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 required.

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. Hazelnuts 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 Hradište (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.

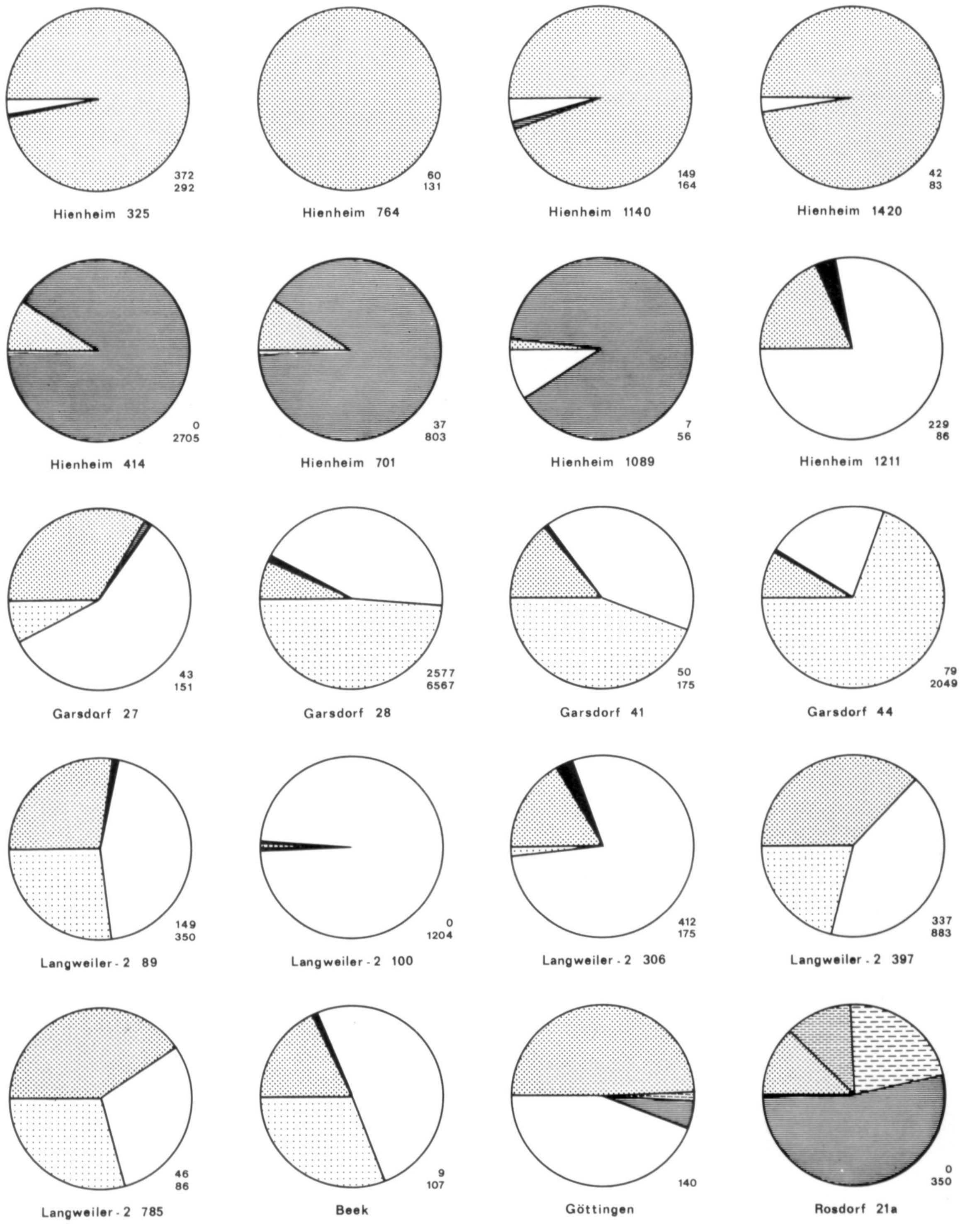
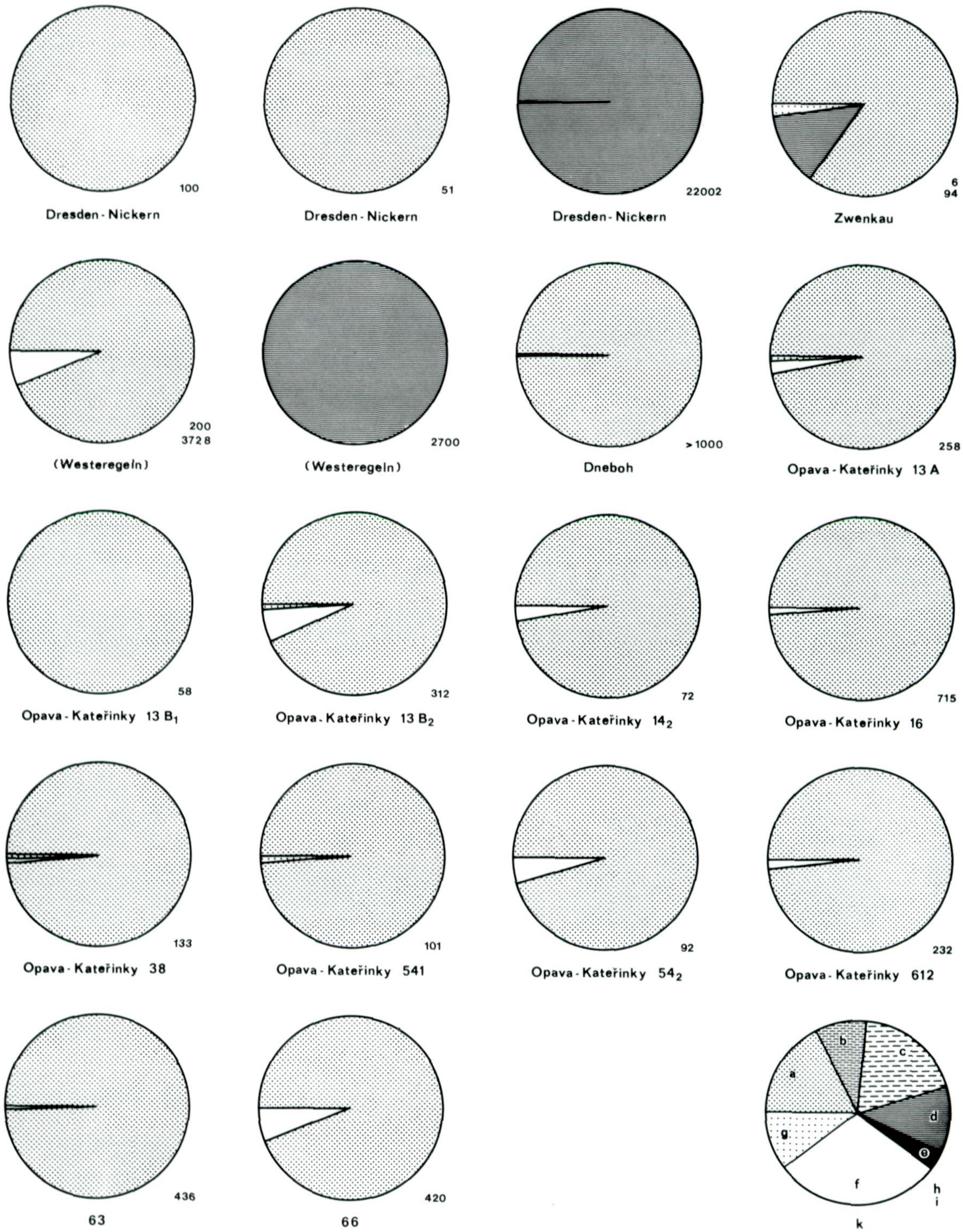


