III The Environment

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III

THE ENVIRONMENT

III. 1 GENERAL OBSERVATIONS ON THE RECONSTRUCTION

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

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

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

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

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

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

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

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

On the basis of the above-mentioned considerations, we arrive at a three fold division of the environment around a settlement:
1) an area with a radius of two hours' walking distance, the environment of which must be reconstructed in detail.
2) a zone with a radius of six hours' walking distance, of which the topography, the location of other settlements and the presence of essential raw materials must be reconstructed.
3) the area beyond, the environment of which need not be reconstructed in the first instance.

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

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

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

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

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

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

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

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

Human group	*Type of economy*	*Radius of action or "territory"*	*Way of travelling*	*Author*
Anbara Australia	hunters/ gatherers	50 km^2	on foot	L.R. Hiatt 1968 p. 101
Australian aborigines	hunters/ gatherers	10-13 km	on foot	A.A. Yengoyan 1968 p. 187
Women from Arnhemland Australia	gatherers	6-8 km	on foot	M. McArthur 1960 p. 130
Pitjandara women Australia	gatherers	5 km	on foot	N.B. Tindale 1972 p. 245
Kung Bushmen Botswana	hunters/ gatherers	10 km	on foot	R.B. Lee 1969 p. 61

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

Human group	*Type of economy*	*Radius of action or "territory"*	*Way of travelling*	*Author*
G/wi Bushmen			on foot	G.B. Silberbauer
men	hunters	24 km		1972 p. 290
women	gatherers	8 km		p. 287
Botswana				
Hadza women Tanzania	gatherers	hour's walk	on foot	J. Woodburn 1968 p. 51
Birhors India	hunters/gatherers	4-8 km	on foot	D.P. Sinha 1972 p. 377
Copper Eskimo Canada	hunters	8 km	on foot	D. Damas 1972 p. 23
Bemba Zambia	swidden cultivators	for cultivation a few km for fishing up to 16 km for visiting up to 25 km	on foot	A.I. Richards 1939 p. 18 and Table E
Yako Nigeria	swidden cultivators	120 km²	on foot	C.D. Forde 1968 p. 161
Kapauku New Guinea	swidden cultivators	45 min = 1.8 km	on foot	L. Pospisil 1963 p. 87
Tsembaga New Guinea	swidden cultivators	orthographically 8.2 km² to gardens: 20 min walk down hill and 30 min walk up slope	on foot	R.A. Rappaport 1968 p. 33 and Table 5
Iban Borneo	swidden cultivators	up to 1.5 km slightly further than 1.5 km	on foot by boat	D. Freeman 1970 p. 161
Hanunóo Philippines	swidden cultivators	6 km² one hour's walk to garden = 1 km with heavy load 2 hours' walk for a coil of rattan	on foot	H. Conklin 1957 p. 12 Plate 29
Lamet Indochina	swidden cultivators	2.48 km walking speed 3 km/h	on foot	K.G. Izikowitz 1951 p. 40
Maroni River Carib women Surinam	swidden cultivators	45 min 2 hours or more	on foot by boat	P. Kloos 1971 p. 26
Kuikuru Brazil	swidden cultivators	6-8 km	on foot	R.L. Carneiro 1956 p. 232
Average Amazonian cultivators Brazil	swidden cultivators	5 km	on foot	R.L. Carneiro 1956 p. 232

