The Bandkeramik settlement of Vaihingen an der Enz, Kreis Ludwigsburg (Baden-Württemberg): an integrated perspective on land use, economy and diet

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Introduction

The site of Vaihingen is one of the few Bandkeramik sites in Europe that have not only been completely excavated, but also analysed using a range of bioarchaeological and environmental approaches, alongside studies of the material culture (Krause 1994; 1996; 1997a–c; 1998a–b; 2000; 2001; 2002; Krause et al. 2000; Hönscheidt 2002; Bentley et al. 2003; Bogaard 2004; 2011; Bentley / Knipper 2005; Strien 2005; 2011; Bogaard et al. 2011; Knipper 2011; Fraser et al. 2013a; Styring et al. 2015). A combination of favourable preservation conditions for bone and seed remains, together with systematic recovery procedures, have created a unique archive and resource for scholars investigating the early farming communities of the region, their ecology and social life.

Here we seek to integrate and synthesise post-excavation work to date on the architecture and bioarchaeology, with particular emphasis on faunal and botanical remains. Our aim is to bring the results of specialist analyses together as a new basis for future work on the site, such as Bayesian chronology building, modelling of land use, full analysis of human skeletal remains and further application of multi-isotope analysis to bioarchaeological materials. In the context of the increasingly well documented diversity of LBK (Linearbandkeramik or Bandkeramik) communities and lifeways (Bickle / Whittle 2013), our intention is not to promote a new 'Vaihingen-based model'. Rather, the work brought together here sheds light on Vaihingen's remarkable development as a relatively large, nucleated community of the earlier (ältere) LBK that incorporated multiple regional traditions, and on its subsequent occupation as a smaller but still substantial 'village' of the Middle Neckar tradition. We contend that the archaeology of Vaihingen prompts new questions about the nature and ecology of LBK communities that can and should rejuvenate interdisciplinary studies on this singular Early Neolithic complex of central Europe.

In the following contributions we seek to address the following key questions:

1. To what extent did practices at Vaihingen, ranging from domestic architectural arrangements to herding and farming regimes, change through time (for example transition from the Flomborn period to the later LBK)? Are any changes correlated in time across datasets, or did different aspects of practice develop on independent timescales?

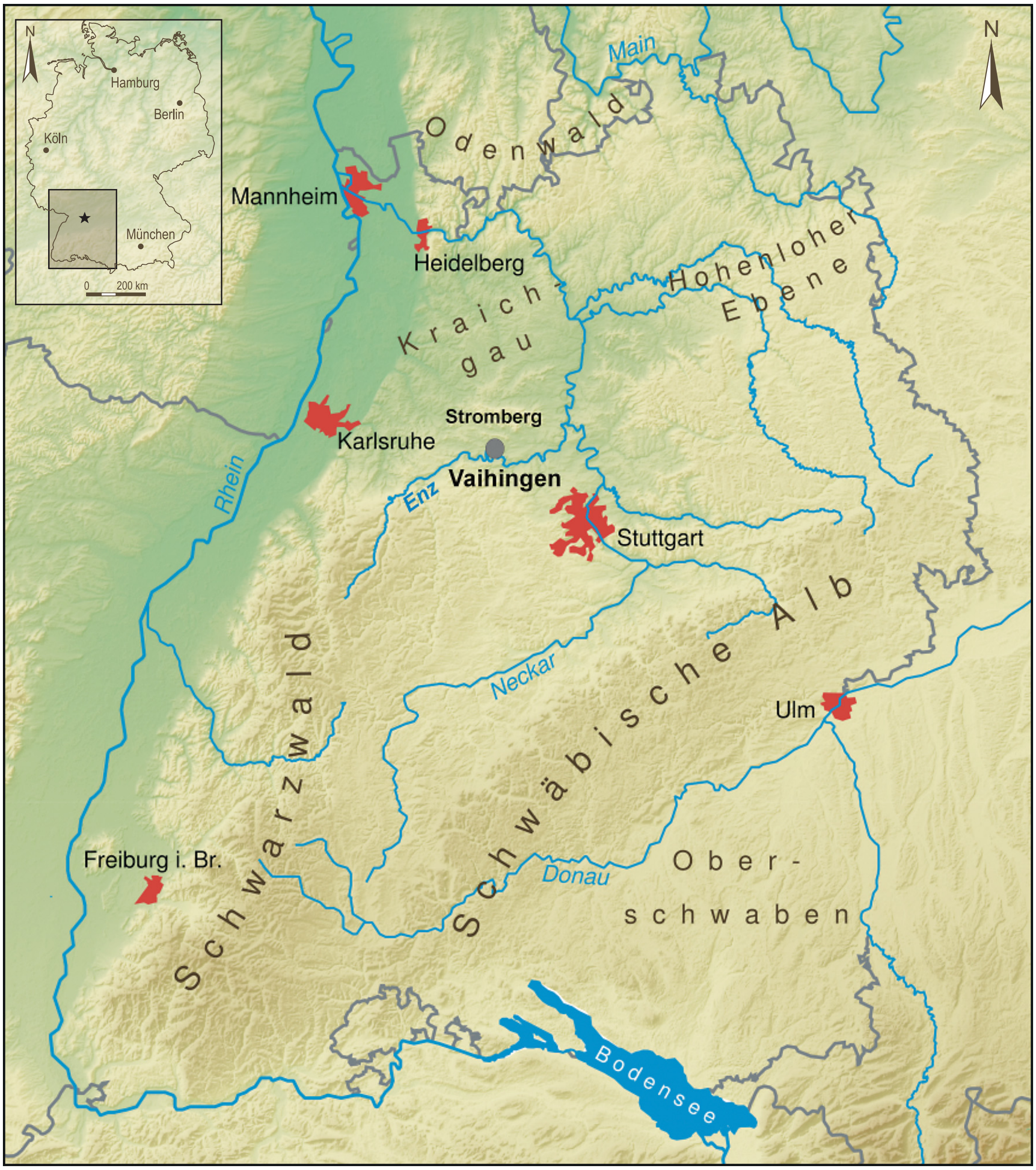

Fig. 1. Topographical map of south-west Germany showing the location of the Bandkeramik settlement of Vaihingen an der Enz.

Fig. 2. View of the Bandkeramik settlement with ditch system and double palisade in the foreground, looking north towards the Keuperbergland of the Stromberg.

2. What was the extent and nature of spatial variation in practice at Vaihingen, and how far does it correspond to the internal divisons of large LBK sites at different scales (farmstead, lineage or 'clan' groups, regional tradition groups)? Are other spatial patterns evident in specific datasets?

3. What light is shed by late LBK practices at Vaihingen on the ending of its occupation? Is there evidence of 'crisis'?

The site

The extensive settlement remains and burials revealed by the 1994–2003 excavations at Vaihingen, located on the western edge of the Middle Neckar River region between Stuttgart and Karlsruhe, south of the Stromberg mountains and at the transition to the Kraichgau *(figs 1–3)*, have provided a unique opportunity to evaluate the development, economy and social life of a long-lived Bandkeramik community (Krause 1994; 1996; 1997a–c; 1998a–b; 2000; 2001; 2002; Krause et al. 2000). Large-scale excavations over a ten-year period brought to light a nearly complete settlement of c. six hectares occupied from the earliest Linearbandkeramik (älteste Linearbandkeramik, or äLBK) to the end of the LBK *(fig. 4)*. After an interruption of perhaps a few generations, a Hinkelstein settlement was established at the same location, marking the beginning of the Middle Neolithic.

The settlement's development was topographically constrained to a relatively restricted area upon a flat ridge; hence, it presents a high density of features and overlapping settlement phases. The loess here is clay-rich due to solifluction layers derived from underlying Keuper sandstone, resulting in high lime content and excellent preservation of bone as

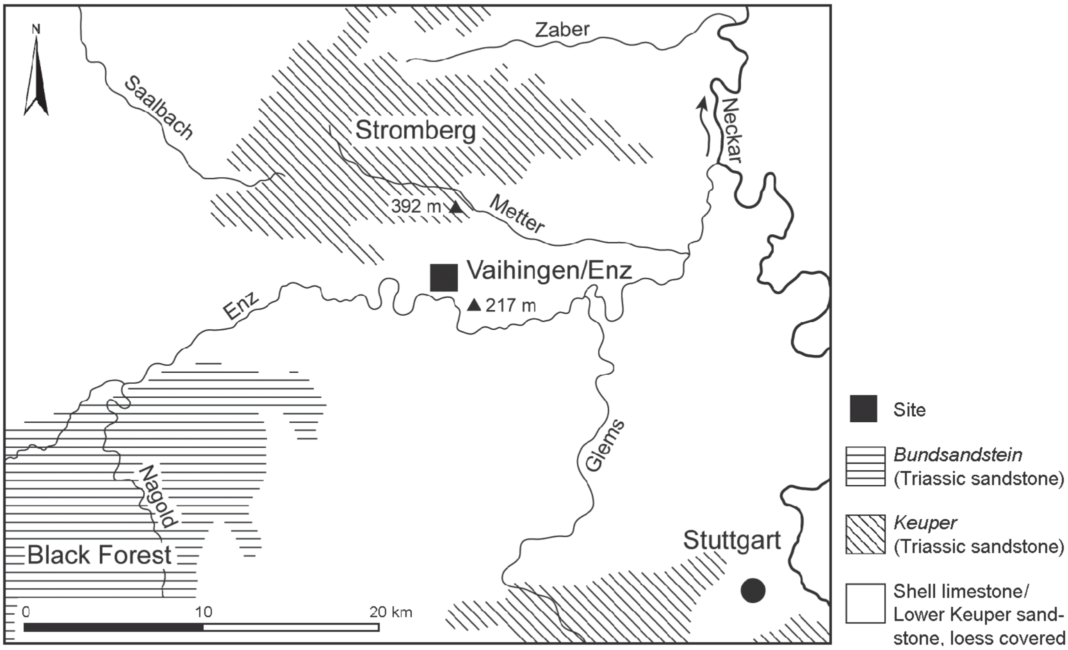

Fig. 3. Map showing the major features of the Vaihingen region.

well as charred plant remains across the site. Generally, erosion of settlement features was more severe in the southern area than in the area north of the road running through the site *(fig. 4)*. Therefore, shallow structures like post holes of smaller posts might be under-represented in the southern area, and the reconstruction of house plans here was more difficult.

Alongside the remains of numerous houses and associated pits, the ditch of an oval enclosure represents the most remarkable feature of the settlement. The ditch was established during the Flomborn period (ältere or earlier LBK) around an existing settlement area and was in use for a relatively short period of time, perhaps one to two generations. At the transition to the middle (mittlere) LBK the ditch was filled in and its northern half used as a burial ground. These events, together with the subsequent abandonment of this so-called 'ditch cemetery' and other changes – including burials within the settlement and establishment of collective burial pits – suggest a shifting social geography of the later LBK community (Strien 2005; 2011) and provide a historical framework within which to interpret the architecture and subsistence practices of the inhabitants *(fig. 5)*.

Relative chronology

Grouping Bandkeramik features and finds into chronological units has been widely practised for decades and is based upon the so-called 'Hofplatz' model (Boelicke 1982; Boelicke et al. 1988; Lüning 2005). According to this model, LBK residences consist of a centrally placed longhouse surrounded by different types of pit that form a chronological and functional unit. The overall combination of the known total duration of the LBK, stylistic developments in material culture and the number of houses at given sites have led to the well supported hypothesis that houses are roughly equivalent to generations. As the

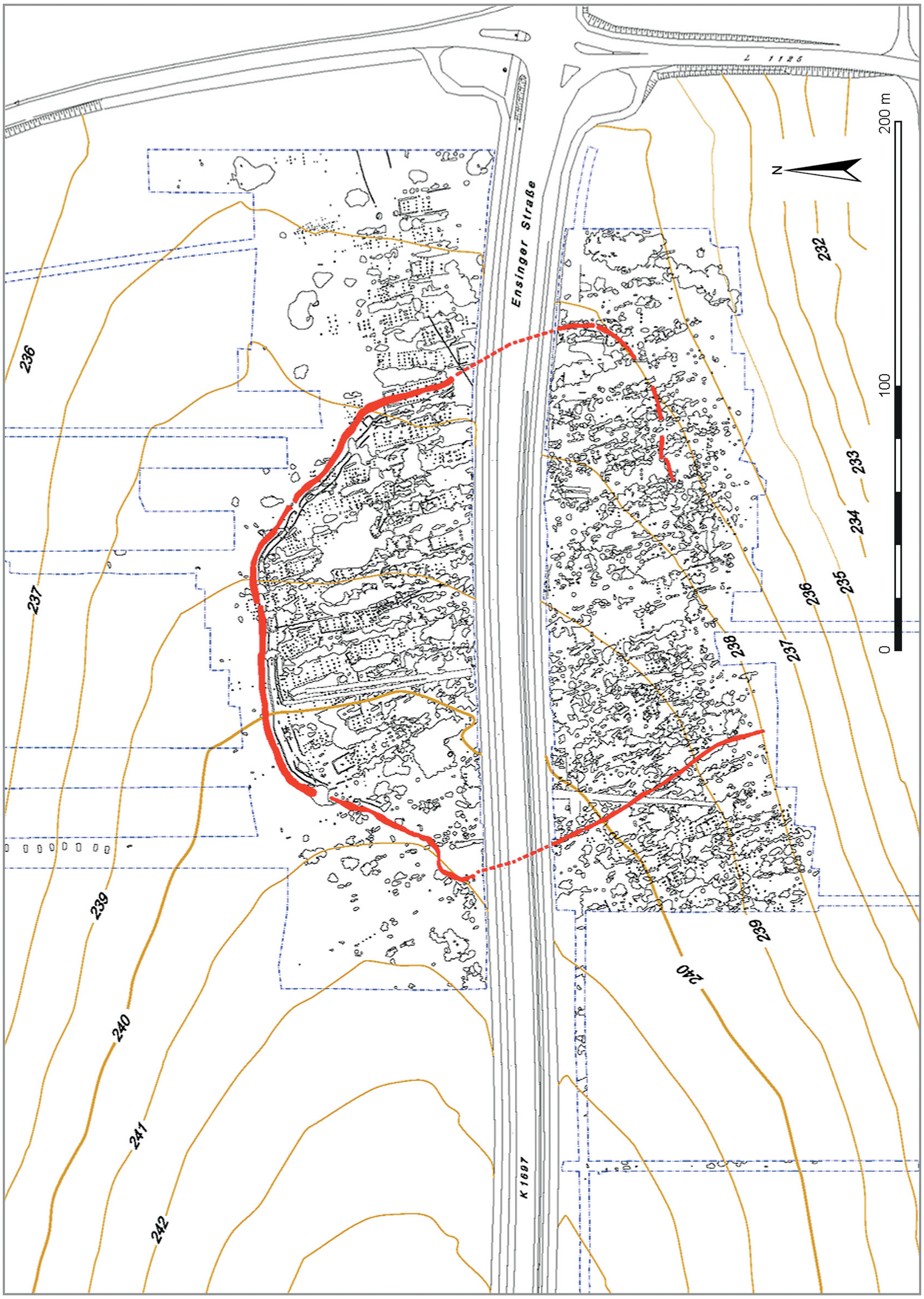

Fig. 4. Plan of the Bandkeramik settlement in the “Seite field” (Gewann Seite). Red: the ditched enclosure.

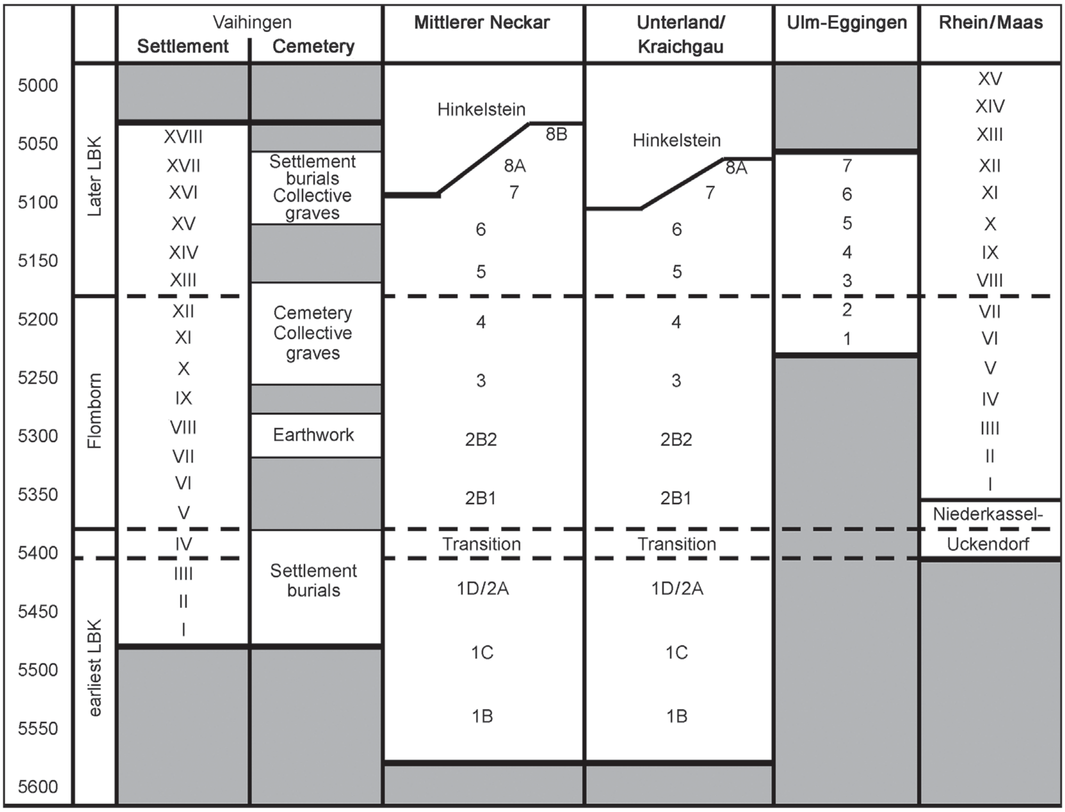

Fig. 5. Chronological summary.

floors of the longhouses are usually not preserved, there is rarely any archaeological material associated directly with a house or its surviving post holes. The majority of material is found in pits. Therefore, the chronological framework is based upon the pit fills. As LBK fine ware pottery is decorated in sophisticated and relatively strict ways, it is possible to establish both a temporal and spatial grouping of the material with the help of a decoration catalogue and seriations of pits and its decorated pottery (for example Strien 2000). The dating of features and houses is then deduced from the relative chronological position of their pit inventories. Additional chronological information – though usually with a coarser resolution – is available from stratigraphic observations as well as changes in material culture.

If sites are settled very densely and over a long time period – as at Vaihingen – it is difficult to associate any given house plan with its pits. Furthermore, mixed assemblages occur including later re-use of older features. On the other hand, overlapping of houses and other structures can help to disentangle relative sequences.

The huge amount of pottery and stone artifacts from Vaihingen was studied by Hans-Christoph Strien. He not only established a relative chronology, but also linked the inhabitants of Vaihingen to different scales of regional and local tradition in material culture. The following remarks are based upon his work (Strien 2005; 2011; 2014). Generally, the LBK in Württemberg can be divided into three main periods, each consisting of several phases and 'house generations' *(fig. 5)*.

The earliest LBK

The earliest (älteste) LBK (äLBK, phases 1B to 1D / 2A) is attested in Württemberg, especially in the upper Gäu region (see Bofinger 2005). Most of the Württemberg material dates to the last two generations of the earliest LBK and the transition to the Flomborn phase. The Vaihingen material fits into this general pattern well and starts with the later phases of the earliest LBK. Grouping the available material according to the highest possible temporal resolution of 'house generations', four building phases belong to the earliest LBK period (Strien 2011).