Fig. 10. Assemblages of carbonized seeds and fruits from LBK settlements.



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 loam 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 m^2 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 m² (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 m^2. 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

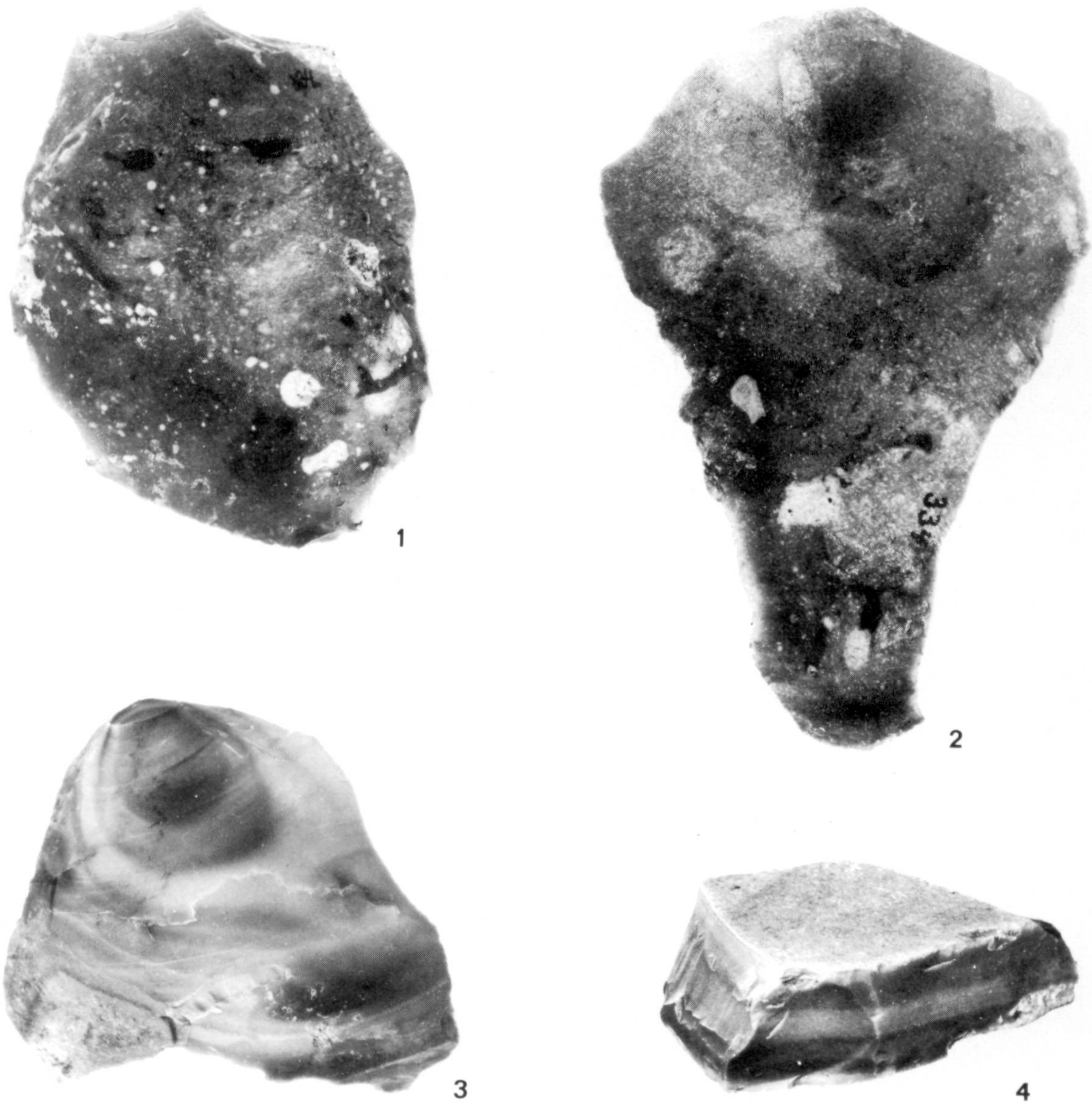


Fig. 11. Typical cherts. Scale 1:1.
nos. 1 and 2: chert from the Gulpen Formation, flakes excavated at Elsloo.
no. 3: chert from the Jurassic, flake from a nodule, excavated at Hienheim.
no 4: chert from the Jurassic, core from a plate, excavated at Hienheim.