III. 2 THE CLIMATE

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

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

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

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

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

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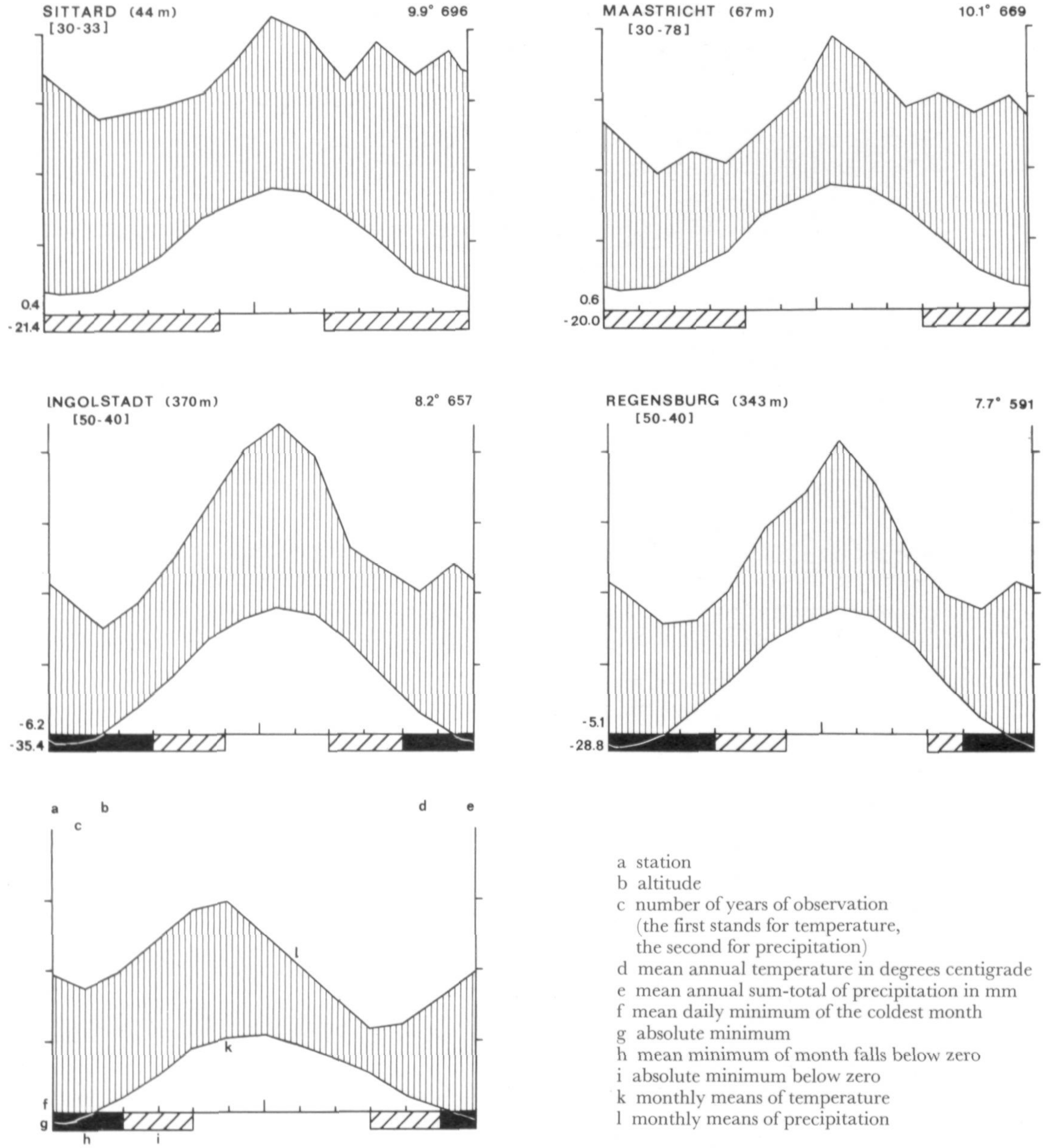
* One LBK settlement: Caberg, is located at a distance of 1,5 km.



a station
b altitude
c number of years of observation
(the first stands for temperature,
the second for precipitation)
d mean annual temperature in degrees centigrade
e mean annual sum-total of precipitation in mm
f mean daily minimum of the coldest month
g absolute minimum
h mean minimum of month falls below zero
i absolute minimum below zero
k monthly means of temperature
l monthly means of precipitation

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

III.3 THE SUBSTRATE

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

SOUTHERN LIMBURG

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

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

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* Nowadays these names are only of local use. For the correllation with the lithostratigraphy the reader is referred to the explanation of the "Geologische overzichtskaarten van Nederland 1:600 000" (Zagwijn & van Staalduinen 1975).