The Flomborn period

The Flomborn period (earlier or ältere LBK, phases 2 B1 to 4) is the best represented in the Vaihingen material. The whole stylistic development of Flomborn is apparent, and even its continuous evolution out of the earliest LBK. Also the majority of dated houses belong to the Flomborn period, and Strien estimates that up to 40 houses existed simultaneously, with at least 320 inhabitants (Strien 2010). During the Flomborn period, the settlement was surrounded by a ditched enclosure, and dwellings located outside of the ditch were abandoned or relocated within the enclosed area. According to the material found in the ditch and overlapping with later houses, it might have been in use only for a period of about two generations. According to Strien, the Flomborn material in Vaihingen covers eight 'house generations' or roughly 200 years. At the end of Flomborn, the number of datable pits dwindled considerably, which seems to be connected with a general decrease in population density at Vaihingen. At the same time, there were profound changes in decorative motifs on pottery. The previously continuous development from the first establishment of the site to the end of Flomborn now collapsed and was replaced by a new iconographic system. The network of communication and exchange partly collapsed as well, as is recognisable in the poorer supply of flint raw material. This 'crisis' at the end of Flomborn is evidenced in supra-regional contexts as well (Strien / Gronenborn 2005).

The later LBK

The later (jüngere) LBK (phases 5 to 8 B) is represented by six 'house generations' (Strien 2011) and reaches the latest phases of the LBK, but find densities and thus settlement density are lower during the whole period compared to the Flomborn. As mentioned above, the transition from Flomborn to the later LBK was not continuous, but shows a marked interruption in the ceramic decorative canon and in flint supply.

To sum up, continuous settlement activity can be demonstrated through typochronological studies of mainly pottery decoration, encompassing most of the LBK span with the exception of the very first phase. Following the concept of 'house generations', 18 generations might have lived in Vaihingen for more than 400 years. The highest find densities and numbers of datable houses belong to the Flomborn period. Generally, in the southern part of the site dating of houses by pit fills is more difficult than in the northern area.

Social geography

Alongside chronological developments, LBK material culture shows distinct regional patterns as well as individual 'house styles' (for example Fridrich 1994; Krahn 2006;

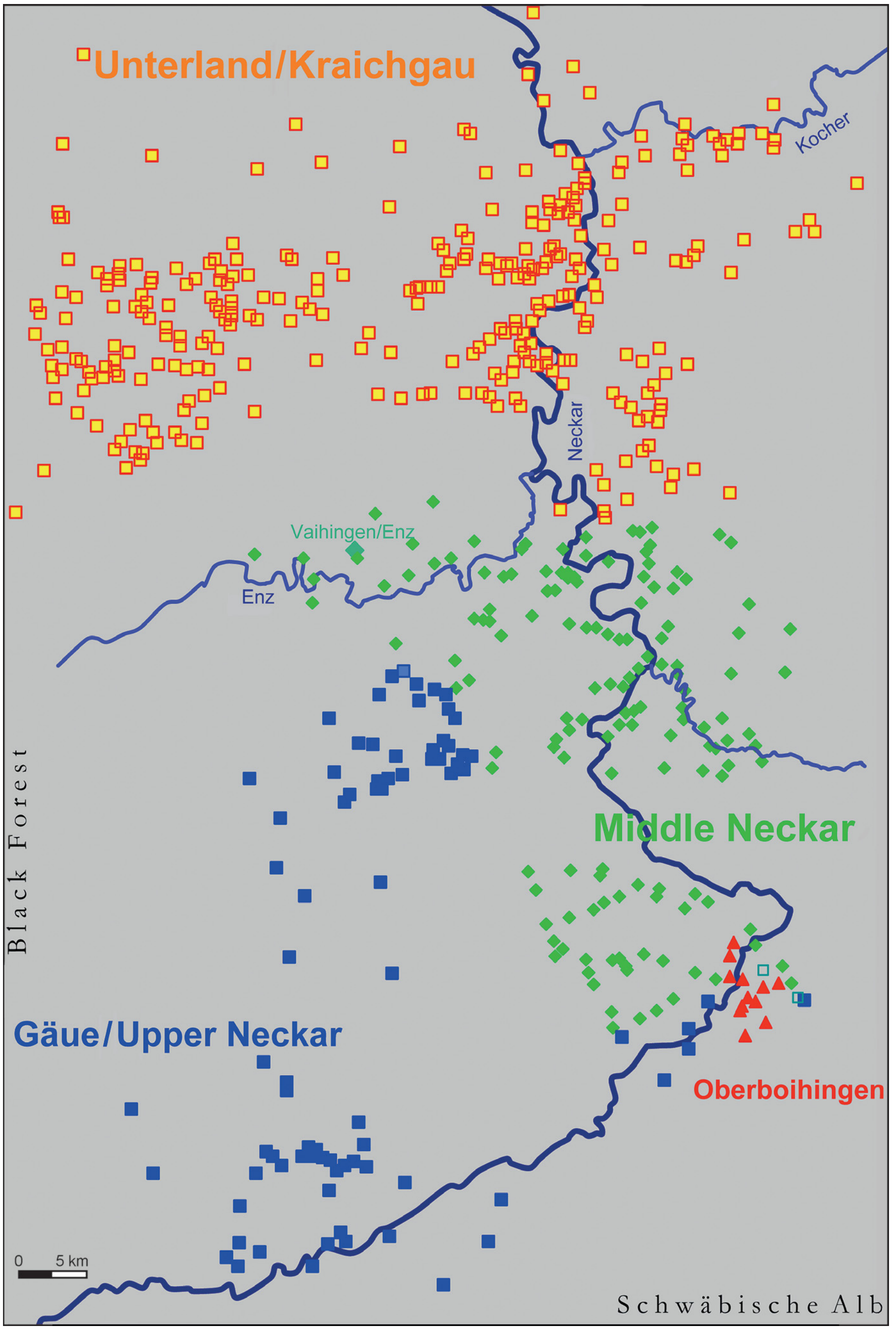

Fig. 6. Distribution of LBK regional traditions in the Neckar valley.

Classen 2011). Recently a further division into local units placed between the single longhouse and the whole regional group has been discussed, termed either 'lineage' or 'clan' (Strien 2005). Not only huge settlements like Vaihingen but also small äLBK settlements such as Schwanfeld in Franconia (Kreis Schweinfurt, Bavaria) show agglomerations of different groups, either regional or local (Lüning 2006).

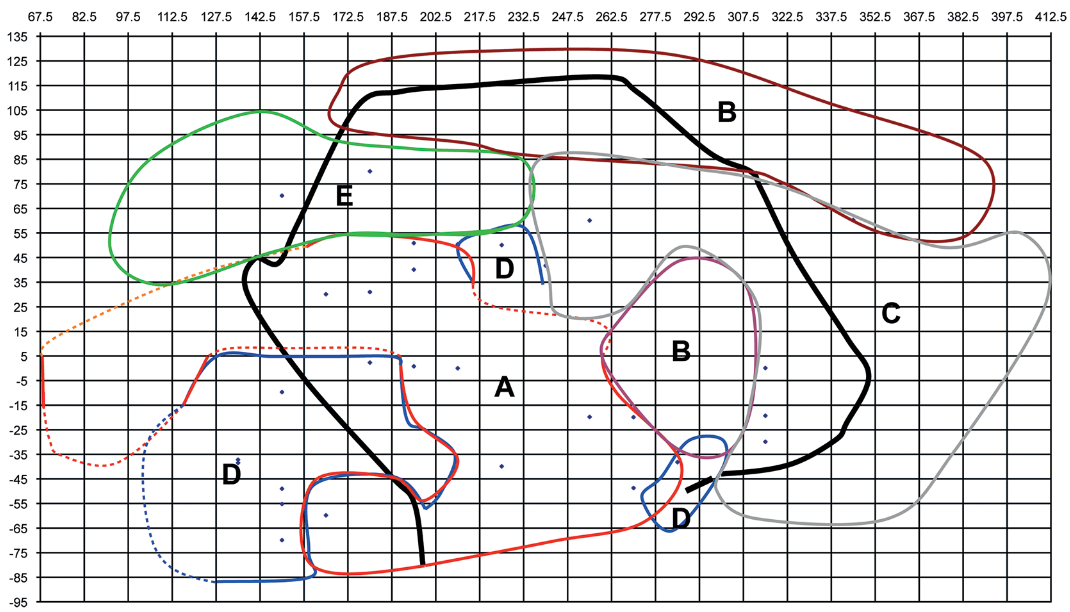

Fig. 7. Distribution of the Flomborn-period 'clan' groups at Vaihingen an der Enz.

Based on material culture analyses including adze forms, it can be shown that the LBK in the Neckar River area is divided into four regional groups (Wahl / Strien 2007; Strien 2009), shown in *figure 6*. Two of them – the Middle Neckar and the Unterland / Kraichgau group – lived next to one another in Vaihingen during the äLBK and Flomborn periods. During the later LBK period, only pottery of the Middle Neckar group is attested at Vaihingen.

On the 'clan' level, Strien (2005; 2011) noted differences in pottery decoration, architecture, earthwork construction and stone industry. Ceramic decorative motifs and other material culture differences among the 'clans' were recognised not only at Vaihingen, but also at other LBK sites in the Neckar region. Therefore each of the 'clans' seems to be connected across the region with different networks.

At Vaihingen, Strien differentiated four different 'clans' labelled A to D and a fifth group labelled E, which is defined solely by the absence of all distinct features of the other clans in its material (*fig. 7*, Strien 2011). Pottery associated with Clan A seems to be the oldest material at the site, suggesting that Clan A people may have been the founders. Houses attributed to Clan A are mainly situated in the south-western area of the site. Clan B can be traced in two different areas of the site, while Clan C house plans are mainly situated in the south-east and Clan D in the south-west *(fig. 7)*. Clans A and D belonged to the regional tradition of the Middle Neckar, while clans B, C and E are attributed to the Unterland / Kraichgau group. Although grave goods are sparse, all of the burials in the ditch-cum-cemetery appear to belong to the 'local' Middle Neckar tradition (Bogaard et al. 2011).

As mentioned above, regional traits of the Middle Neckar group are still visible in the later LBK at Vaihingen, although the characteristic traits of the Flomborn 'clans' do not continue into the later phases. Rather, during the later LBK period a north-western and a southern / eastern group (labelled by Strien as Clan I and Clan II) can be differentiated on the basis of pottery decoration, albeit with some overlap (*fig. 8*, Strien 2011). Here as

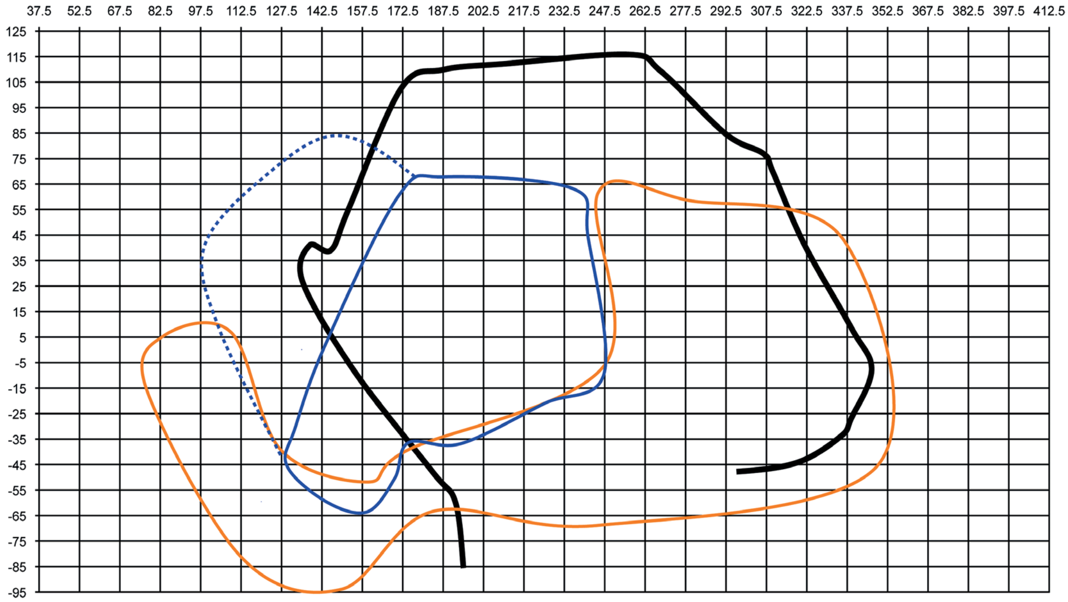

Fig. 8. Distribution of post-Flomborn 'clan' groups at Vaihingen an der Enz.

well differences can be noted in flint supply, suggesting that the groups were linked into distinct regional communication networks.

The buildings

Archaeological investigations were able to document the Bandkeramik settlement at Vaihingen almost completely; with the exception of the south-western part, the limits of the settled area were clearly recognisable within the excavated area (see *fig. 4*). Across a settlement area of at least six hectares, a total of 229 ground plans of buildings was encountered *(fig. 8)*. Particularly in the northern area, with the remains of 125 buildings, the houses stood so closely together that some of the inhabitants had only a small yard of 300–400 m^2 at their disposal.

Of the 229 ground plans of buildings that could be identified only eleven longhouses could be documented in their entirety *(fig. 9)*. The numerous overlapping ground plans – with up to five structures overlapping – and the resultant problem of securely assigning post holes, long pits and other pits to a specific house complicated the dating of the houses based on archaeological finds. The density of find contexts as well as the high rate of mixed find associations rendered the evaluation and dating of pit fills all the more difficult.

A number of ground plans could be dated in view of typological features in their construction. Accordingly, the especially deeply dug, transverse row of posts at the beginning of the middle part of some ground plans in the southern area of the settlement are typical for buildings erected during the älteste LBK to the early Flomborn phase. The frequent presence of outer ditches *(fig. 10)* also indicates that these particular houses were built during this time span (Stäuble 2005, 214 fig. 150). The ditches were usually deeper than the post holes and, therefore, even without accompanying long pits and associated post

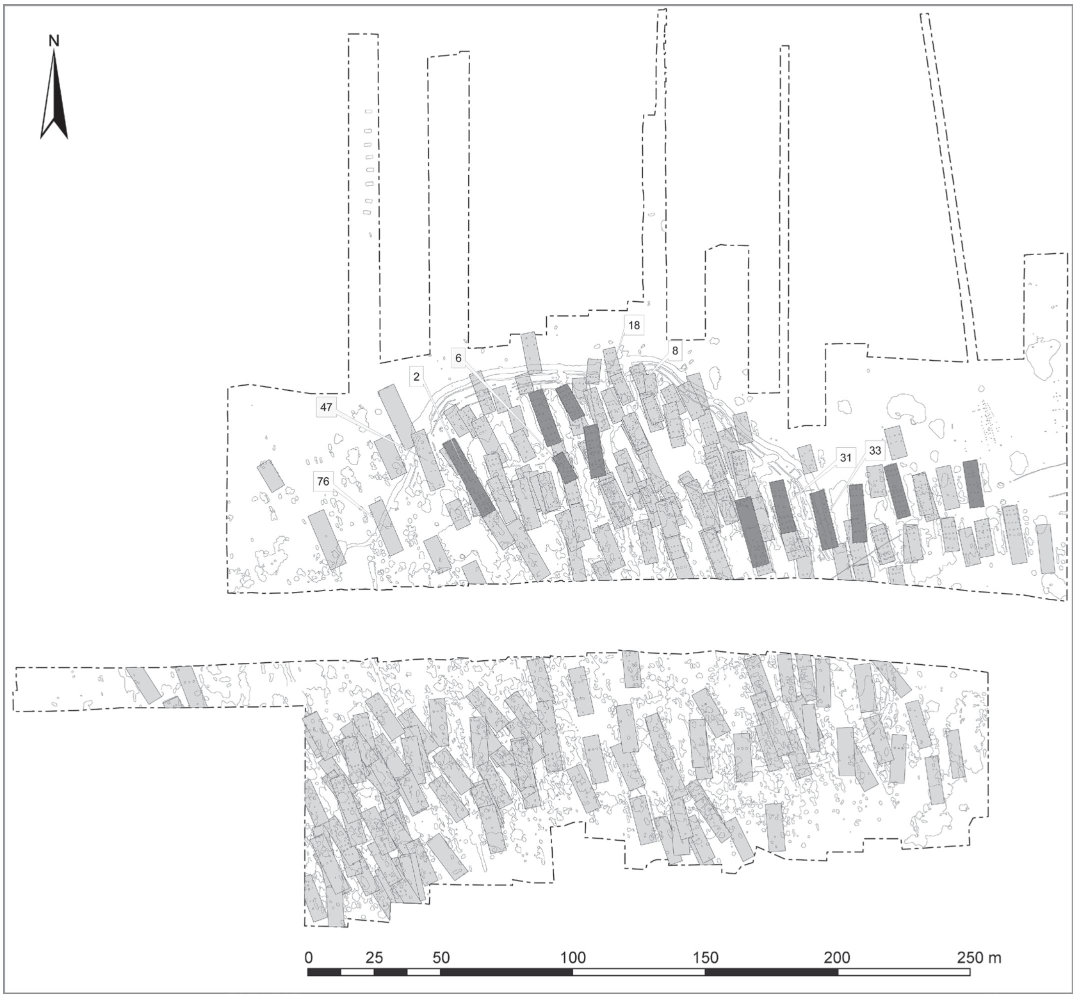

Fig. 9. Plan of the Bandkeramik settlement of Vaihingen an der Enz with complete (dark grey) and incomplete (grey) building ground plans indicated.

structures they can be viewed as secure indicators of a building. The feature of a 'post-free middle section' also can be drawn upon in dating. Like the Y-position of posts in the middle of a building that dates to the early phase of the Bandkeramik, the 'post-free' feature is somewhat later (Modderman 1970, 11 fig. 12). Both features appear in the northern and southern areas of the site. House constructions of the later Bandkeramik display typological architectural features including double rows of posts in wall construction, trapezoid ground plans and an interior structure with rows of posts at regular intervals (Cladders et al. 2012, 152 fig. 5).

Based on stratigraphic observations some buildings could be associated with the time prior to or after the construction of the ditch complex (phase 2 B 2, see *fig. 5*). Consequently, houses 8, 18, 33 and 76 are older than the ditch complex, whereas house 47 is younger. A probable contemporaneity exists in the case of building 31, for the ditch complex was built to the north around this house: that is, the house already stood when the earthwork was constructed *(fig. 9)*.

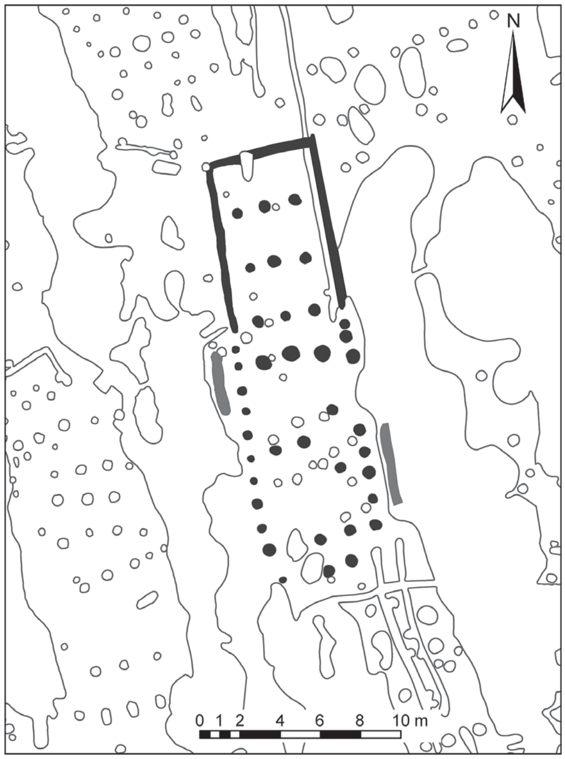

Fig. 10. Ground plan of Building 5 (black) with outer ditches (grey). Scale 1 : 400.

The orientation of the ground plans varies strongly and appears to relate only partially to chronology. Whereas building 2 is firmly oriented NW-SE, building 5, which is scarcely older, is directed N-S. Aside from the constraints associated with successive construction and existing activity zones within a densely built and intensively used settlement area, the variations in the orientation of houses perhaps reflect family traditions, though a simple link with 'clan' groups or regional traditions cannot be established.

The size of the buildings likewise varies. Small houses like building 6 with a length of barely 12 m were documented, as well as large houses like building 2 with a length of more than 31 m. As a total of only 13 houses could be documented in their approximate entire length, a reliable estimate of the average length of houses at the site cannot be made. According to the typology of buildings by P. J. R. Modderman (1970, 111 fig. 12; id. 1986, 384), large buildings (type 1, with north-western, middle and south-eastern sections) with different variations, buildings of type 2 (with north-western and middle sections) and small buildings (type 3, with middle sections only) are represented at Vaihingen. Recent work in the Rhineland has shown that each building type can vary considerably in length (Schiesberg 2007).