& 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

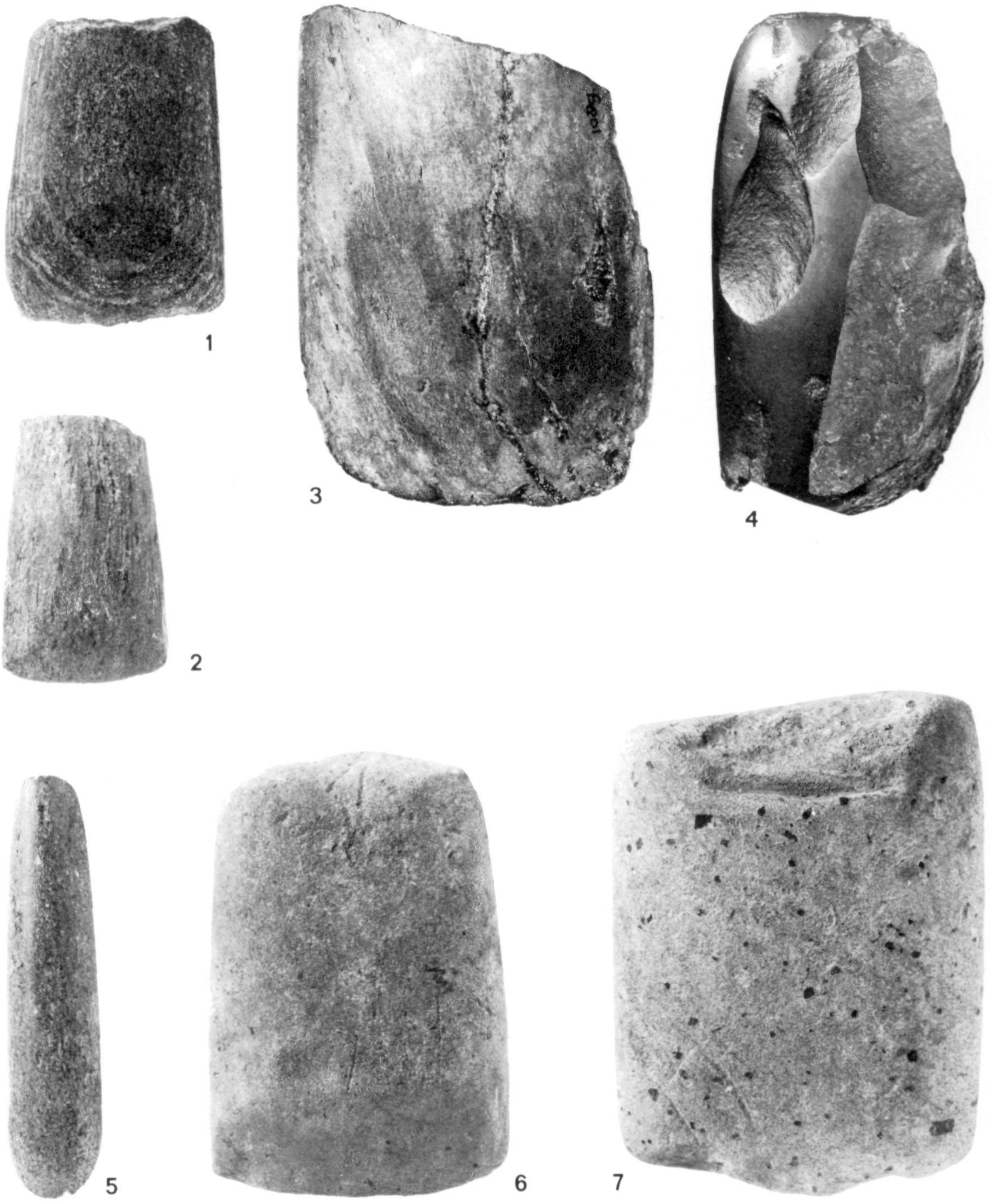


Fig. 12. Adzes. Scale 1:1.
nos 1 and 5: Elsloo 454 and 337, amphibolites.
no 2: Hienheim 703, "homogeneous" amphibolite.
no 3: Hienheim 1089, "fine inhomogeneous" amphibolite.
no 4: Elsloo 75, lydite.
no 6: Stein 129, basalt with small phenocrysts.
no 7: Sittard 66, basalt with relatively large phenocrysts.

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 q u e r n s and g r i n d i n g - s t o n e s.* 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