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

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

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

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

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

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

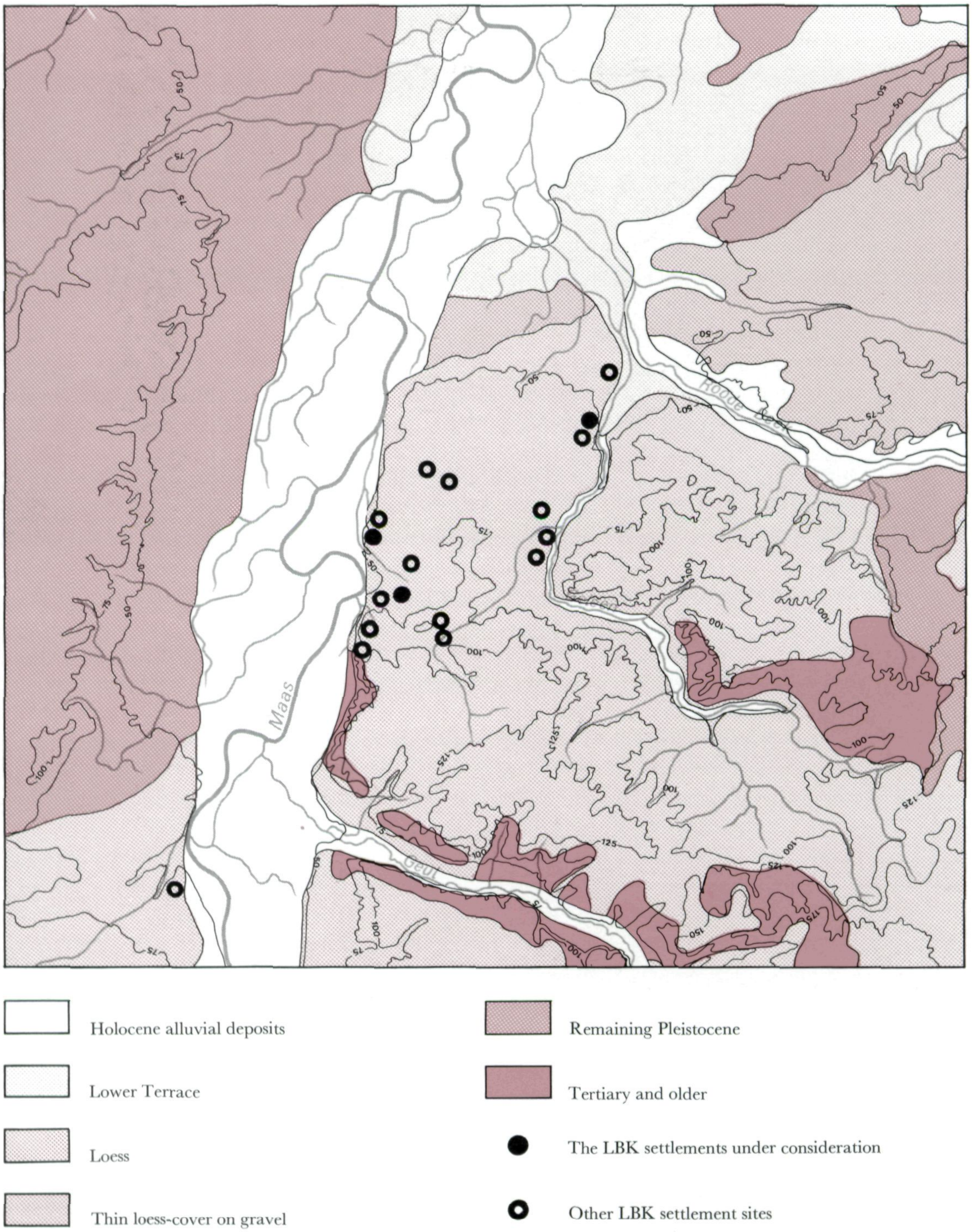

Fig. 2. The substrate within a radius of 10 kms around the LBK settlements in Southern Limburg. Scale 1:200 000.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