The depth of individual post holes also varies. Aside from the necessity of anchoring those posts that supported major building structural elements deeper in the ground, as opposed to supplementary posts set less deeply, the depth and shape of post holes were likely adapted to the kind of wood employed. The preservation of find contexts in the northern area of the settlement was better than in the south and south-east, due to a depression in the terrain that filled with colluvium. Whereas the depth of contexts in the north was often at least 60–70 cm, those found in the southern area had an average depth of 30 cm.

The 229 documented longhouse ground plans at Vaihingen represent a minimum number of the buildings that were originally present at this settlement site. Moreover, the number of buildings that lay underneath the county road between Kleinglattbach and Illingen that crosses the site, and thus could not be excavated, is unknown. The probable number of more than 300 houses that was originally present encompassed 18 settlement phases (see *fig. 5*), a distribution that is attested by the decoration on the pottery. Thus, up to 40 buildings could have existed at the same time (Strien 2010); the 125 ground plans identified in the northern area of the site are grouped around 20 'Hofplätze', while 104 ground plans identified in the southern area could be allocated to 'Hofplätze' 21–43.

Aside from the difficulty of clearly assigning pits to longhouses within a densely settled site, the answer to the question concerning which houses stood at the same time in which settlement phase is problematic for another reason: observations in a less densely populated Bandkeramik settlement of shorter duration have shown that the spatial association of pits to the structures is neither constant nor uniform. Instead, flexibility in the use of activity zones is apparent (Stäuble 2013, 235–238).

Christiane Krahn

The faunal remains

From a zooarchaeological perspective, Vaihingen is one of the most important LBK settlements in Europe. Due to very good preservation, the faunal bone assemblage is unusually large, and Vaihingen thus offers one of the largest faunal datasets from the Bandkeramik. Given the nearly complete excavation of the settlement and its lengthy occupation, it is possible to explore both spatial and chronological patterning in animal consumption. These circumstances make it possible to address fundamental questions concerning animal use systems:

1. How intensively were different animal resources used? Can any changes in use systems be recognised? Are such changes related to environmental change, cultural influences and / or economic developments such as more intensive agriculture?
2. Are spatial patterns in the deposition of domesticated and / or hunted animals apparent within the settlement? If so, what is the social significance of such patterning?

Materials and methods

Bone fragments totalling c. 38 100 specimens (531.9 kg in weight) were hand-collected from the entire settlement area. These are augmented by a further 8 779 (6.9 kg) of bone remains found in sediment samples collected for wet-sieving, as well as by 204 fragments of antler (*tabs 1–2*, Schäfer in prep.). This material was identified at the IPNA in Basel; the fish remains were identified by Friederike Johansson, Göteborgs Naturhistoriska Museum. Of the total assemblage, 35 % could be taxonomically determined and 77 % recorded by weight.

The role of hunting from the älteste to the jüngere LBK

The relative amount of game, taking all identified fragments into account, remains uniform at c. 15 % of specimens, or c. 25 % by weight, from the earliest to the latest LBK

SETTLEMENT PITS							SEDIMENT SAMPLES				
Taxa		**N**	**n%**	**Weight**	**Weight %**	**D-Weight**	**n**	**n%**	**Weight**	**Weight %**	**D-Weight**
Bos taurus	Cattle	5752	44.4	273461.5	62.0	47.6	71	18.7			
Sus domesticus	Pig	3254	25.1	39410.9	8.9	12.1	204	53.8			
Ovis aries	Sheep	238	1.8	4941.3	1.1	20.8	1	0.3			
Capra hircus	Goat	119	0.9	4117.8	0.9	34.6	3	0.8			
Ovis/Capra	Caprinae	1441	11.1	11222.9	2.5	7.7	60	15.8			
Canis familiaris	Dog	19	0.1	144	0.0	9.6	2	0.5			
Total domesticated		**10823**	**83.6**	**333298.4**	**75.5**	**30.8**	**341**	**90.0**	**3182.4**	**87.1**	**9.3**
Equus ferus	Horse	1	0.0	40.0	0.0	40.0					
Bos primigenius	Aurochs	343	2.7	50689.6	11.5	150.8	1	0.3			
Cervus elaphus	Red deer	878	6.8	36275.2	8.2	41.4	10	2.6			
Capreolus capreolus	Roe deer	274	2.1	2759.4	0.6	10.0	8	2.1			
Sus scrofa	Wild boar	453	3.5	15318	3.5	33.7	3	0.8			
Ursus arctos	Brown bear	27	0.2	1216.6	0.3	45.1					
Canis lupus	Wolf	2	0.0	39.7	0.0	19.9					
Vulpes vulpes	Fox	10	0.1	28	0.0	3.1	1	0.3			
Martes spec.	Marten	4	0.0	8	0.0	2.3					
Meles meles	Badger	1	0.0	2	0.0	2.0					
Lutra lutra	Otter	1	0.0	3	0.0	3.0					
Felis sylvestris	Wild cat	2	0.0	2.1	0.0	1.1	1	0.3			
Lynx lynx	Lynx	1	0.0	4	0.0	4					
Castor fiber	Beaver	118	0.9	514.6	0.1	4.4	5	1.3			
Sciurus vulgaris	Red squirrel						3	0.8			
Lepus europaeus	Hare						1	0.3			
Erinacaeus europaeus	Hedgehog	5	0.0	1.4	0.0	0.3	3	0.8			
Talpa europaeus	Mole						2	0.5			
Total wild		**2120**	**16.4**	**106901.6**	**24.2**	**50.9**	**38**	**10.0**	**471.9**	**12.9**	**12.4**
Total identified		**12943**	**34.5**	**441207.6**	**84.2**	**34.1**	**379**	**4.6**	**3654.3**	**52.8**	**9.6**
Bos taurus/primigenius	Cattle/aurochs	103		6505.9		61.4	1				
Sus dom./scrofa	Pig/boar	991		7961.4		8.2	98				
GWK	Large ruminants	1242		19051		15.7	58				
KWK	Small ruminants	708		2144.1		3.0	110				
Canis familiaris/lupus	Dog/wolf	3		38.4		12.8					

SETTLEMENT PITS							**SEDIMENT SAMPLES**				
Taxa		**N**	**n%**	**Weight**	**Weight %**	**D-Weight**	**n**	**n%**	**Weight**	**Weight %**	**D-Weight**
Canis fam. / Vulpes vulpes	Dog / fox	2		16.5		8.3	2				
Carnivore	Carnivores	2		2.7		1.9	4				
Indet		21528		47141.7		2.2	7569				
Total Indet		**24579**	**65.5**	**82861.7**	**15.8**	**3.4**	**7842**	**95.4**	**3272.4**	**47.2**	**0.4**
Total mammals		**37522**	**100**	**524069.3**	**100**	**14.0**	**8221**		**6926.7**		**0.8**

Tab. 1. Taxonomic and quantitative summary of mammals in the Vaihingen faunal assemblage.

occupation *(fig. 11)*, a period of c. 400 years. The proportion of game observed as a whole, ranging from 12 % to 16 %, is low compared with some other settlements of the Bandkeramik, such as Rottenburg "Fröbelweg", Kr. Tübingen, (älteste LBK) with more than 50 % game (Stephan 2005).

Nevertheless, the proportion of 25 % by weight at Vaihingen signifies that at least one quarter of the meat supply was provided by hunted game. The consistency in the proportion of game argues against the possibility of intrusive changes or crises with regard to the food supply during the occupation of the settlement, which might have been counteracted by a pronounced increase in hunting levels. The spectrum of species among hunted mammals is wide; in addition to large game animals, numerous smaller fur-bearing animals as well as birds and fish are attested. The age and sex composition of large game – mostly adult females – shows that they were hunted primarily for meat. Yet, the acquisition of raw material for making artefacts also played a role in hunting, as indicated by usage of metapodia from cervids and canines from wild boar; the bone artefacts and the antler remains will be evaluated by Isabelle Sidéra, CNRS, Maison d'Archéologie et d'Anthropologie Paris.

The demands on the biotope of the various game and fur-bearing animals were quite different, meaning that the Bandkeramik hunters sought out diverse habitats at a local and regional scale. That hunting played an important role is suggested by practices such as hunting of specific age groups, the high proportion of large animals, the great diversity in animal species, the different demands on the biotope and the consistent proportion of game during the entire duration of the settlement.

Domesticated animals from the älteste to the jüngere LBK

In contrast to the marked consistency in the proportions of domestic and wild fauna through time, distinct shifts are apparent in the relative importance of the various domestic taxa from the älteste to the jüngere LBK *(fig. 12)*. Representing a proportion of c. 66 %, domestic cattle were particularly prominent at the beginning of sequence. In the course of time, however, the proportion of cattle decreased to c. 38 % in favour of domestic pigs. A similar shift has been observed in LBK assemblages from Alsace (Arbogast / Jeunesse 1996). The relative proportion of cattle in some Alsatian settlements decreased during the earlier to the later LBK. Some of these settlements raised pigs more intensively

Birds			n
Identified	*Anas crecca / querquedula*	Teal	1
	Cotunix cotunix	Quail	1
	Accipiter gentilis	Goshawk	1
	Turdus viscivorus	Mistle thrush	1
	Asio otus	Long-eared owl	3
	Tetrao urogallus	Wood grouse	1
	Buteo buteo	Buzzard	2
	Scolopax rusticola	Woodcock	1
	Columba palumbus	Wood pigeon	1
	Grus grus	Crane	2
Total identified			**14**
Indet	Accipitridae	Hawk / eagle	1
	Anas spec.	Teal-like	1
	Turdus spec.	Thrush-like	2
	Passeriformes	Song bird	5
	Anser / Tetrao urogallus	Goose / grouse	4
	Aves	Bird indet	27
Total indet			**40**
Total			**54**

Fish			n
Identified	*Salmo spec.*	Trout	3
	Salmo trutta	Brook trout	4
	Siluris glantis	Wels catfish	1
	Thymallus thymallus	Grayling	2
	Perca fluviatilis	Perch	1
	Coregonus spec.	Whitefish	1
	Leuciscus idus	Ide / orfe	1
	Leuciscus spec.	Carp	2
Total identified			**15**
Indet	Piscis indet	Fish indet	126
	Cyrinidae	Carp-like	329
	Cyprinidae?	Carp-like?	7
	Salmonidae	Trout-like	3
	Salmonidae?	Trout-like?	1
Total indet			**466**
Total			**481**

Antler:			n
	Capreolus capreolus	Roe deer	5
	Cervus elaphus	Red deer	180
	Cervidae		19
Total			**204**

Tab. 2. Taxonomic and quantitative summary of birds, fish and antler in the Vaihingen faunal assemblage.

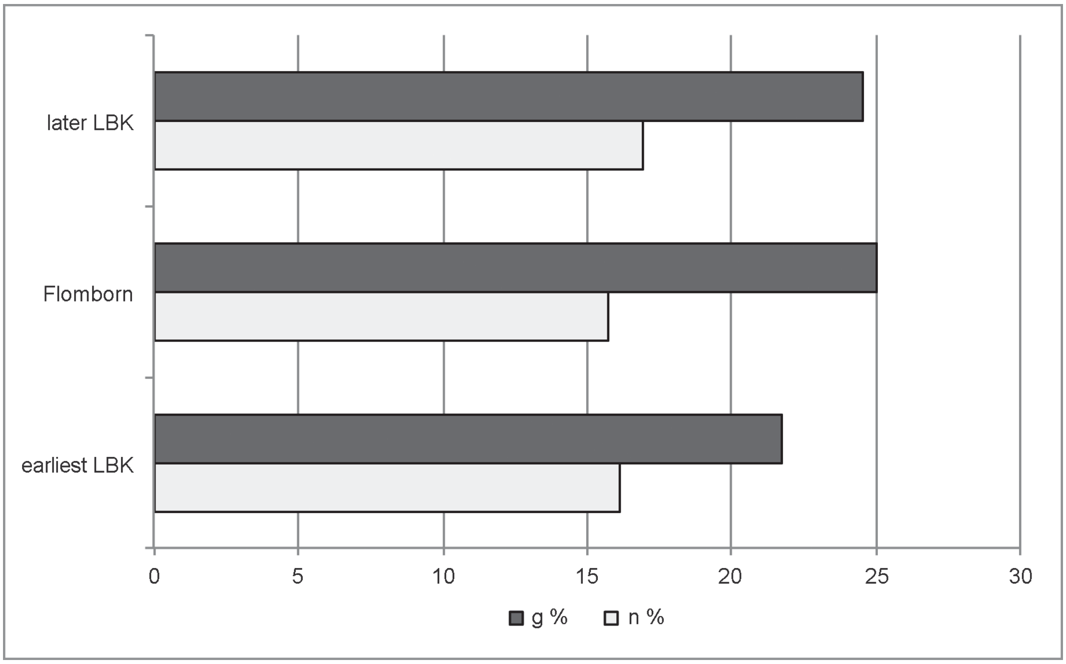

Fig. 11. Proportions of hunted taxa among identified specimens dating to the äLBK (n = 144, total n = 892; weight = 7 791 g, total weight = 35 922.4 g), earlier LBK (n = 705, total n = 4 496; weight = 41 452.4 g, total weight = 165 700 g) and later LBK (n = 78, total n = 462; weight = 3 209.8 g, total weight = 13 087.6 g).

– for example, at the sites of Colmar "Route de Rouffach" (upper Alsace) and Dachstein "Am Geist" (lower Alsace) – while others kept more sheep and goats, as at Ensisheim "Ratfeld" (Haut-Rhin, F) (Arbogast 1994; Döhle 1994). This chronological change in the composition of domestic animals reflects a change in stock keeping that not only affected the meat supply, but also led to decisive changes in the labour requirements of stock raising; it probably influenced property relations and related traditions observed until then as well.

This change seems primarily related to an adaptation to changes in environmental conditions at the time. The more or less densely forested early Neolithic landscape offered little pasturage for cattle, and available open areas were used mostly for cultivating crops. Nevertheless, at the end of the settlement occupation cattle were still the predominant domestic animal. Evidently, environmental conditions alone did not shape these changes, since otherwise a far more severe and rapid reduction in cattle raising would be expected. The demand for meat had likely increased due to the pronounced growth in population at the beginning of the earlier LBK (Flomborn), a need that perhaps could not be met with the stock keeping practiced until then. Because of their essentially less problematic management and their high rate of reproduction, domestic pigs could cover the increased demand on meat within a short time. However, the size of the settlement in Vaihingen decreased considerably in the later LBK, a development that is not reflected in the relative proportion of pigs. On the other hand, intensive agriculture is often correlated with a high proportion of domestic pigs, since pig keeping is more compatible with labour-intensive farming than cattle raising, which itself requires high labour investment (Arbogast / Jeunesse 2013). It is unlikely that every household kept two or three heads of

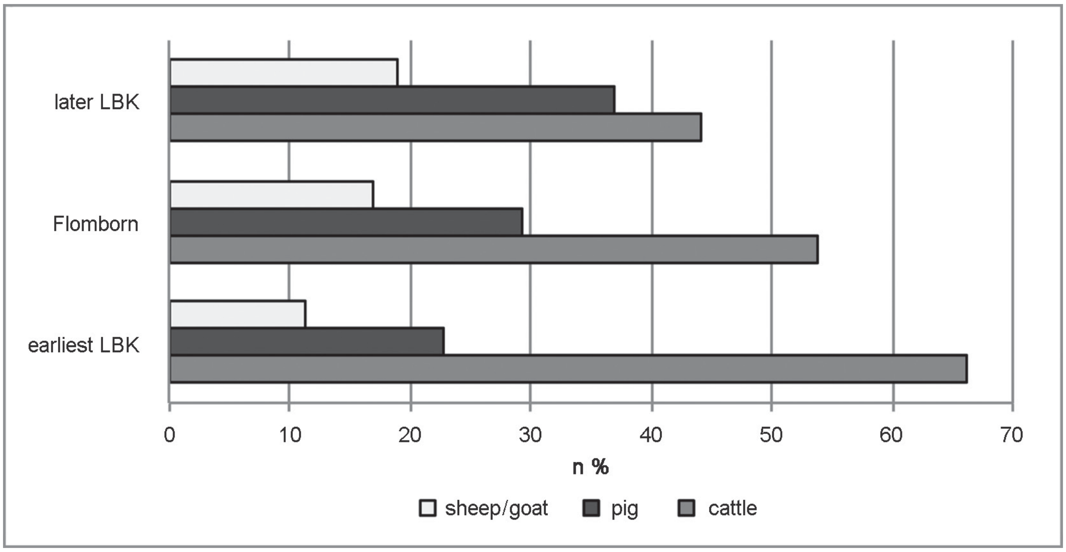

Fig. 12. Proportions of domesticated taxa dating to the äLBK (cattle [n = 494], pig [n = 170], Caprinae [n = 84]), earlier LBK (cattle [n = 1 902], pig [n = 1 032], Caprinae [n = 566]) and later LBK (cattle [n = 173], pig [n = 146] and Caprinae [n = 70]).

cattle on its own, since most labour was probably invested in cultivation. It is far more likely that herding was organised on a supra-household basis, more specifically at the level of two regional groups: based on strontium and oxygen isotope investigations, Knipper was able to show that, for at least part of the cattle herd, different grazing areas were sought in the summer months, probably depending upon the affiliation of herders with groups differentiated by their links to regional material culture traditions (see below and Knipper 2011).

The importance of crop cultivation in the human diet at Vaihingen is suggested by palaeodietary stable isotope analysis of plants, fauna and people at this settlement (see below; Fraser et al. 2013a). But labour-intensive farming was likewise not the only cause for a decrease in cattle keeping, since intensive agriculture was also carried out during earlier settlement phases. A reduced population size starting with the late Flomborn indicates that fields of the departed inhabitants, which were no longer worked or perhaps only to a small extent, lay fallow and were available for use. Thus, the remaining inhabitants could have improved cattle keeping and even enlarged the number of animals. However, the relative proportion of cattle decreased further. It is far more probable that several factors contributed to the change in the composition of domestic animals from the earliest to the later LBK, among which a change in cattle raising traditions was just one.

Primary and secondary uses of domesticated animals

The economic importance and use of domestic animals for inhabitants at Vaihingen can be reconstructed quite well in some cases, especially the question of regular secondary products use. The potential use of cattle as a source of milk or muscle power would help to explain their predominance in the assemblage, since use of cattle for meat alone seems

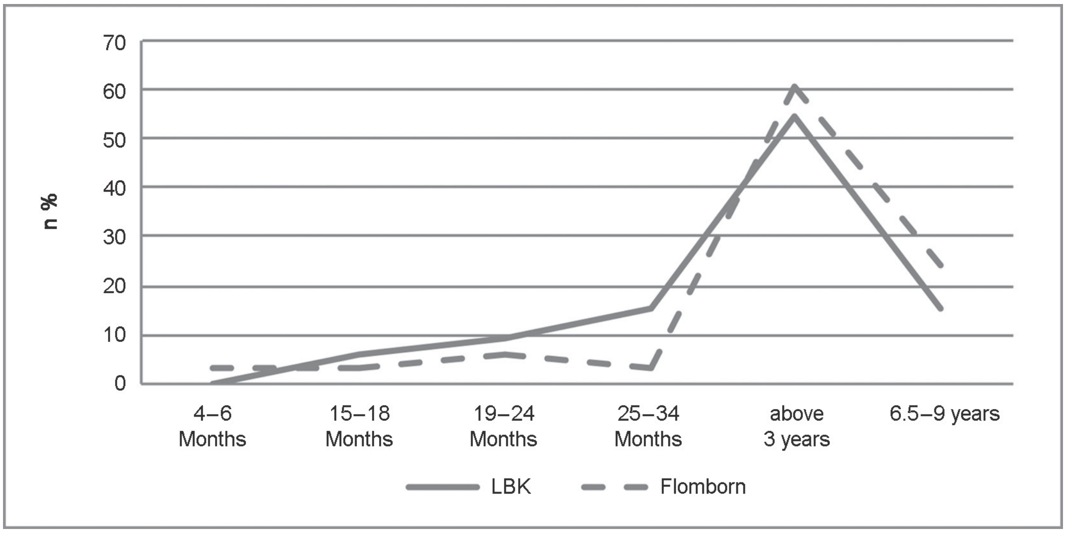

Fig. 13. Age distribution of domesticated cattle (*Bos taurus*) based on eruption and wear of mandibular teeth dating to the earlier LBK (n = 35) and to the LBK in general (n = 38).

quite irrational for early Neolithic environmental conditions. However, in archaeozoology there are clear limits to demonstrating a milk-producing economy. Regular milk production with specific herd management practices can only be identified from the distribution of the slaughter age, while an occasional production / use, by contrast, can scarcely be measured. Investigations of lipid residues on ceramics – for example, at Schela Cladovei (5950–5500 cal BC) in Romania, Ecsegfalva (5800–5700 cal BC) in Hungary (Craig et al. 2005) and at LBK sites in the Kuyavia region, Poland (Salque et al. 2012) – have proven the consumption of milk in early Neolithic contexts, but do not allow any quantification of its importance.

