063–2
H 721–2	‡	—		‡	‡			+		‡	○	○	●	●	○	○	●			●	●						○					mf		H 721–2
H 685*	‡		—	‡					+	‡	○		●		●	○	●	○	○	○	●	○		○	●		○	●	○		●	m		H 685*
H 1140–1	‡			‡		+			+	‡		●			●	○	○		●	●	●	○		○	○		○					mc	46	H 1140–1
H 1082–1	‡		?	‡		‡			+	‡	○	●			●		●	●		●	●	○	○	○	●	○	○		○	○	○	m		H 1082–1
H 718*	‡	—		‡		—			+	‡		●	○		●	○	○	●	○		●	●	○		●	●	○					m		H 718*
H 919	‡		—	‡					+	‡		●	○		●	○	○	●		●	●	●			●	○	○	○				mc	38	H 919
St 115–1	‡	—		‡					+	+			●		●	●	●	○		○	○	○		○	●		●	○	○			mf		St 115–1
E 444	‡	+		‡	—	—	+	—	+	+		●	○		●		○	●			●				●		○	○			○	mf	40	E 444
E 334–1	‡		—	‡		+			—	‡		●			●	○	●	●		○	●			○			○	●			○	mf	54, 59	E 334–1
E 111	‡	—		‡	—	—	—		+	‡		●			●	○			●	○	●	○	○	○	○		○					c	56	E 111
E 154	‡	—		‡	—		+		+	‡	○	●			●	○	○	●			●	○	○	○	●		○		○	○		mc		E 154
St 163	‡	—		‡	—	—			+	‡		●			●		●	●			●	●		●	●	○						mc	55	St 163
St 48	‡	—		‡			—		+	‡		●	○		●	○	○	●		●	●	○		●	●		○	○				mc	58	St 48
St 168	‡	—	?	‡					—	‡		●	○		●	○	●	●		●	●			○	○		○	○				mc	57	St 168

‡ / + } main constituent
— accessory constituent
• relatively important property
○ relatively subordinate property
average grain sizes:
c relatively coarse grained
m relatively medium grained
f relatively fine grained
* Not LBK.

petrographic properties / find	mineral constituents: olivine phenocrysts	groundmass	titanaugite phenocrysts	groundmass	brown hornblende	biotite	titanomagnetite phenocrysts	groundmass	plagioclase phenocrysts	ground mass	leucite	nepheline	chlorite	serpentine	calcite	limonite
St 239	■	—	■	+	■		□	+	□	+				—	—	—
E 185	■		■	+	■		□	+		+				—		—
St 164–1	■	—	□	+			■	+		+						
E 102	■	—	□	+			□	+	□	+				—		—
E 366	■	—	□	+			□	+	□	+		?	—			—
E 608	■		■	+			■	+	□	+		?			—	
St 115–3	□	—	■	+			■	+	□	+		—				—
E 354	■		□	+				+	□	+			—	—	—	+
St 164–2	■		□	+			□	+		+		—			+	
E 600–1	■		□	+			□	+		+		?	—		+	—
E 344	■		□	+			□	+		+						+
E 600–2	■		□	+			□	+		+			—			+
E 389	■		■	+		□	■	+			+	+				
E 398	?		■	+				+		+		?				—
St 135	■	—	■	+		?	□	+		+		?	+			
E 334–2	■		□	+				+		+		+				+

petrographic properties / find	mineral and rock properties: olivine					titanaugite				brown hornblende				titanomagn.			plagioclase			fabric				photomicrograph (fig. nr. in text)	find numbers
	rimmed by pyroxene	rimmed by biotite	hourglass structure	mesh structure	phenocryst clusters	twinned	zoned	hourglass structure	phenocryst clusters	twinned	zoned	partly altered	completely altered	inclusion in olivine	inclusion in pyroxene	secondary to brown hornblende	twinned	zoned	clusters	flow structure	porphyritic	grain size groundmass	relative sizes phenocrysts		
St 239	○			○	○	○	●	○	●			○	●	●	●	●	●			●	●	f	mc	64	St 239
E 185	○			●	○	○	●		○	○		○	●	●	●	●	●			●	●	f	mc		E 185
St 164–1				○	○		○		○					○	●		●			○	●	f	mc		St 164–1
E 102	○			○	●		○		○					○	●		●	○		●	●	mf	m		E 102
E 366	○				●	○	○		○					○	●		●	○	○	●	●	mf	m	65	E 366
E 608	○			○	○	●	●	●	●					○	●		●	○			●	f	m	61	E 608
St 115–3	○			○	○	●	●	●	○					○	●		●	○	○		●	mf	m		St 115–3
E 354				●	●	○	○	○	○					○	○		●	●		●	●	f	f		E 354
St 164–2	○		●	○	●		○	○	○					○	○		●	○		●	●	f	mf		St 164–2
E 600–1	●			○	○		○	○	●					○	○		●			●	●	f	mf	62	E 600–1
E 344	○		○	○		○	●	○	●						○		●			●	●	f	mf		E 344
E 600–2	○		○	○	○	○	●	○	●					○	○		●			●	●	f	mf		E 600–2
E 389	○	●				●	●	○						○	●					●	●	mc	m	66	E 389
E 398							●	●	●						●		○				●	f	mf		E 398
St 135	●			●	○	●	●	●	●					○	●		●	○		○	●	f	mc	63	St 135
E 334–2	○			○	●		○								○		●	○			●	mf	m		E 334–2

Table 23: Qualitative mineralogical composition and other petrographic properties of basaltic implements from Elsloo and Stein (Southeastern Netherlands)

■ phenocrysts (many) □ few

\+ main constituent ● relative important property

— accessory constituent ○ subordinate property

average grain sizes: relatively fine grained f

relatively medium grained m

relatively coarse grained c