HIENHEIM

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

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

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

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

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

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

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

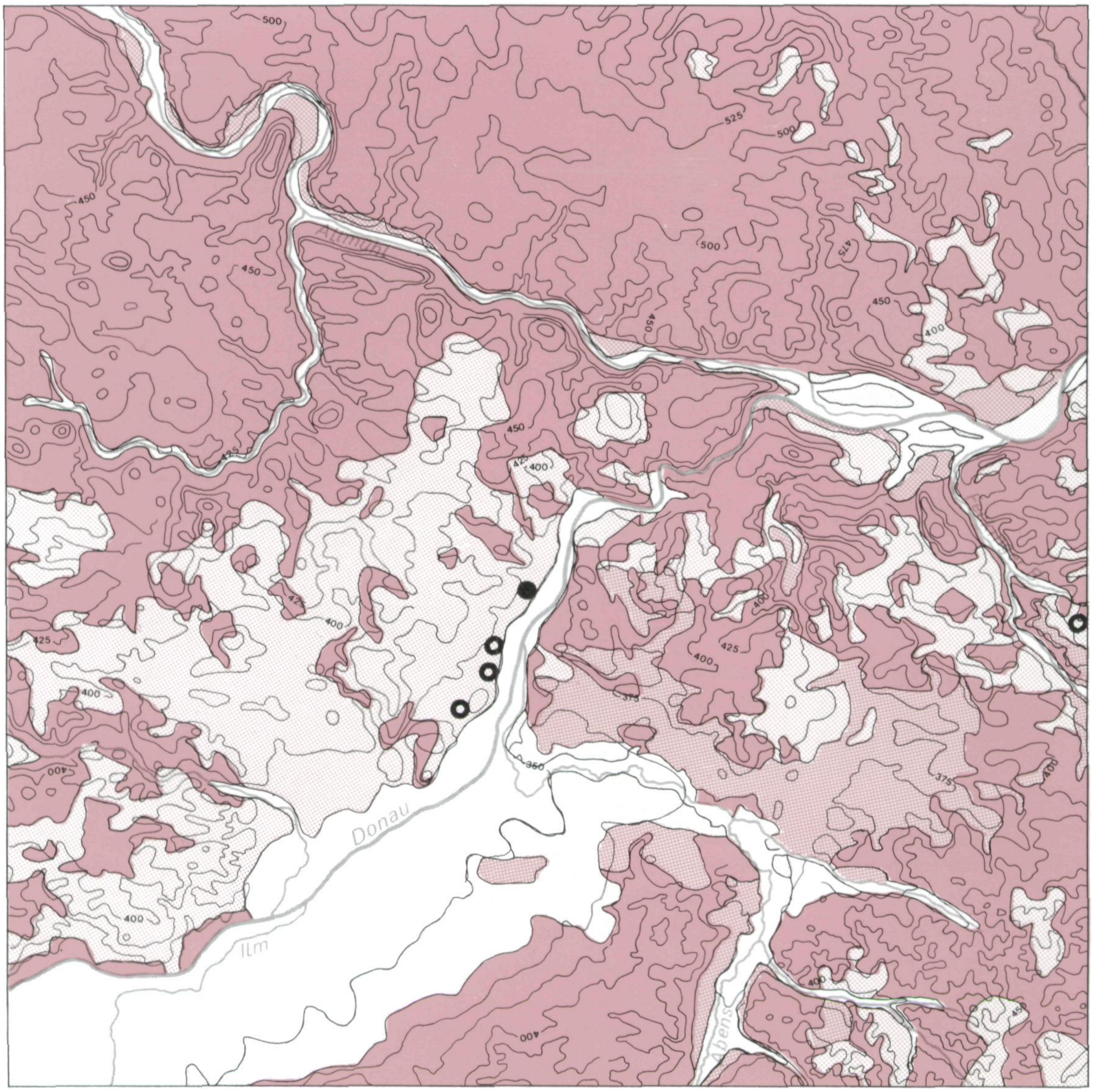

Fig. 3. The substrate within a radius of 10 kms around Hienheim. Scale 1:200 000. For the legend see fig. 2.

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

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

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

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

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

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

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

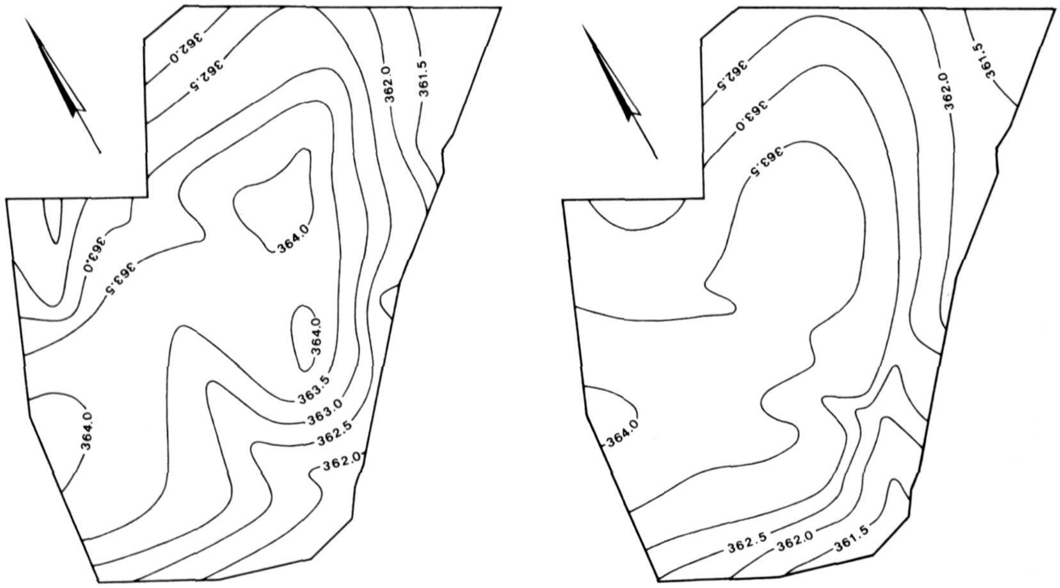

Fig. 4. Contour map of the settlement area "Am Weinberg" near Hienheim. Scale 1:5000. Left: reconstruction of the original relief. Right: recent situation.

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

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

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

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

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

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

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

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

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

It appears from the above that we may distinguish the following types of landscape:

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

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

III. 4 THE VEGETATION

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

SOUTHERN LIMBURG

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

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

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* Sometimes faunal assemblages can be used for this purpose.

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

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

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

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

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

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

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

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

We shall give a short description of these vegetation types.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

HIENHEIM

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

III. 5 THE FAUNA

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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* See our reference van den Brink 1972.