The sex structure among adult cattle at Vaihingen was clearly biased towards cows. Their greater number is not necessarily associated with a milk economy, but rather reflects careful herd management. For the maintenance and increase of a herd not only is the number of steers important, but also that of cows. The distribution of slaughter ages shows that the slaughter rate among domestic cattle increased at the third year of life, reaching a high point between the third and fourth year, and decreasing thereafter *(fig. 13)*. Based on the teeth, the highest age represented among slaughtered animals was nine years. If a milk economy really played a decisive role in cattle raising, the slaughter rate for one-year-old or younger animals should clearly be higher, even if it is assumed that cows of primitive breeds only produced milk when their calves were present (Peške 1994; Balasse 2003). According to the slaughter-age distribution, a regular intensive milk economy can be excluded. This applies as well to the use of cattle as work animals. The animals would first have had to be trained for such use. Training could only have been attained and worthwhile when the animals had reached the necessary bodily maturity and could work for as long a time as possible. By contrast, in Vaihingen cattle were slaughtered as a rule at an age under nine years. In addition, the corresponding pathologies caused by work are absent on cattle bones, which would have been present after years of specific demands on the body: for example, broadened phalanges like those found in the early Neolithic settlement of La Draga, Catalonia, or in the late Neolithic settlement of Arbon Bleiche 3 (CH) at

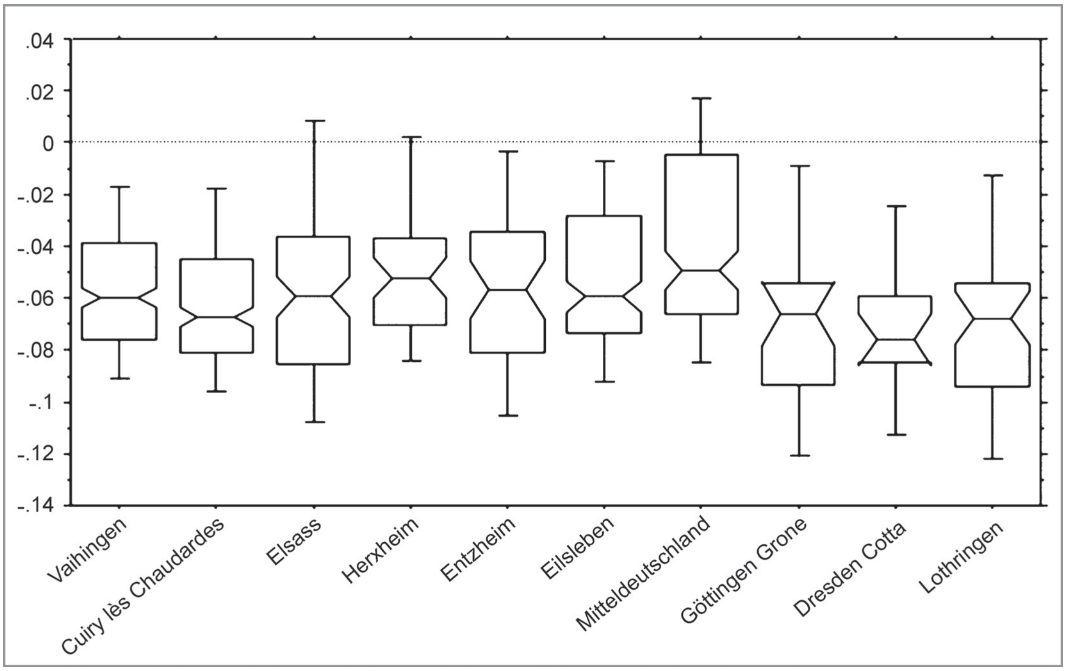

Fig. 14. Box-Plot of LSI values for domesticated cattle (*Bos taurus*) from Vaihingen an der Enz (n = 228), Cuiry lès Chaudardes (n = 228), Elsass (n = 102), Herxheim (n = 45), Entzheim (n = 43), Eilsleben (n = 156), central Germany (n = 163), Göttingen-Grone (n = 25), Dresden-Cotta (n = 17) and Lorraine (n = 37). Reference skeleton: female aurochs as in Steppan (2001). The box extends from the 25th to the 75th percentile, while the median is indicated by the central horizontal line. The vertical 'whiskers' above and below the box encompass all values, including outliers. (Data from Müller 1964; Arbogast 1994; 2001; 2007; 2009; Döhle 1994; Benecke 1999; Hachem 2011; and unpublished data provided by Arbogast, Guthmann, and Schoon. The osteometric data from Vaihingen are at: <http://ipna.unibas.ch/archbiol/tabpubl/index.html> [last access 2 February 2017]).

Lake Constance (Bartosiewicz et al. 1997; von den Driesch 1975; Deschler-Erb / Grädel 2004; Tarrùs et al. 2006).

Comparison of the logarithmic size index (LSI values)[1] from Vaihingen with those from other Bandkeramik sites shows an amazing uniformity in the stature of domestic cattle *(fig. 14)*. This uniformity across such a vast distribution area and lengthy time span could *only* occur through the repeated exchange of cattle between individual settlements. Perhaps cattle were of rather material or even symbolic value. The decrease in the proportion of domestic cattle during the time from the earliest to the later LBK might be reflective of a reduction in their importance within the traditional system of values.

Inferences can also be made regarding usage of secondary products from the small domestic ruminants, sheep and goats, concerning possible use for milk and wool / hair.

[1] For a LSI evaluation only the width and depth of joint surfaces were regarded. They are not directly dependent upon body size, but are also influenced by the weight and proportion; thus, the stature of an animal can be recorded approximately (Meadow 1984; Uerpmann 1990). The measurements of a Holocene female aurochs (*Bos primigenius*) served as a standard (Steppan 2001).

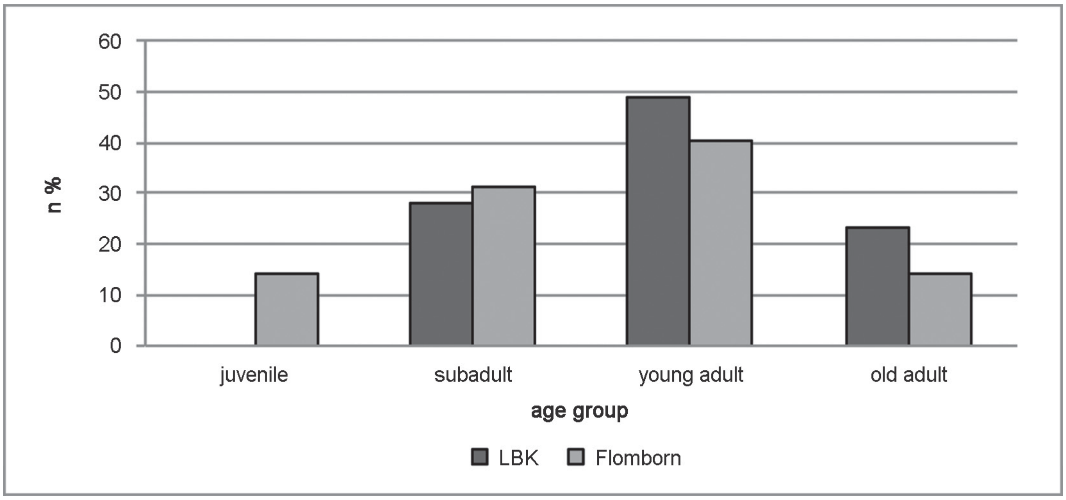

Fig. 15. The age distribution of sheep (*Ovis aries*) and goat (*Capra hircus*) based on eruption and wear of mandibular teeth dating to the earlier LBK (n = 37) and the LBK in general (n = 45).

The sex distribution of both taxa shows that the majority of female sheep as well as female goats reached adult age, while the proportion of adult males lies at 40 %. Such a high proportion of adult males was not observed in any other domestic animal at Vaihingen. Clearly recognisable for the earlier LBK is that the group of infant small ruminants is poorly represented, while older adult animals constitute a relatively large proportion *(fig. 15)*. Regular, intensive use of milk was apparently not practiced with sheep and goats; the group of infant animals that would indicate this is too small. In contrast to domestic cattle, the lambs and kids of primitive sheep and goat breeds can be slaughtered without causing the flow of milk from the mother animal to cease (Payne 1973). On the other hand, the relatively high proportion of rams and the older adult animals could be interpreted as an indication of the use of wool / hair. Yet, even with small domestic ruminants, their role as a source of meat seems to have predominated.

While there is no question concerning secondary products from domestic pigs, the bone finds from Vaihingen allow a more precise reconstruction of the practice of keeping pigs in Neolithic central Europe. Most of the male animals did not reach adult age. They were slaughtered even before reaching one year of age, preferably in the winter and early spring *(fig. 16)*.

The spatial distribution of domesticated and wild fauna across the settlement

As noted above, the near complete excavation of the settlement makes it possible to explore the distribution of specific taxa across the site and the possibility of different strategies amongst households or house groups. However, the dense overlapping of features and house plans limits our ability to disentangle separate households and groups. Hans-Christoph Strien's 'clan' groups of the Flomborn period and subsequent two groupings of the later LBK (see above) offer a starting point for comparing households and house groups (Strien 2005; 2011). The distribution of game among the different Flomborn 'clans' shows only slight variation based on proportions of identified specimens, between c. 12 % and 16 % *(fig. 17)*. By contrast, the relative distribution according to find

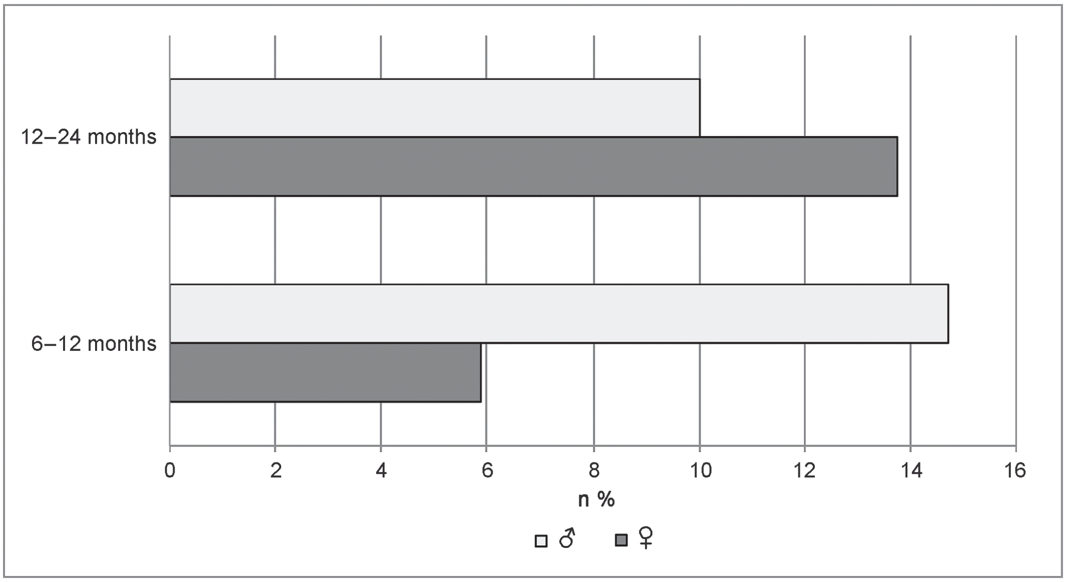

Fig. 16. Proportions of male and female domesticated pigs (*Sus domesticus*) in age classes 6–12 months (females n = 2; males n = 5) and 12–24 months (females n = 11; males n = 8). The basis of the calculation is the total number of teeth belonging to juvenile domesticated pigs (n = 114).

weight fluctuates between c. 20 % (Clan A) and 35 % (Clan B). All in all the percentage of game according to weight associated with 'clans' of the Unterland / Kraichgau regional tradition was somewhat higher. Differences can also be recognised in the combination of game animals *(fig. 18)*. Individual 'clans' had a distinct preference for certain kinds of game. Red deer was hunted above all by Clans A and D, both belonging to the Middle Neckar regional tradition, while Clans B and C of the Unterland / Kraichgau tradition hunted mostly wild pig and aurochs. This higher proportion of aurochs, with its heavy bones, explains the bone weight of hunted game associated with the Unterland / Kraichgau group. The combination of game animals in Clan E is somewhat distinct but shares a high propotion of aurochs with other groups of the Unterland / Kraichgau tradition. During the later LBK, distinct contrasts between the two 'clan' groups are apparent in the relative proportion of hunted versus herded specimens, both by count and by weight. Members of Clan I hunted more red deer, while Clan II hunted more aurochs *(fig. 18)*. Thus, during both the Flomborn period and the later LBK, 'clan' groupings of houses differ in the predominance of specific hunted taxa, but not in the relative proportions of game versus domesticated animals.

During the Flomborn phase, differences are also apparent in the predominance of particular domestic taxa in the various 'clan' groups. In Clans A, D, B and C cattle predominate, with 53 % to 55 % of counted specimens *(fig. 19)*. But differences in the distribution of pig and small ruminants also occur: Clan groups A and D, of the Middle Neckar tradition, possessed clearly more pigs than Clans B and C, of the Unterland / Kraichgau tradition, who instead kept relatively more sheep and goats. A completely different strategy of keeping domestic animals was practised by Clan E of the Unterland / Kraichgau tradition: sheep and goats (34 % of identified specimens) were as important as cattle (32 %). The relative proportions of domestic animals in Clan E differ

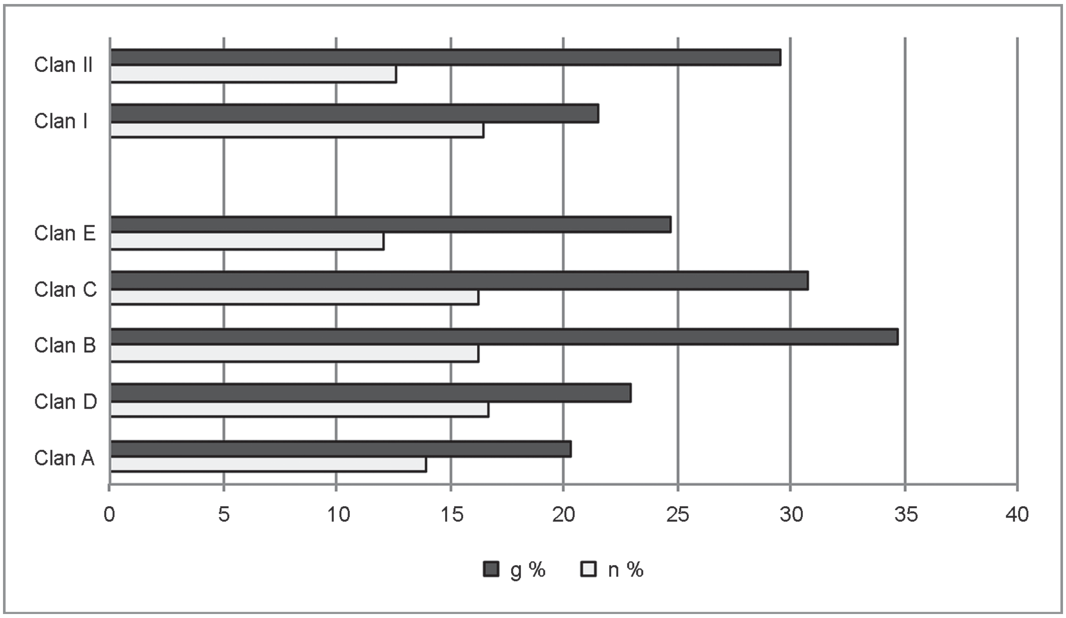

Fig. 17. Proportions of hunted fauna among identified specimens of the Flomborn period 'clan' groups A (n = 198, weight = 9 782.1 g), D (n = 164, weight = 8 688 g), B (n = 94, weight = 5 962.5 g), C (n = 59, weight = 5 284 g), E (n = 23, weight = 1 151.5 g), and later LBK groups I (n = 54, weight = 2 039 g) and II (n = 18, weight = 1 095 g).

clearly from those of Clans B and C, also of the Unterland / Kraichgau tradition, as well as from the Middle Neckar Clans A and D. This observation clearly demonstrates that in Vaihingen at least two different traditions of stock raising existed at a local / regional level.

Pig keeping increased in relative importance in later LBK Clan groups I and II: the proportion of domestic pigs reached about 44 %, while that of cattle averaged 38 % *(fig. 19)*. Clear differences between Clan groups I and II comparable to those observed in the relative importance of specific hunted taxa are not observed in the relative proportions of individual domesticated taxa.

In sum, archaeozoological study of the Vaihingen assemblage suggests that the meat supply was based on a wide spectrum of local and regional wild resources alongside herding. The diversity in supply protected the community from shortfalls due, for example, to livestock illness or lack of forage. Chronological analysis of the faunal assemblages reveals a clear change in animal keeping through time, whereas the proportion of hunted game varied only slightly among phases. An ecological crisis leading to an abrupt shift in animal consumption is not apparent; rather, a gradual process of change in domesticated animal keeping emerges that probably had multiple causes, including adaptation to the local environment, intensification of agriculture and change in cultural traditions including the material and symbolic value of cattle.

In terms of the 'clan' groups proposed by Strien, distinct herding strategies appear to have co-existed. Equally, hunting practices show clear differences among 'clans' through both the Flomborn and later LBK periods.

Marguerita Schäfer and Rose-Marie Arbogast

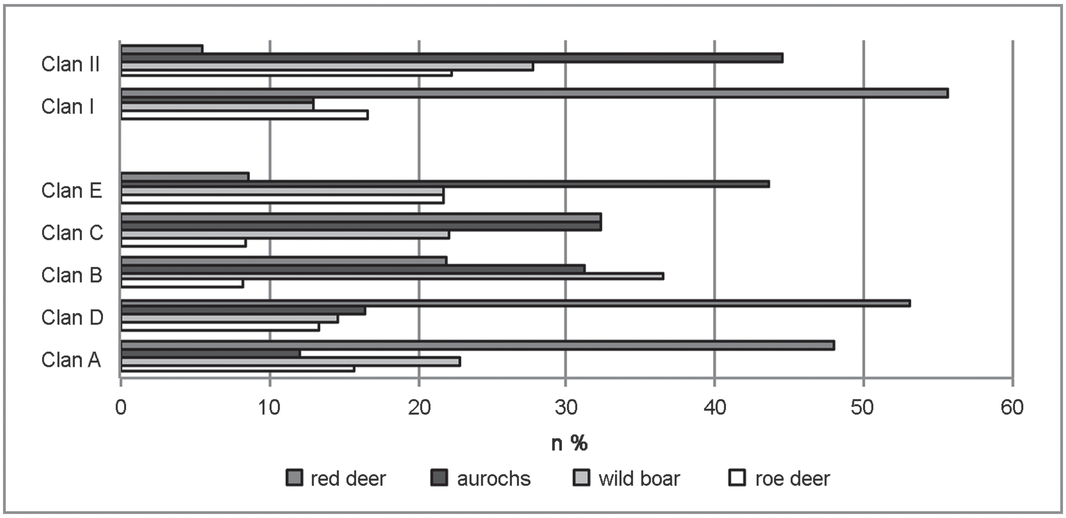

Fig. 18. Proportions of hunted taxa of among identified specimens of the Flomborn period ‘clan’ groups A (red deer n = 95, Ur n = 24, wild boar n = 45, roe deer n = 31), D (red deer n = 87, aurochs n = 27, wild boar n = 24, roe deer n = 22), B (red deer n = 20, aurochs n = 29, wild boar n = 35, roe deer n = 8), C (red deer n = 19, aurochs n = 19, wild boar n = 13, roe deer n = 5), E (red deer n = 2, aurochs n = 10, wild boar n = 5, roe deer n = 5) and of the later LBK groups I (red deer n = 30, aurochs n = 7, wild boar n = 7, roe deer n = 9) and II (red deer n = 4, aurochs n = 5, wild boar n = 8, roe deer n = 1).