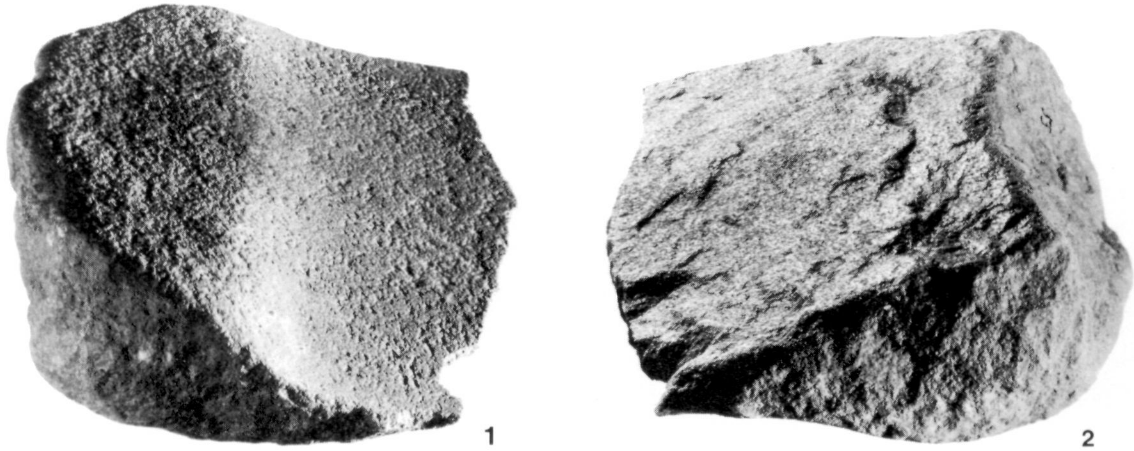


Fig. 13. Quern-fragment from the LBK settlement at Elsloo. Scale 1:2 Left: surface, worn down by grinding
Right: reverse of the same fragment showing its provenance from a gravel bed.

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

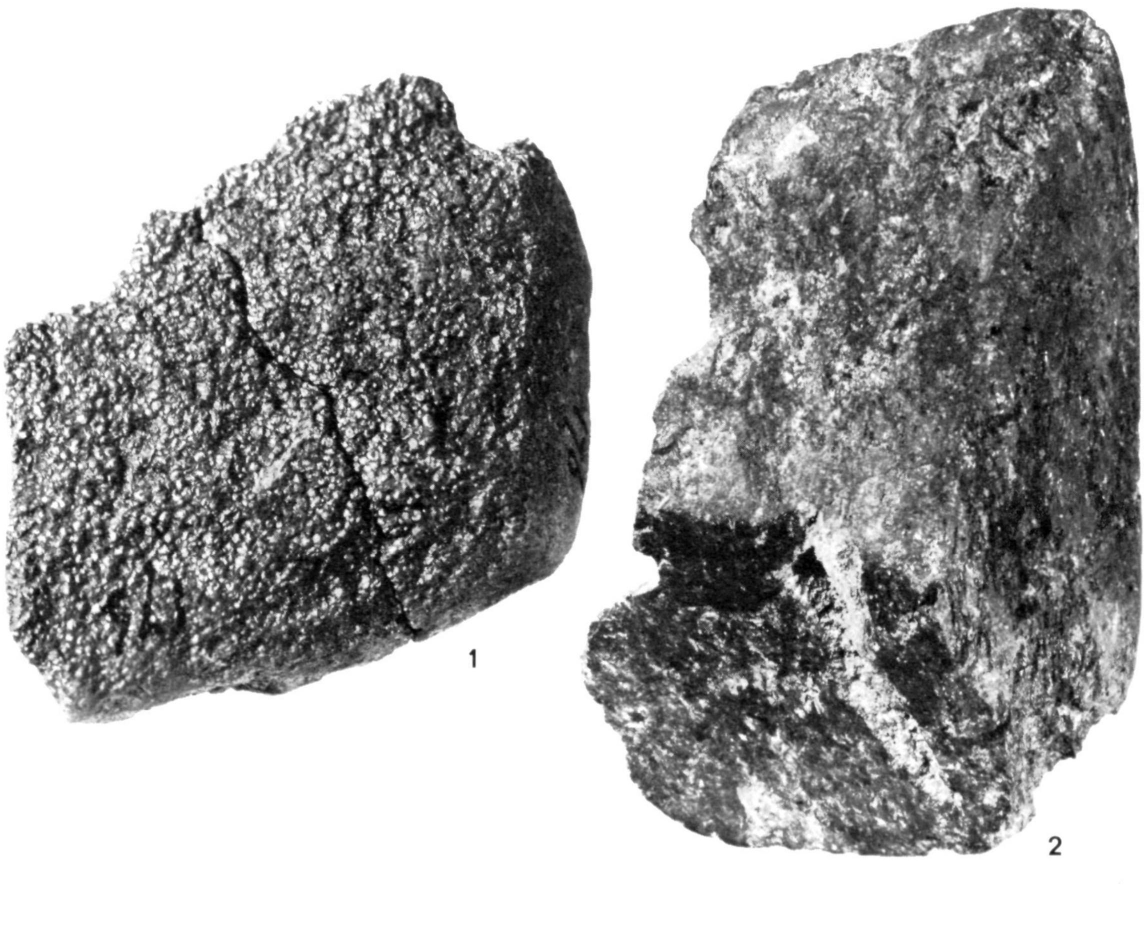


Fig. 14. Hematite from the LBK settlement at Elsloo. Scale 2:1
Left: oölithic type. Right compact type.

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.