III. 6 HUMAN POPULATIONS

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

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

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

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

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

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

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

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

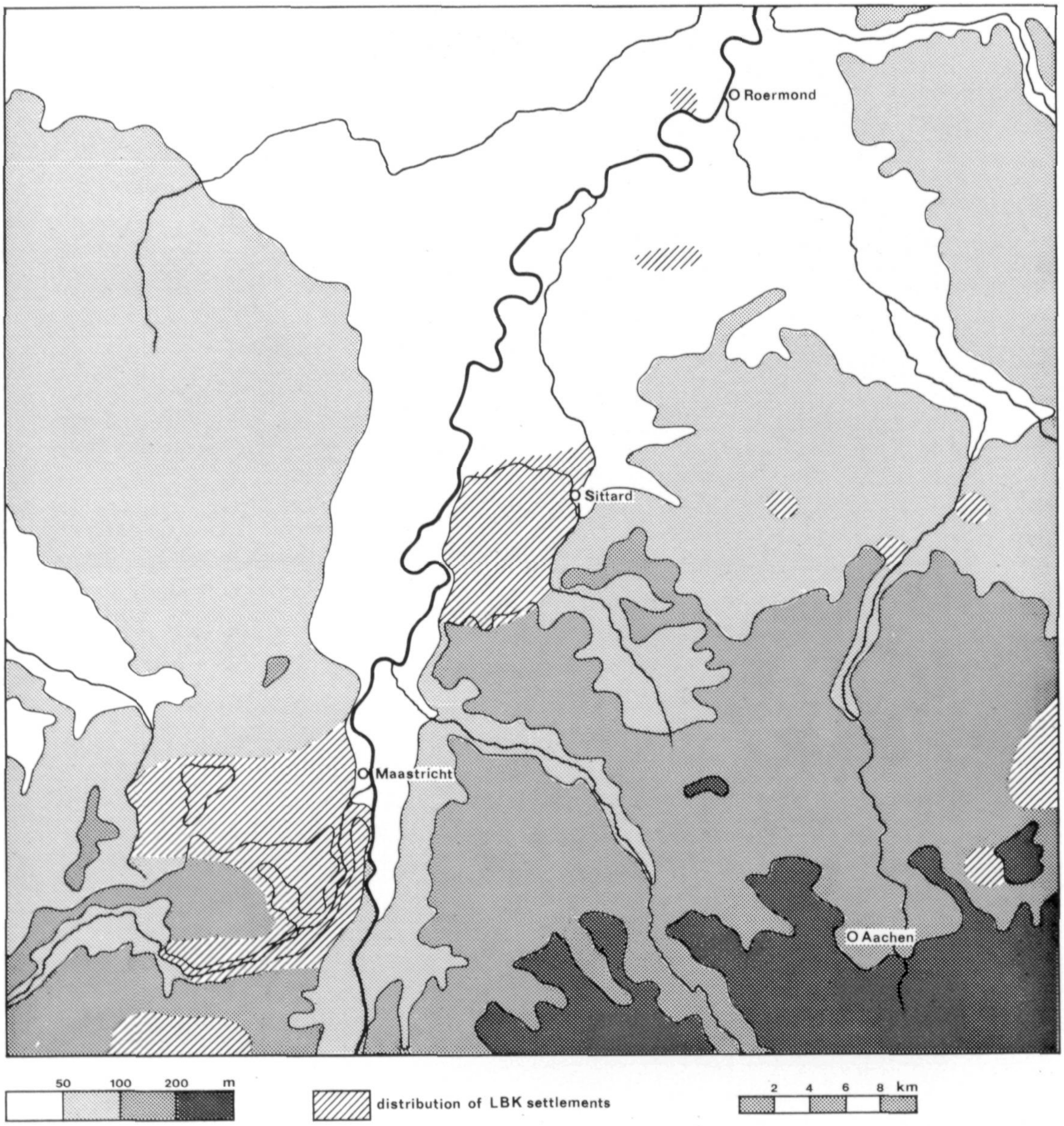

Fig. 8. Generalised distribution of LBK settlements within a 30 km distance of Sittard, Stein and Elsloo. Scale 1:400 000.