The archaeobotany

Extensive excavation and sampling at Vaihingen / Enz also provided a unique opportunity to investigate a complete LBK settlement with a lengthy sequence of occupation using archaeobotanical methods (Bogaard 2004; 2011). Analysis of charred macroscopic plant remains (seeds, fruits, chaff etc.) from archaeological deposits was designed to address questions concerning the social significance of plant use and farming practice, including potential variation across the settlement and through time.

Materials and methods

Systematic sampling of the fills of pits and other negative features across the c. 6 ha of settlement remains resulted in around 3700 samples (20 000 litres of soil), all wet-sieved to 0.5 mm and sorted for preliminary assessment. Nearly 700 samples (c. 20 %) were selected for full archaeobotanical analysis based on richness in charred plant remains and / or archaeological criteria (for example attribution to phase and / or house group). Individual samples were often defined arbitrarily in stratigraphic terms, and so particular attention was paid to the definition of ‘analytical units’ approximating discrete depositional episodes. This process often resulted in amalgamation of adjacent samples in a pit fill (where justified by similarity in botanical content and lack of stratigraphic boundaries). The analytical units formed the basis of all subsequent interpretation.

The samples analysed yielded more than 250 000 charred botanical items, the overwhelming majority being cereal chaff (glume bases of glume or hulled wheats), followed by wild plant taxa (mostly potential arable weeds with a minor component of collected

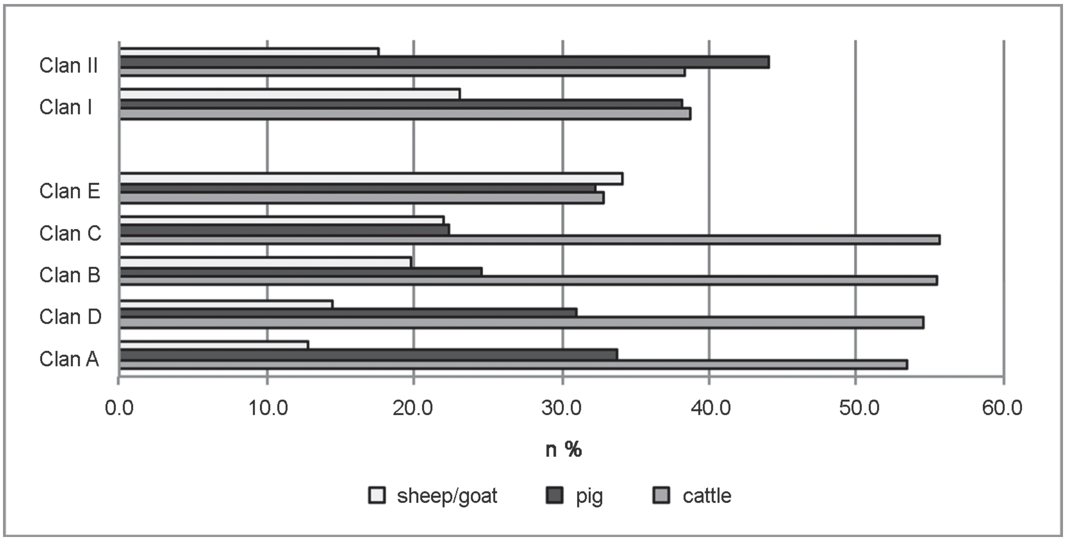

Fig. 19. Proportions of domesticated taxa among identified specimens of the Flomborn period 'clan' groups A (n = 1 227), D (n = 819), B (n = 495), C (n = 309), E (n = 156) and of the later LBK groups I (n = 286) and II (n = 125).

fruits / nuts), pulses and oil seed crops (mostly flax). The fully analysed samples cover all areas of the site and all occupation phases.

Plant-related practices through the sequence and across the settlement

Broad continuities in plant use through the occupation sequence and across the site plausibly reflect food-related practices that contributed to long-term communal identity. These generalised practices included cultivation and use of six crop types (the glume wheats einkorn, emmer and the 'new type'[2]; peas, lentil and flax / linseed) *(tab. 3)*, regular and widespread dehusking of the glume wheats *(fig. 20)* and use of wild plants such as hazelnut and strawberry *(tab. 4)*. Though dehusking of glume wheats stored as spikelets (grains enclosed by protective glumes) overrepresent this crop type relative to others, the relative frequency of wheat *grain* in comparison with pea and lentil suggests that the wheats were the dominant crop, though pea in particular may have been a close second. Einkorn was consistently the dominant component of glume wheat dehusking residues across the site *(fig. 20)*, while pea was the more frequent pulse in comparison with lentil. Flax / linseed was deposited at low levels throughout the occupation, as was hazelnut *(tabs 3–4)*.

Against this background, extensive sampling intercepted evidence for the introduction of new plants and associated practices through time. Two novel plants began to be depos-

[2] This glume wheat type has been described by Jones et al. (2000) and Kohler-Schneider (2001; 2003). It is morphologically distinct from both emmer and einkorn and seems to be a separate glume wheat variety, now largely extinct.

Subperiod	Total units	Einkorn chaff	Einkorn, 1-seeded	Einkorn, 2-seeded	Einkorn grain*	Emmer chaff	Emmer grain	'New' chaff	'New' grain	cf. barley grain	cf. naked wheat grain	Pea	Lentil	Flax	Poppy
Early Flomborn	11	11	3	2	4	11	2	5				1	3	2	
Middle Flomborn	27	26	7	6	10	23	3	22				4	1	6	
Late Flomborn	21	21	9	6	9	21	12	17				9		4	2
Total Flomborn**	115	112	39	25	49	104	28	71	1			17	5	18	2
Middle LBK	22	22	9	7	12	22	11	16				7	4	12	3
Late LBK	9	9	6	6	8	8	4	7		2		5	2	2	1
Unphased	92	92	52	25	59	91	37	79	1	2	1	34	14	26	4

* includes 'einkorn indeterminate' grain
** includes units assigned to the subperiod, but of uncertain phase

Tab. 3. The number of analytical units in which potential crop taxa occur, by subperiod.

Subperiod	Total units	fat hen	strawberry	hazelnut	reed culm	rose	raspberry	feathergrass	sloe	bulrush / clubrush	Total taxa
Early Flomborn	11	6	1	3							3
Middle Flomborn	27	9		1							2
Late Flomborn	21	17	3	7				1			4
Total Flomborn*	115	47	4	13				1			4
Middle LBK	22	20	3	6			1	3	2		6
Late LBK	9	8	1	2					1	1	5
Unphased	92	74	13	16	2	1		6			6

* includes units assigned to the subperiod, but of uncertain phase

Tab. 4. The number of analytical units in which wild plant taxa occur, by subperiod

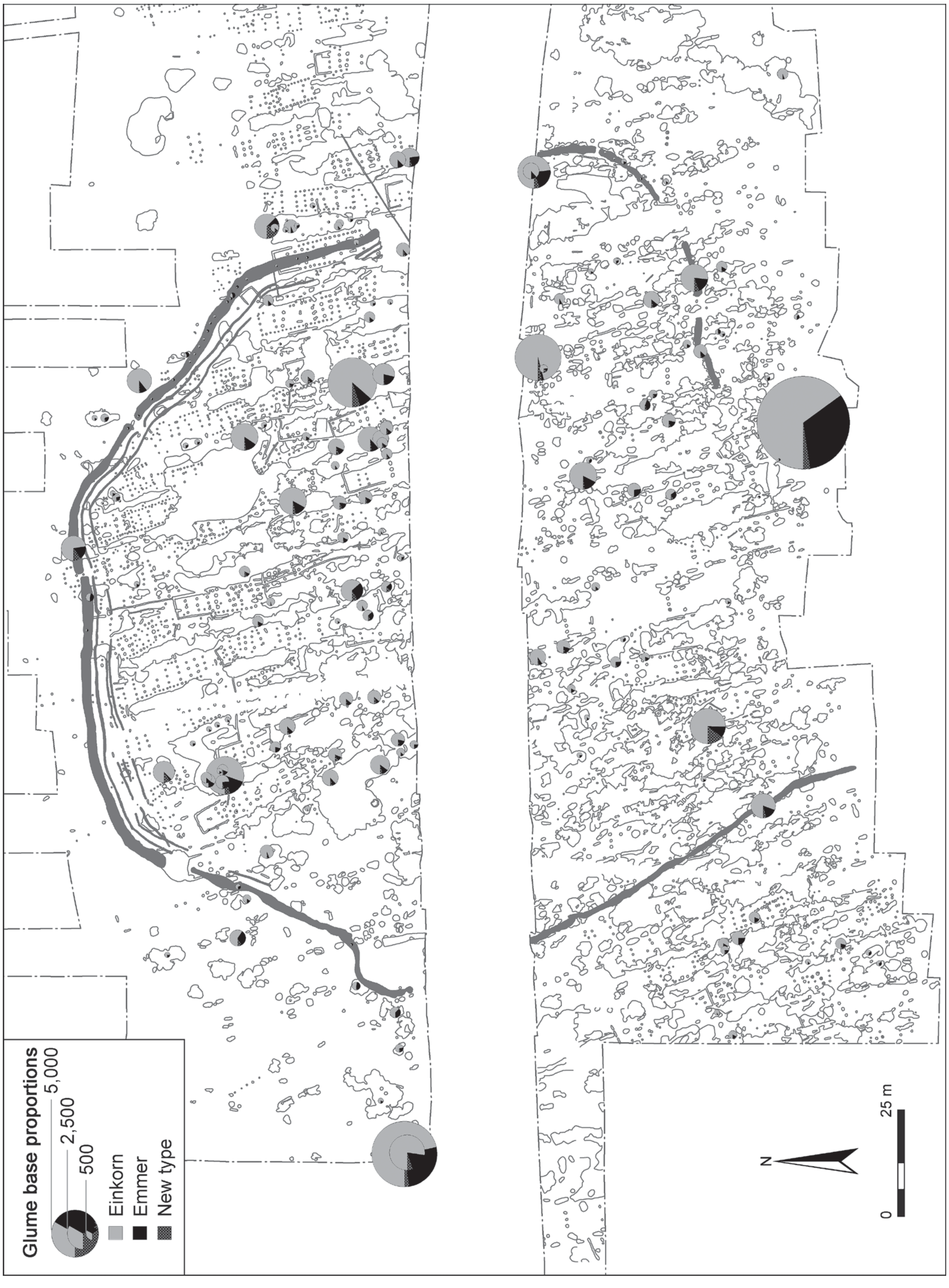

Fig. 20. Mapping of the proportions of einkorn, emmer and 'new type' glume bases per unit.

ited in the late Flomborn period *(tabs 3–4)*, forming distinctive spatial distributions through subsequent phases: opium poppy, a potential crop, and feathergrass, a wild plant represented only as awn (bristle) fragments *(fig. 21)*. Opium poppy seeds occur sporadically from the late Flomborn through the middle and late LBK, and deposition is restricted to the south-eastern part of the site. By contrast, awns of feathergrass are concentrated in the north-western sector of the settlement. The restricted distributions of these taxa suggest that their introduction reflects specific associations with certain households / household groups rather than community-wide diversification of plant use. In the post-Flomborn phases, use of opium poppy and feathergrass articulated with the two major social groupings identified on artefactual grounds: Clan I to the south-east and Clan II to the north-west, respectively.

Ethnoarchaeological, ecological and statistical approaches shed light on crop production and consumption techniques. For the most part these inferences relate to the most abundantly represented crops, the glume wheats (einkorn, emmer and the 'new type'). Their predominance reflects frequent dehusking of stored spikelets combined with charring of the resulting chaff in domestic hearths and / or use of fire in processing (for example singeing of ears to remove awns / straw prior to dehusking). Concentrations of by-product material are consistent with small-scale processing by households. The glume wheats were probably sickle-harvested high on the straw, a more rapid technique than ear-plucking which also limited collection of straw and hence the burden of subsequent processing.

Ecological analysis of weeds associated with crops reveals no evidence for shifting cultivation / slash-and-burn at Vaihingen; samples from each subperiod of occupation reflect plots that were well established. New plots were presumably cleared as needed through the life of the settlement but, managed for long-term use, their relic woodland floras would likely disappear in less than a decade, and none of the weed-rich samples available from the site appears to capture this fleeting stage. Use of long-lived cultivation plots in the wider landscape echoes long-term spatial continuity in certain longhouse sequences and stable patterning of artefactual characteristics over multiple phases, interpreted as 'clan' groupings (Strien 2005; 2011).

Maintenance of fixed plots likely reinforced concepts of land 'ownership' by households or 'clans'. Comparison of archaeobotanical data with modern weed flora from relatively high- and low-intensity cultivation, combined with assessment of variation in weed composition amongst analytical units, suggests that the glume wheats at Vaihingen were quite intensively managed overall, but with appreciable variation from plots that were intensively worked (with high mechanical disturbance of the soil) to more poorly worked plots. Stable nitrogen isotope analysis of glume wheat grain samples (see below) suggest consistent soil nitrogen conditions compatible with moderate levels of manure dispersal from multiple penning areas and / or livestock grazing stubble / fallow plots. Furthermore, stable carbon and nitrogen isotope determinations of a 'storage' deposit containing a mixture of einkorn, emmer and 'new type' glume wheat grain suggest that these cereals were grown together as a mixed crop (Fraser et al. 2013a).

Exploratory multivariate analysis of Vaihingen units based on their composition in potential arable weeds reveals contrasts in cultivation intensity and soil type that coincide to a remarkable degree with 'clan' groupings of the Flomborn period (Strien 2005; 2011; Bogaard 2011; Bogaard et al. 2011). In particular, units from Clan A, and to a lesser extent Clan D, reflect relatively intensive disturbance of basic soils, while units of Clan C are linked with relatively poor disturbance levels and soils of intermediate pH. The two post-Flomborn groups (Clans I and II) share distinctive similarities in their

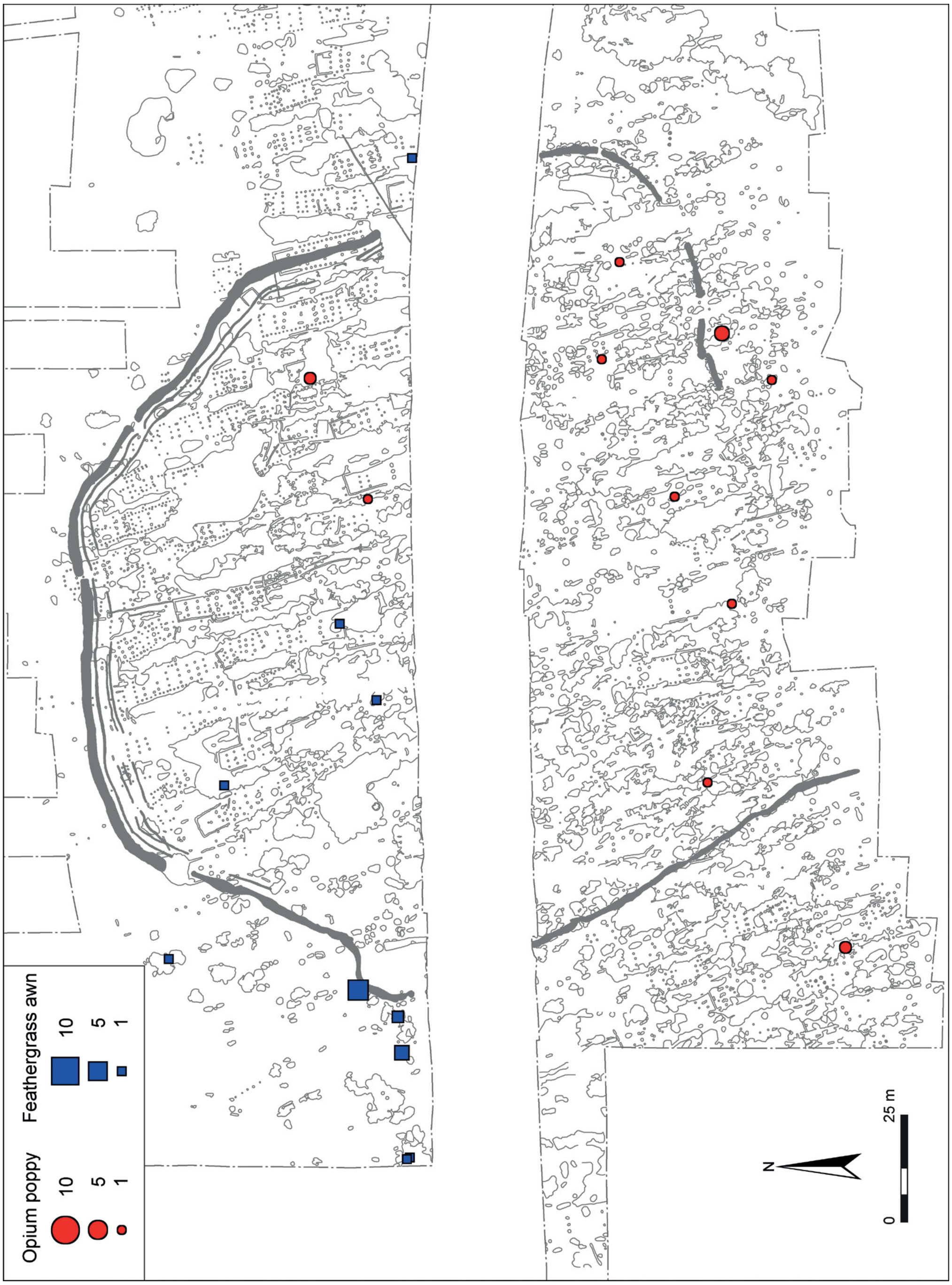

Fig. 21. Mapping of feathergrass awn and opium poppy seed counts per unit.

weed composition with earlier Clan A along with material culture traits of the Middle Neckar tradition. The combined implication of these results is that house groups maintained cultivation plots with differing levels of tillage / weeding on different soils. The fact that these differences persisted over multiple phases suggests that particular 'clan' groups were associated with distinct parcels of land at varying distances from settlement and hence of varying accessibility for intensive maintenance. The botanical results show how matters of territoriality, inheritance and 'ownership' extended from settlement space into the wider productive landscape. A further implication concerns the economic importance of social groupings intermediate between the individual longhouse and the community.

Extension of the radius of cultivation during the Flomborn occupation, combined with a land tenure system in which supra-household groups held land in 'parcels' at varying distances from the settlement, may ultimately have subverted relatively high levels of nucleation at Vaihingen. Reduction in settlement size at the end of the Flomborn period, associated with the departure of 'clan' groups (including Clan C) that were part of the Unterland / Kraichgau regional tradition, had the ecological effect of narrowing the range of growing conditions for glume wheat crops in favour of high soil productivity and disturbance. The later LBK settlement of households belonging to the Middle Neckar tradition clearly maintained the more accessible cultivation areas surrounding the settlement.

We can conclude that the 'clan' groupings defined on the basis of pottery decoration and other aspects of material culture coincided with contrasts in farming practice (and to some extent plant use, in the later LBK) alongside differences in herding and hunting practice. The faunal and botanical data also converge on a trend towards more localised and intensive land use through time. Neither dataset suggests evidence of an ecological 'crisis' towards the end of the Bandkeramik occupation at Vaihingen.

Amy Bogaard

Strontium isotope analysis of land use and the mobility of humans and animals

Investigation of land use and mobility on the basis of strontium isotope analyses has been implemented ever more frequently since the mid 1990s (Price et al. 1994). With a view to studying residential mobility with the spread of the Neolithic and the lifestyle and economy of early farmers, the Bandkeramik has been subject to some of the most comprehensive strontium isotope studies (Price et al. 2001; Bentley et al. 2002; Price et al. 2006; Bentley 2007; Bickle et al. 2011; Bentley et al. 2012; Bickle / Whittle 2013). In this context, human skeletons as well as animal teeth from Vaihingen / Enz played a principal role (Bentley et al. 2003; Bentley et al. 2004; Bentley / Knipper 2005; Knipper 2009; 2011).

Hypotheses on the spatial organisation of raising domestic animals

Hypotheses on land use and the spatial organisation of animal keeping, especially cattle, during the LBK are based on decades of archaeobiological research. These include archaeozoological studies (Döhle 1993; Benecke 1994; Lüning 2000; Kuhn 2008), among which the extraordinarily abundant material found at Vaihingen / Enz is of fundamtental importance (Arbogast 2000; Schäfer in prep.), as are pollen analyses and studies of botanical macroremains. Palynological data on landscapes of Bandkeramik settlements attest to extensive forests with a minimal amount of open land and without any indications of extensive pastures (Zoller / Haas 1995; Knipper 2011 with further references). Hypotheses based on these data have postulated that small, cleared and fallow plots in the direct vicinity of a settlement did not suffice for a year-round supply of fodder for all domestic animals and that the seasonal use of upland pastures was necessary for keeping animals (Bakels 1982; Kalis / Zimmermann 1988; Lüning 2000; Ebersbach / Schade 2004).

On the other hand, archaeobotanical macro-remains from Vaihingen and other settlements provide evidence of intensive, garden-like cultivation of domesticated plants, including weeding, careful tillage and manuring (Bogaard 2004; Bogaard et al. 2011). This system is most plausible when practiced together with herding on a small scale in the immediate surroundings of the settlement, because time-intensive cultivation bound a large work force to the site. Furthermore, a preponderance of long-distance pasturing is not compatible with the use of domestic animal dung to manure arable land near the settlement.

Methodical background of isotope analyses and geological conditions in the surroundings of Vaihingen

On the whole, convincing arguments for both a seasonal, extensive use of upland pastures and year-round keeping of domestic animals in the vicinity of the settlement can be drawn from the bioarchaeological data available until now. For evaluating both hypotheses, isotope ratios of oxygen ($\delta^{18}O$) and strontium ($^{87}Sr/^{86}Sr$) in the tooth enamel of domestic animals of the Bandkeramik culture provide essential direct evidence. In particular, the high-crowned molars of cattle can disclose high-resolution temporal and spatial information, through the serial sampling in parallel horizontal bands. Oxygen isotopes ($\delta^{18}O$) stand in causal association with temperature-based seasonal fluctuations in the isotopic composition of drinking water and food. This makes it possible to distinguish portions of a tooth crown that formed in summer from those that formed in winter (Stephan 2008; Knipper 2011 with further references). In contrast to this, strontium isotope ratios ($^{87}Sr/^{86}Sr$) reflect the geological characterisitics of the site at which the tooth formed (Capo et al. 1998; Knipper 2004; Schweissing 2004; Bentley 2006) and are indicators of the localities from which the fodder for the animals originated. The combination of seasonal and spatial information from both isotopic systems enables the recognition of year-round continuity of grazing areas or of seasonal differences, and in some cases also a spatial assignment to specific areas.

The geological conditions in the surroundings of Vaihingen offer very good prerequisites for differentiating between potential sources of animal forage by means of Sr isotope analysis *(fig. 22)*. The site of the Bandkeramik settlement itself lies on soil that developed on loess, for which characteristic bio-available Sr isotope ratios range from 0.709 to 0.710 in the Neckar region (Price et al. 2003; Knipper 2011 with further references). This corresponds in Vaihingen with the $^{87}Sr/^{86}Sr$-ratios in nine pig teeth, on the basis of which from the mean value of $\pm$ 2 σ a local range of between 0.70913 and 0.70979 could be determined (Bentley et al. 2004). Only a few kilometers south of the settlement, the Enz River cuts into the shelly limestone (Muschelkalk), which is a source of less radiogenic biologically available strontium with isotopic ratios of c. 0.708 to 0.709 (Matter et al. 1987; Obertová 2008). It is expected that the limestone in the early Neolithic period characterised the slopes as well as the bottom of the valley. Only a few kilometers north of Vaihingen, the Stromberg hills rise. They consist of middle Triassic Keuper sediments

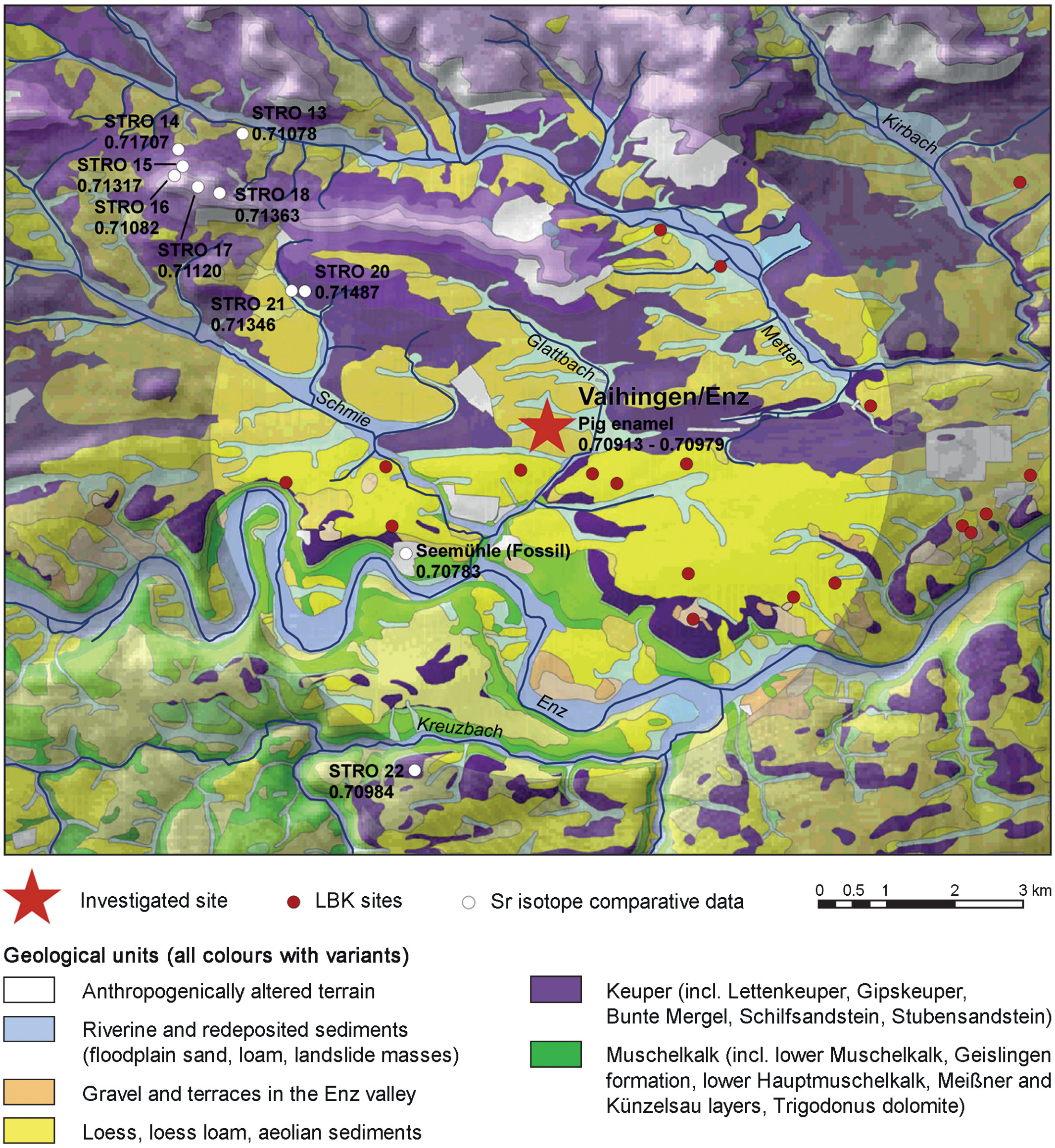

Fig. 22. Topographical and geological conditions and distribution of other Early Neolithic settlements in the region surrounding the Bandkeramik settlement of Vaihingen an der Enz (after Knipper 2011, fig. 9.17).

which form a sequence of dolostone, claystones, and marls. This area is a source of – in comparison to loess – very variable, but also more radiogenic strontium, with $^{87}Sr/^{86}Sr$ ratios of up to 0.717 (Ufrecht / Hölzl 2006; Knipper 2011). Beyond the immediate surroundings of the LBK settlement in Vaihingen, more loess and limestone areas of the Neckar region and the Gäu landscapes prevail. To the west, they are replaced by the red sandstone (Buntsandstein) of the northern Black Forest, which is likewise a source of radiogenic strontium. Around 30 km to the east there are further low mountain ranges of Keuper sediments.

If indeed differentiated land use in the variable surroundings of the Vaihingen settlement had been practised and localities beyond the loess were routinely used, this use should be recognisable in the different Sr isotope ratios between the teeth of different animals and / or at different positions along the tooth crowns of the same individual.

Material under study and sampling strategy

The first Sr isotope investigations on cattle teeth were carried out by R. A. Bentley, who analysed one sample each of 14 teeth (Bentley et al. 2004). This stimulated further analyses using a serial sampling technique. Initial results for three animals revealed that they were fed from different geological substrates and indicated a differentiated use of land (Bentley / Knipper 2005). Subsequently, an expanded set of samples comprised 45 teeth from 32 individuals. Each of them was sampled at first in two places at c. 2 cm distance for Sr-isotope analysis, a distance that corresponds to a c. one-half year interval in enamel mineralisation. When significant differences appeared between the two sample positions, a sequence of oxygen isotope analyses was conducted to disclose seasonal information. At present the Vaihingen dataset encompasses a total of 59 teeth from 46 individuals, among them two probable female aurochs (Knipper 2011).

Isotopic indicators for the spatial organisation of cattle-raising

The results of isotope analyses on cattle teeth from Vaihingen reveal three different patterns of forage supply for animals. But differences in sampling resolution and the ambiguous spatial assignment of isotope ratios in the settlement's surroundings lead to certain limitations in data interpretation (Knipper 2011, 249–279). Of the 44 domestic cattle examined, for 16 animals all of the Sr isotope ratios determined lay within the range typical for loess, as based on tooth enamel data from pig teeth (cf. *fig. 23a*). If twelve animals are also included for which only one single measurement is present, the proportion increases to 64 % of all examined animals. Thus, the loess areas in the settlement's immediate surroundings prove to be the most important for the supply of animal forage. In addition, repeated signals typical for loess noted in samples from the same individuals confirm the possibility of a year-round supply of cattle with feed from this geological unit.

A second group of teeth is marked by variations in the $^{87}Sr/^{86}Sr$-ratios along the crowns, encompassing values in the loess range as well as those of other bedrock formations *(fig. 23c)*. Here an occasional supply of forage from valleys, which cut into the shelly limestone (Muschelkalk) or from the Gäu landscapes, where this geological unit also prevails, can be assumed. This group consists of seven animals (16 %), to which a further four individuals with a single measurement can be added. Their proportion thus increases to 25 % of all animals under study. The available O isotope data allow a linkage between forage supply from river valleys mostly with the warm season of the year. However, there is no indication that these habitats were used the year-round.

In the case of five animals (11.4 %), a single value or part of the data from serial analyses are higher (more radiogenic) than the characteristic values for loess *(fig. 23b)*. This result might be associated with grazing in the Keuper hills of the Stromberg near the settlement, or possibly in the more distant periphery of the northern Black Forest. However, the latter seems less probable, because the animals would also have traversed landscapes with less radiogenic strontium on their potential path through the Enz valley and other

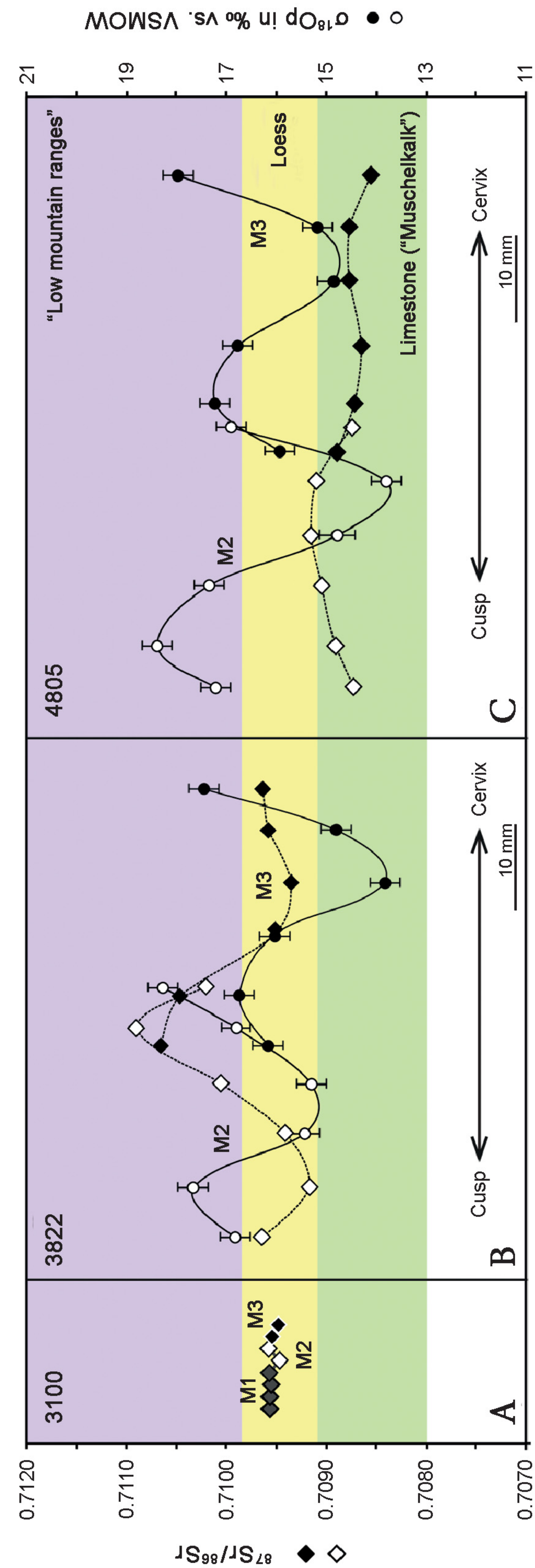

Fig. 23. Examples of variation in $^{87}Sr/^{86}Sr$ ratios (diamonds) and $\delta^{18}O$-values (circles) in cattle teeth from Vaihingen an der Enz: A) Very homogeneous Sr isotope ratios in several teeth of an animal indicate year-round presence on loess. B) Fluctuations in $^{87}Sr/^{86}Sr$ ratios reflect a lengthy stay in the Mittelgebirge during the warm season, presumably in the Stromberg mountains north of Vaihingen. C) Relatively low $^{87}Sr/^{86}Sr$ values are most likely explicable as grazing in river valleys cutting into shelly limestone. These resources were especially used in the warm season.

areas dominated by shelly limestone. Grazing on their way through these landscapes should have resulted in even more variable isotope ratios through the cattle's dental sequence. Nevertheless, animals with higher Sr-isotope values offer indications of grazing in the low mountain ranges, which – so far as the O isotope data available suggest – can be associated with the summer months.

Although the dataset on the whole is relatively extensive (cf. Schweissing / Grupe 2003; Viner et al. 2010; Stephan et al. 2012), with regard to chronological tendencies the evaluation quickly reaches its limits due to the few samples per time-unit. Nonetheless, throughout the entire LBK at least half of the animals exhibited Sr isotope ratios that can be associated exclusively with a supply of forage from loess areas. This again points to the continuous importance of the immediate surroundings of the settlement for feeding domestic stock. The use of land during the earliest LBK and the Flomborn phase differed from that in later times: in the early settlement phases, almost one-half of the animals revealed indications of a seasonal supply of fodder from river valleys or from Keuper heights *(fig. 24a)*. During the later LBK, only one-fifth of the cattle studied showed signs of fodder from limestone areas or from river valleys, while there are no signs of the use of upland pastures. This possibly went along with increased clearance of the landscape and therefore better conditions for animal feed acquisition from the settlement's vicinity. Moreover, this result was possibly connected with a decrease in the number of inhabitants in the settlement of the younger LBK.

Furthermore, with regard to the longhouse groups within the settlement discussed above, referred to as 'clans' or 'lineages' (Strien 2005; Strien 2011), some contrasting tendencies appear, though the loess areas were in all cases major sources of forage *(fig. 24b)*. Most indications of upland grazing (15 %) and use of river valleys (33 %) derive from cattle teeth associated with material remains of the "Middle Neckar" group (n = 27). By contrast, the variability of animals identified in the find contexts of the "Unterland / Kraichgau" group (n = 10) is less, each with only one possible indication of the use of these areas without loess cover.

The proportion of animals with Sr isotope ratios within the range typical for loess as well as above or below it can be best evaluated with regard to the proportion of the major geological units in the vicinity of the Bandkeramik settlement of Vaihingen *(fig. 24c)*. Accordingly, Keuper of the Stromberg uplands and its foothills make up over 30 % of the surroundings in a 2 or 5 km radius around the settlement, while elevated Sr isotope ratios are found in only 11 % of the cattle teeth. Thus, the seemingly exotic elevated $^{87}Sr/^{86}Sr$ values are under-represented compared to the proportion of Keuper in the vicinity. By contrast, shelly limestone surfaces and the incised valleys are over-represented. Namely, 25 % of the cattle Sr isotope ratios lie below the range of values typical for loess, while only 11 and 16 %, respectively, of the landscape within a 2 or 5 km radius is formed by shelly limestone. The representation of loess in animal teeth and in the landscape is about even.

All in all, the Sr isotope data of cattle teeth point to a differentiated use of land, which was associated with an intensive, small-scale economy in the proximity of the settlement. The elevated Sr isotope ratios in the teeth of some animals attest to the use of upland pastures, which nonetheless was the exception rather than the rule. Hypotheses about a regular seasonal change of pastures within the framework of a large-scale extensive form of economy cannot be confirmed based on the present data. They rather show a preference for the supply of forage for animals from river valleys and loess surfaces: that is, the use of areas that also served for building and agricultural purposes.

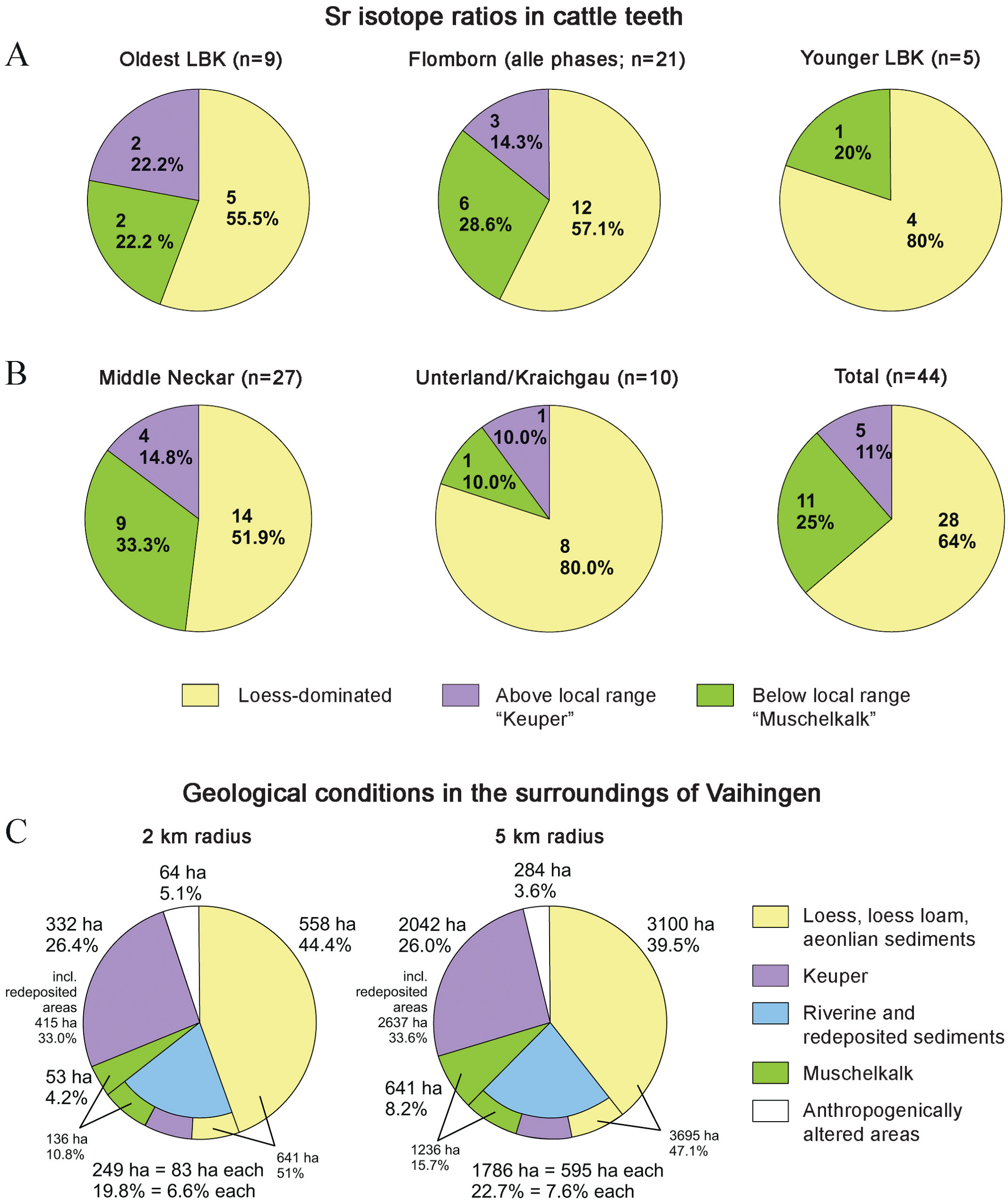

Fig. 24. Distribution of Sr isotope ratios in cattle teeth by A) LBK subperiod and B) regional ceramic tradition) in comparison with C) proportional areas of dominant geological substrates, loess, shelly limestone (Muschelkalk) and Keuper (after Knipper 2011, fig. 9.45; 9.46).