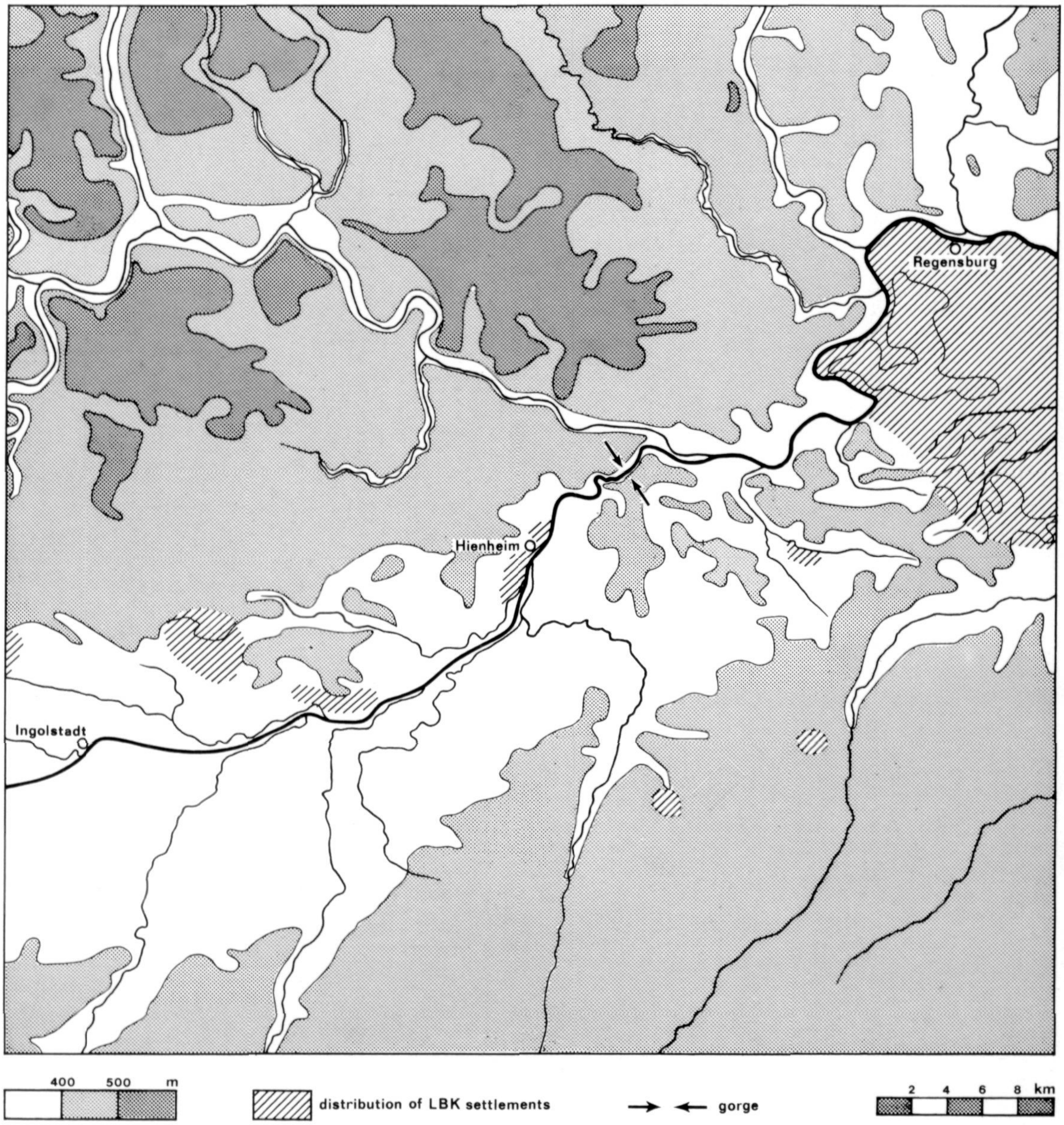

Fig. 9. Generalised distribution of LBK settlements within a 30 km distance of Hienheim. Scale 1:400 000.

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

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

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

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

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

III.7 FINAL REMARKS

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

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

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

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