Studies on human mobility

In the course of archaeological excavations in Vaihingen, human skeletal remains were uncovered, from which 46 individuals were sampled for Sr isotope analyses (Bentley et al. 2003). In most cases, the investigations concentrated on the first molars, whose isotope ratios reflect the source of food during the first years of life. C. 70 % of the analytical results correspond with the range of values for pig teeth, which can be linked with arable land on loess. C. 30 % of the human teeth exhibit either more or less radiogenic Sr isotope ratios. Among these are about the same number of males and females, whereas a higher number of children with lower isotope ratios is particularly noteworthy. Like the isotope ratios of the animal teeth, the data indicate use of areas other than loess for economic activities. Possible explanations include not only changes of residence of single individuals, but also the consumption of wild plants and meat of wild game, in which context possible contact with the last groups of hunters and gatheres has been considered (Bentley et al. 2003). Yet, on the basis of the available data on domestic animals, which completely coincide with those for humans *(fig. 25)*, and of archaeobotanical indicators for differentiated methods in crop cultivation and the use of different economic areas by different groups within the settlement (see above and Bogaard et al. 2011), the human teeth could just as well reflect such differentiated strategies in the economic pursuits and land use in the close surroundings of the settlement. Nevertheless, the presence of non-local persons cannot be excluded.

While in other Bandkeramik burial communities indications of patrilocal residence could be inferred (Bentley 2007; Bentley et al. 2012), the present data from Vaihingen appear to be rather indifferent in this regard. However, considering a total of c. 130 documented individuals, the sample can still be enlarged. Especially in combination with the evaluation of material culture, botanical and archaeozoological data, as well as further sampling of teeth of domestic and wild animals, this promises a more nuanced understanding of groups within the settlement.

Summary and perspectives

The Sr and O isotope data from human and animal skeletal remains found in Vaihingen / Enz have provided decisive insights into animal husbandry and land use strategies of early farmers in present-day south-western Germany. The data speak in favour of small-scale strategies of keeping domestic animals, in which loess areas in the vicinity of the settlement were of great importance, yet not used exclusively for the supply of feed to animals. Instead, river valleys or shelly limestone areas were also an important source of food. Some domestic animal teeth were indicative of grazing in upland pastures, such as the Stromberg hills north of the settlement. These indications were, however, rather an exception and hardly speak for an extensive economy with regular seasonal mobility between summer pastures in the uplands and the use of resources in the settlement's near vicinity during the winter. The data on animal teeth closely correspond with the spectrum of values for humans, which likewise cannot be explained solely by plant cultivation on the loess.

The rich spectrum of finds from Vaihingen, together with the results already achieved, offer a key means for understanding early farming economy in central Europe. Decisive for further investigations would be the enlargement of the dataset through a targeted selection of new samples from find contexts that are well dated and clearly assignable to social groups.

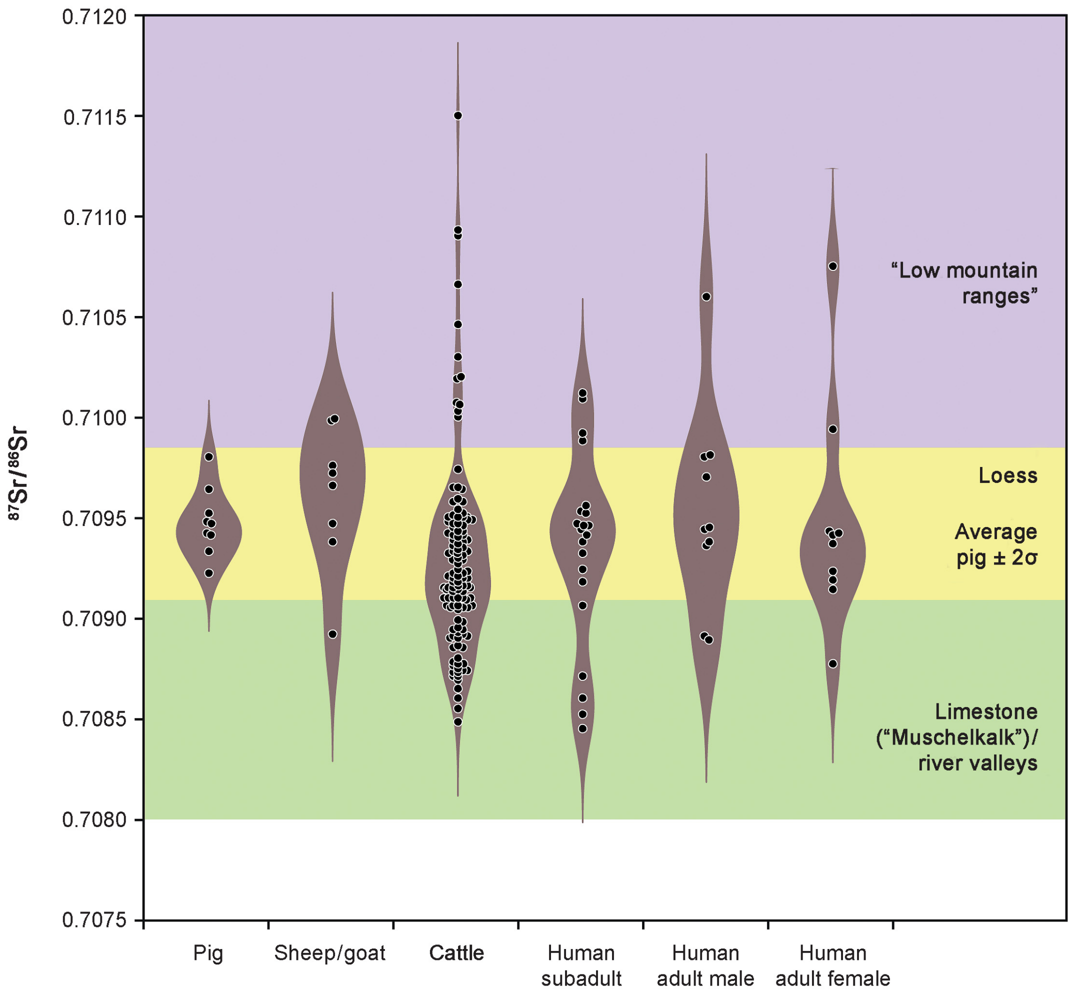

Fig. 25. Distribution of $^{87}Sr/^{86}Sr$ ratios of humans and domestic animals from the Bandkeramik settlement of Vaihingen an der Enz, on the basis of individual measurements and kernel density curves of value distributions. The dataset of cattle includes samples from 57 teeth and 44 individuals, while for all other groups each data point represents one tooth / individual (data: Bentley et al. 2003; 2004; Knipper 2011).

In the remainder of this paper, the Vaihingen data on botanical, faunal and human stable carbon and nitrogen isotope values are integrated, and a first attempt to model land use and diet in the Vaihingen community is presented based on these data.

Corina Knipper

An integrated study of botanical, faunal and human stable carbon and nitrogen isotope values

Stable carbon and nitrogen isotope analysis of human and faunal bone collagen is routinely used to reconstruct past diet. Carbon isotope ($\delta^{13}C$) values can be used to assess the relative importance of marine versus terrestrial protein in human diet (Schoeninger / DeNiro 1984) and nitrogen isotope ($\delta^{15}N$) values are commonly used to estimate the proportions of plant and animal protein that people consumed (Bocherens / Drucker 2003; Vanderklift / Ponsard 2003; Hedges / Reynard 2007).

A common method of estimating the proportion of terrestrial animal protein consumed by humans assumes that the $\delta^{15}N$ values of plants consumed by people and herbivores are identical. This is particularly implausible if cereals consumed by humans were manured, since manuring can substantially increase the $\delta^{15}N$ values of plants (Fraser et al. 2011; Kanstrup et al. 2011). The effect of this increase on crop $\delta^{15}N$ values is to raise the bone collagen $\delta^{15}N$ values of humans eating manured crops above those of co-existing herbivores eating unmanured plants, therefore leading to an overestimation of the amount of animal protein in the human diet. As has been stated above, ecological analysis of the arable weed assemblage associated with glume wheats at Vaihingen points to maintenance of long-lived cultivation plots (Bogaard 2004; 2011), suggesting a plausible context for manuring. Crop $\delta^{15}N$ values from Vaihingen can therefore not only improve interpretations of human diet, but by comparing with the estimated $\delta^{15}N$ values of herbivore diet can also provide independent evidence for crop manuring.

Another method with the potential to improve reconstruction of human diet in the past uses the $\delta^{15}N$ values of individual amino acids that make up bone collagen protein (Naito et al. 2010; Styring et al. 2010; Chikaraishi et al. 2014; Styring et al. 2015). The following equation, developed by Chikaraishi et al. (2009), uses the $\delta^{15}N$ values of the amino acids phenylalanine ($\delta^{15}N_{Phe}$) and glutamic acid ($\delta^{15}N_{Glu}$) in human bone collagen to estimate the proportion of animal protein that they consumed (f):

$$f = \frac{(\delta^{15}N_{Glu} - \delta^{15}N_{Phe} - \Delta^{15}N_{Glu\text{-}Phe}{}^{*})}{\Delta_{Glu} - \Delta_{Phe}} - 1$$

$\Delta^{15}N_{Glu\text{-}Phe}{}^{*}$ is the difference between the $\delta^{15}N_{Glu}$ and $\delta^{15}N_{Phe}$ values in cereal grains (–8.0 ‰, which was determined in cereal grains from two modern sites; Styring et al. 2015), and Δ_{Glu} and Δ_{Phe} are the amounts by which the $\delta^{15}N$ values of glutamic acid and phenylalanine increase between diet and consumer (8.0 and 0.4 ‰ respectively; Chikaraishi et al. 2009). This method eliminates the need to rely upon the bone collagen $\delta^{15}N$ values of co-existing fauna, whose tissues may not in fact have contributed to the human diet. For further discussion of amino acid $\delta^{15}N$ values in bone collagen and cereal grains and descriptions of the other methods used to reconstruct human diet at Vaihingen see Styring et al. (2015).

Good preservation and systematic recovery of bioarchaeological materials at Vaihingen / Enz provided the rare opportunity to assess the role of manuring in cereal and pulse cultivation and to explore a Neolithic dietary 'food web' through bulk and amino acid stable carbon and nitrogen isotope analysis of botanical, faunal and human remains.

Sampling strategy

Sixteen grain-rich archaeobotanical samples were selected for subsampling and isotopic analysis. Each subsample consisted of c. 15 to 25 cereal grains (emmer and einkorn wheat) or pulse seeds (lentil and pea) from the same stratigraphic unit; these bulk samples were homogenised to take account of present-day variation observed in stable isotope values within and among crop plants from the same arable plot (Fraser et al. 2011; 2013a). Recent experimental work on the isotope effects of charring, burial and chemical pretreatment suggests that original $\delta^{13}C$ and $\delta^{15}N$ signatures are retrievable from ancient plant remains (Fraser et al. 2013b; Styring et al. 2013; Vaiglova et al. 2014). The large size of the mammal bone assemblage permitted isotopic analysis of a total of 79 faunal specimens; the same body part (distal humerus) from the same side of each animal was chosen to avoid sampling the same individual twice. Of the 138 human skeletons found, mostly as crouched burials in the ditch fill or in nearby settlement pits (Krause 2002), 45 were available for sampling (mostly of the femur) and stable isotope analysis. A subset of five human, five cattle and five red deer bone collagen isolates were selected for the more time-consuming amino acid $\delta^{15}N$ analysis.

Results

Figure 26 presents the $\delta^{13}C$ and $\delta^{15}N$ values of cereals, pulses, fauna and humans. After (generous) adjustment to take account of potential charring effects (Fraser et al. 2013b; see also Nitsch et al. 2015), cereal grain $\delta^{15}N$ values range from 3.9 ‰ to 5.0 ‰; though precise manuring rates cannot be inferred from these values, cereal grain values higher than c. 4 ‰ have only been observed in modern arable fields receiving regular manure input (Bogaard et al. 2007; Fraser et al. 2011). One pulse (pea) sample has a $\delta^{15}N$ value of 1.1 ‰, typical of nitrogen-fixing pulse species, whereas the other two pulse samples have $\delta^{15}N$ values similar to the cereal crops, and are consistent with high levels of manuring (Fraser et al. 2011, tabs 3c; 5c).

Herbivore $\delta^{15}N$ values range from 5.1 ‰ to 8.1 ‰, with a mean $\delta^{15}N$ of 6.7 ± 0.7 ‰. Aside from a juvenile individual (no. 403) with the lowest $\delta^{15}N$ value of 5.8 ‰, all human $\delta^{15}N$ values fall within a narrow 2.2 ‰ range from 8.0 to 10.2 ‰ (mean = 9.1 ± 0.5 ‰). There are no significant differences in the mean $\delta^{13}C$ or $\delta^{15}N$ values relating to age group or sex.

A simple linear-mixing model using plant, herbivore and human $\delta^{15}N$ values was used to illustrate four possible dietary scenarios to estimate the fraction (percentage) of dietary protein obtained from animal or plant sources by humans at Vaihingen *(fig. 27)*. Our approach incorporates the 'standard model' (A) described by Hedges / Reynard (2007, fig. 1), but also modifies the input data to include measured archaeobotanical crop $\delta^{15}N$ values from Vaihingen in three additional models (here B–D). The models require a ^{15}N trophic level enrichment factor between diet and consumer; in this study we have used a $\delta^{15}N$ value of 4 ‰ (the mean of the 2 to 6 ‰ ^{15}N-enrichment determined in previous studies; Hedges / Reynard 2007; O'Connell et al. 2012).

The 'standard model' *(fig. 27a)*, using an inferred plant diet $\delta^{15}N$ value (2.7 ‰) calculated by subtracting the above enrichment factor from the $\delta^{15}N$ values of co-existing herbivores, indicates a human diet consisting of ~60 % animal protein. This estimate is similar (~57 %) when a diet of 100 % pulses *(fig. 27d)* is considered because the starting $\delta^{15}N$ value of Vaihingen pulses, 2.8 ‰, is very close to the inferred plant-diet $\delta^{15}N$ value in the standard model. The mean $\delta^{15}N$ value of the cereal grain samples (einkorn and emmer wheat) of 4.5 ‰, however, is 1.8 ‰ higher than the inferred plant-diet value in the standard model; therefore, model scenarios incorporating cereal $\delta^{15}N$ values reduced the estimated percentage of animal protein in the human diet to ~29 % for the 'cereal' model and ~46 % for the 'cereal / pulse' model. These effects are apparent despite generous adjustment of cereal and pulse $\delta^{15}N$ values (subtraction of 1 ‰) to account for potential charring over a prolonged period (24 hours – Fraser et al. 2013b). Low-temperature charring for shorter periods may also be relevant and appears to have less or no biasing effect on $\delta^{15}N$ values (Kanstrup et al. 2012; Nitsch et al. 2015).

The mean $\delta^{15}N$ values of bulk collagen, glutamic acid and phenylalanine for the five humans selected for amino acid isotope analysis are 9.1 ± 0.1 ‰, 12.2 ± 1.2 ‰ and 10.7 ± 1.6 ‰, respectively. Using the equation defined above, the proportion of animal protein in their diet is estimated as ~25 %.

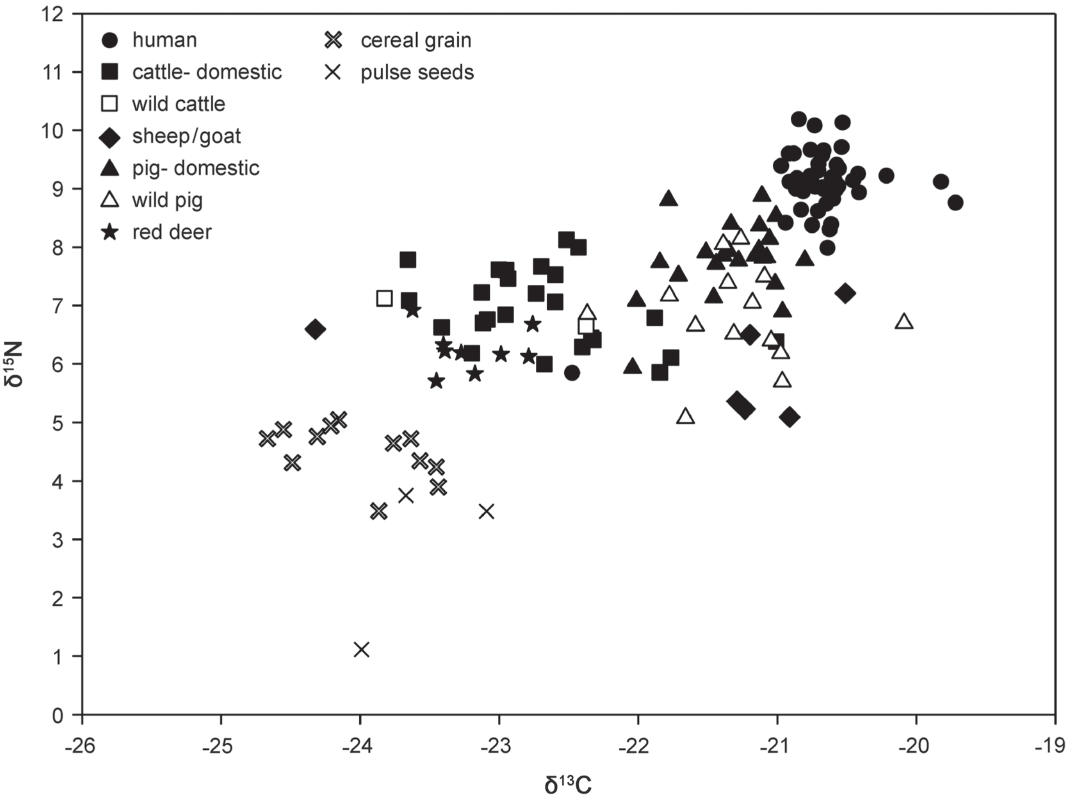

Fig. 26. Plot of human and animal bone collagen and archaeobotanical cereal grain and pulse seed $\delta^{13}C$ and $\delta^{15}N$ values. Charred crop $\delta^{15}N$ values are adjusted for charring effects.

Discussion

The consistency of cereal grain $\delta^{15}N$ values at Vaihingen contrasts with more variable signatures detected in present-day traditional farming regimes in the Sighisoara region, Romania, and in Asturias, Spain (Fraser et al. 2011, fig. 5). Crop growing conditions at Vaihingen apparently lacked the extremes of very intensive and little / no manuring, perhaps because manure was spread from multiple collection areas (for example pig pens) in the landscape and / or dispersed through grazing of stubble / fallow fields. It is notable that pig manure tends to have a bigger impact on plant $\delta^{15}N$ values than cattle manure (Szpak 2014), suggesting that even low stocking levels (see below, contribution by Ebersbach) could be associated with crop $\delta^{15}N$ values appreciably higher than those of (largely unmanured) herbivore forage, as at Vaihingen. The particular relevance of pig manure is suggested by the consistently 'local' Sr isotope values of pigs (see above, contribution by Knipper), their increasing prevalence through the occupation sequence (see above, contribution by Schäfer and Arbogast) and their particular association with Middle Neckar groups (see contribution by Schäfer and Arbogast) who apparently managed the most intensively worked plots (see above, contribution by Bogaard).

Combined analysis of $\delta^{15}N$ values in crop, faunal and human remains from Vaihingen obviates the problematic assumption that plants consumed by humans and fauna had

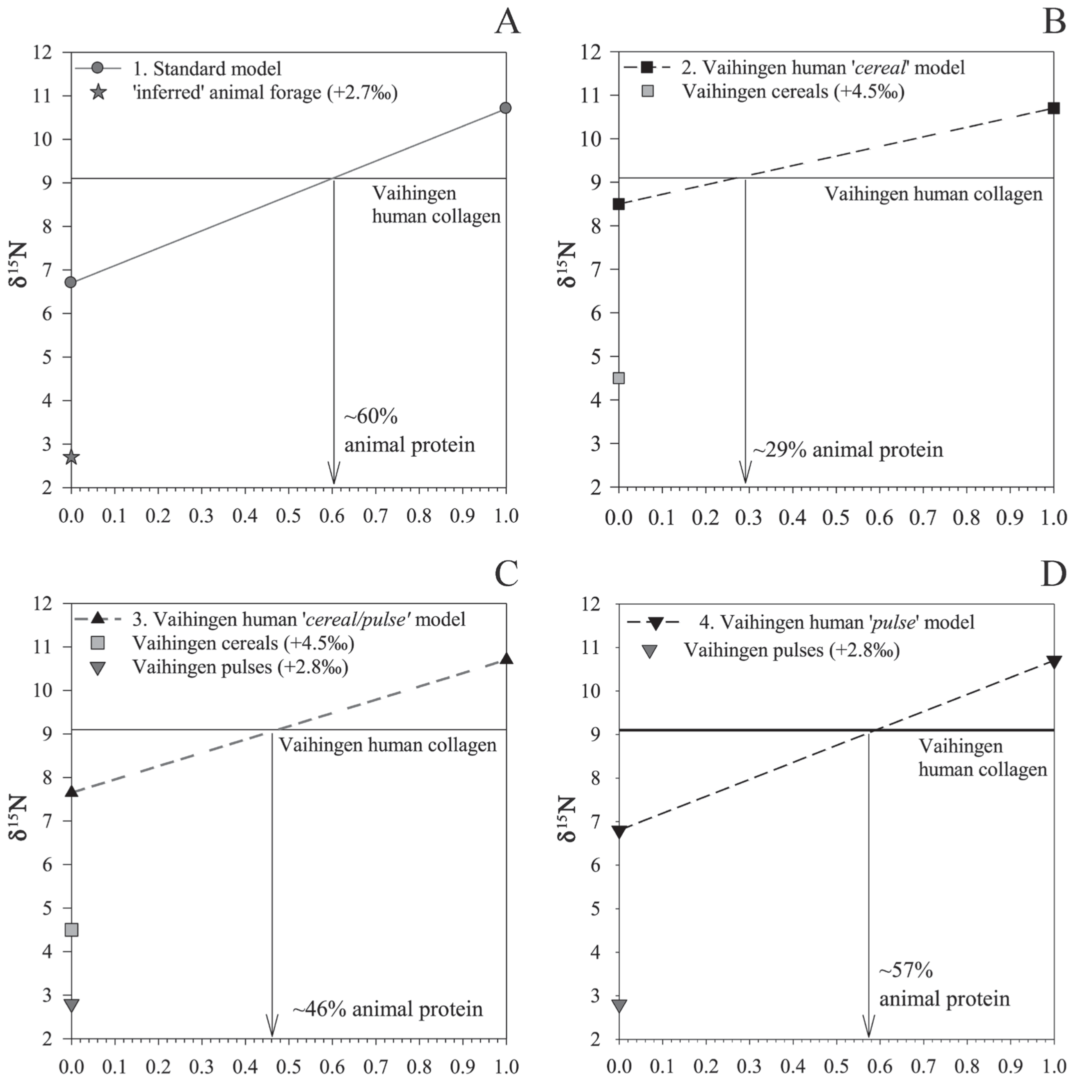

Fig. 27. Four modelled scenarios estimating the animal protein fraction (percentage) of total dietary protein in the Vaihingen human diet. The linear mixing models incorporate: an 'inferred' plant $\delta^{15}N$ value (A), the actual measured Vaihingen cereal and pulse $\delta^{15}N$ values (B–D) and the Vaihingen human bone collagen $\delta^{15}N$ value (mean + 9.1 ‰).

the same isotopic signature. The enrichment of cereal $\delta^{15}N$ values relative to inferred plant forage indicates that a 'standard model' interpretation of the Vaihingen humans and fauna would underestimate the dietary role of cereals. An internal assessment of trophic level using amino acid $\delta^{15}N$ values also indicates a more important role of cereals in the diet compared to animal protein. Only a plant diet consisting entirely of pulses would conform to the expectations of the 'standard model'. The paradoxical implication is that a plant component consisting entirely of (protein-rich) pulses would coincide with the highest possible estimate of animal protein in the diet. It is far more plausible that the plant part of the diet consisted of a mixture of cereals and pulses, or even predominantly of cereals; in both of these scenarios, (manured) crops provide most of the protein in the diet.

Rebecca A. Fraser, Amy Styring, Amy Bogaard

First attempt at an integrated land use and diet model

A quantitative analysis of the landscape surrounding a settlement can yield information about the absolute scale of land use during each settlement phase (Ebersbach / Schade 2004; Ebersbach 2006). Such estimations link up the results and hypotheses of individual disciplines, and enable further discussion of the factors that were particularly influential for land use and food supply at Vaihingen. This kind of quantitative model was developed in the 1980s for investigations of Swiss Neolithic wetland settlements (Jacomet / Schibler 1985; Gross et al. 1990), and further advanced in the 1990s through the addition of basic ethnographic data (Ebersbach 2002; 2007). In LBK research, the analysis of landscape, augmented by GIS-based surface calculations, has been applied to well studied settlement areas (Ebersbach 2006). The model follows a quantitative-systemic approach, like that in research on ecological systems.

Based on the results from Vaihingen presented here, a first attempt at a model that integrates as many results as possible can be made. The basis of the quantitative analysis is a simple linked table *(fig. 28)*. The starting point is provided by the settlement archaeological results: that is, the (hypothesised) number of contemporary houses and inhabitants. For Vaihingen, Strien (2010) proposed a maximum settlement density of 40 coeval households and c. 320 inhabitants during the Flomborn period. If minimum requirements of 2000 kcal and 45 g of protein per person and per day are assumed, the inhabitants of Vaihingen would need a daily caloric supply of 640 000 kcal and a daily protein input of 14 kg for the entire settlement at its peak. If these caloric requirements were covered by cereals alone, the settlement would have consumed 194 kg of cereals daily. If protein were supplied mainly by pulses, then 80 kg of pulses, that is, two kilogram per household, would have been needed daily. Archaeobotanical results have revealed intensive horticulture with some manuring, for which a surface area of c. 1 ha per household would suffice in meeting caloric requirements. At the same time, stable isotope analyses of plants, fauna and humans have shown that the majority of protein required was potentially provided by plant sources, and that animal products played a subordinate role in the diet. With a field size of one hectare per household and an average yearly yield of 1500 kg / ha (after Bogaard 2004, 159) the community at Vaihingen would have already secured 85 % of their daily caloric requirement and 57 % of their protein solely through cereals (1695 kcal and 26 g protein per person and day). If this amount is augmented by food from domestic animals and a value for the cultivation of pulses of, for example, 5 ha for the entire settlement, the result would be a balanced diet that covered the nutritional requirements exactly. Therefore, a very low stocking density would suffice. Estimations of one head each of cattle, pigs and sheep (or goat) per household, and an additional hunting yield of 10 red deer individuals per year for the entire settlement, are integrated in the model in *figure 28*. With these values, an average Bandkeramik inhabitant of Vaihingen would have eaten only 80 g of meat per day on average, but this would have provided more than 30 % of the required daily protein. Alternatively, estimates for cultivating oil plants, gathering or a minimal consumption of milk could be assumed. *Figure 28* shows that the results presented above are internally consistent and can be calculated into a model without contradiction. It also shows that an adequate daily diet is possible with a very low density of domestic animals and almost without relying upon possible wild game

population		**nutritional values**		**meat supply**		**cultivation**	
households	40	**calories (kcal/kg (l))**		adult cattle (MNI)	15	lack of calories	1792.29
duration (y)	1	meat	2420	of them dairy cows (MNI)	0	lack of proteins (g/p/y)	30.41
inhabitants/house	8.0	fish	1000	juvenile cattle (MNI)	15	cereals (ha)	40.00
inhabitants total	320	milk	600	infant cattle (MNI)	10	cereal yield (kg/ha)	1500.00
field size (ha/p/y)	0.14	cereals	3300	slaughtering rate (%/y)	100	sum yield for consumption	60000.00
domestic animals/p/y	0.38	pulses	3400	pigs (MNI)	40	pulses (ha)	5.00
		oil fruits	680	sheep/goats (MNI)	40	pulses yield (kg/ha)	700.00
meat weight (kg for consumption)		hazelnuts	6700	wild animals (MNI)	10	sum yield pulses	3500.00
meat weight adult cattle	275	other gathered species	600			oil plants (ha)	0.00
meat weight juvenile cattle	200	**protein (g/kg)**		sum meat weight adult cattle	4125	oil plants yield (kg/ha)	0.00
meat weight infant cattle	40	meat	170	sum meat weight juvenile cattle	3000	sum yield oil plants	0.00
meat weight pigs	50	fish	180	sum meat weight infantile cattle	400	% of demand from domestic species	
meat weight sheep/goats	25	milk	30	sum meat weight cattle	7525	**sum (% domestic species)**	
meat weight wild animals	50	cereals	*50*	meat weight pigs	1000	cereals	84.76
		pulses	180	meat weight sheep/goats	1000	pulses	5.09
requirements (after WHO)		oil plants	15	meat weight other mammals	500	oil plants	0.00
calories (p/d)	2000	hazelnuts	100	meat weight fish	0	meat (domestic animals)	9.87
protein (g/p/d)	45	other gathered species	20	sum meat weight	10025	milk	0.00
				composition of diet (p/d)			
manpower		**milk cattle**			kg	kcal	Protein
		lactation (y/ind)	0.00	cattle diet	0.06	155.91	10.95
full-time workers (n)	120	lactation period (d/y)	*0.00*	pigs diet	0.01	20.72	1.46
half-time workers (n)	200	milk yield (l/ind/d)		sheep/goats diet	0.01	20.72	1.46
working day (h/d)	8	**milk sheep/goats**		sum meat (domestic animals)	0.08	197.35	13.86
ha cultivated total	45	lactation (y/ind)		wild animals diet	0.00	10.36	0.73
domestic animals total	120	milk yield (l/ind/d)		fish diet	0.00	0.00	0.00
expenditure for fields (h/m2)	0.25	milk yield sum	0.0	milk diet	0.00	0.00	0.00
cultivation hours total	112500.00	milk diet (l/p/d)	**0.00**	cereals diet	0.51	1695.21	25.68
cultivation days per year	117.19			pulses diet	0.03	101.88	5.39
(full-time workers only)		**gathering: hazelnuts**		oil plants/others diet	0.00	0.00	0.00
agricultural period (d/y)	180.00	lack of calories (p/d)	0.00	*site: Vaihingen*			
balance cultivation	62.81	lack of protein (p/d)	0.00	*phase: Flomborn Phase 2B2*	**sum diet**	**2004.80**	**45.67**
		harvest of hazelnuts		*state: Baden-Württemberg*			
harvest time total (d)	200.00	quantity (kg/p/d)	0.00	*source: div. authors*	**percentage of demand**	**100.24**	**101.49**
harvest time per worker (d/y)	1.67	hazelnuts diet (kcal/p/d)	0.00	**gathering: other species**		remarks:	
		hazelnuts sum (kg/y)	0.00	lack of calories (kcal)	0.00	calculation without cultivated oil plants	
harvest time for hazelnuts (d)	30	h/0.5p/y harvest hazelnuts	0.00	diet gathered species (kg/p/d)	0.00	and milk use	
harvest time for other species (d)	135						
hazelnuts yield kg/h	0.20	**hazelnuts (% of demand)**	**0.00**	**other gathered (% of demand)**	**2.80**		

Fig. 28. First attempt at modeling of nutrition based on the peak population estimate and agricultural methods reconstructed for Vaihingen an der Enz (yellow highlight), newly calculated and adapted from Ebersbach 2003 fig. 4.

resources, a result that matches well with results of isotope analyses and with recent studies on the significance of cattle raising in the Bandkeramik culture (for example, Arbogast 1994; 2001; Döhle 1994). A limiting factor in this model is the time required to work the fields. In the present model 117 days a year would be needed to work the fields, a value that is realistic considering the length of the growing season.

Another limiting factor in the Vaihingen model might be the amount of manure produced. According to the stable isotope analyses of crop remains, a certain amount of manure was spread upon the fields (see above, contribution by Fraser et al.). A primitive breed of cattle produces c. 400–600 kg of dung per year (Ebersbach 2002, 152), which for an assumed cattle density of one animal per household and an assumed field size of one hectare per household only yields a dung value of about 0.5 t / ha, and also only when the animals have grazed in the fields (fallow land?) throughout the whole year or dung was collected systematically and transported to the fields.

It is possible that dung from pigs played an important role here, and that use of pig manure contributed to the increasing importance of this animal through time (see above). Moreover, pig manure has a greater influence on nitrogen isotope values in cultivated plants than ruminant dung (Szpak 2014), which could explain the apparent discrepancy between the results of isotope analyses and the potentially very low density of cattle kept. This discussion highlights again the usefulness of combining results from different approaches into an integrative model. In this way, correspondences as well as contradictions among the strands of evidence can be identified in order to achieve a sensible, internally consistent hypothesis on the lifeways of Bandkeramik people at Vaihingen.

Renate Ebersbach

Synthesis

What emerges from the post-excavation analyses brought together here is a dynamic settlement history featuring a multiplicity of social groupings and identities, and of approaches to and through the landscape, against a backdrop of continuity in many practices across the community and through time. This new integrated perspective challenges the idea that Neolithic societies in general, and Bandkeramik groups in particular, were simply conservative; instead, fine-grained analysis of this local community has revealed contrasting ecologies and material relations within the community and shifts through the chronological sequence. Here we highlight a series of interdisciplinary findings that emerge from specialist analysis to date in order to develop new questions and hypotheses for future Bandkeramik studies at Vaihingen and beyond.

Returning to the questions set out in the Introduction, we present integrated responses below that highlight agreements as well as contrasts among the various lines of evidence.

1. To what extent did practices at Vaihingen change through time?

Changes in material culture and settlement size and structure are summarised in the Introduction. *Figure 29* presents a summary of changes in herding and farming practice through time. Most striking is that an initially strongly cattle-dominated herding spectrum shifts steadily in favour of pigs and the small ruminants through the occupation sequence. There is also a broad correspondence between the faunal results – including Sr/O isotope data – and archaeobotanical data. All reflect a change from relatively extensive land use in the Flomborn period, entailing variable cultivation intensity (presumably due to an extended 'radius' of cultivation from the settlement) and a relatively high frequency of cattle grazing in local river valleys and Keuper uplands beyond the surrounding loess, to a post-Flom-

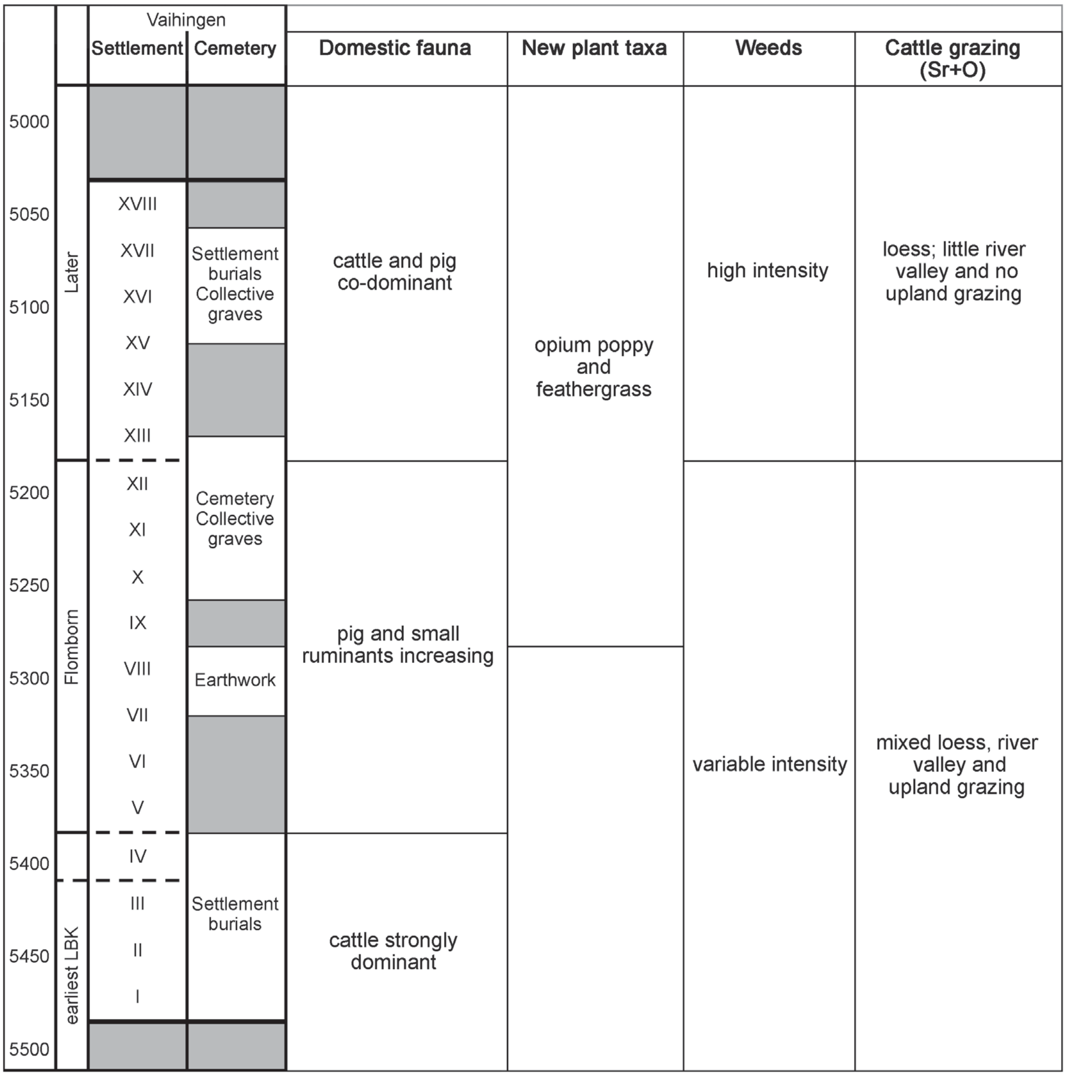

Fig. 29. Summary of chronological changes in land use at Vaihingen an der Enz.

born situation in which cultivation plots surrounding a smaller settlement were all quite intensively maintained, and cattle were infrequently grazed beyond the loess. Moreover, locally kept pigs were increasingly dominant in the spectrum of herded animals. All of this evidence points to a kind of intensification of local land use as the scale of aggregation at Vaihingen decreased at the end of the Flomborn period.

These coincident shifts from the Flomborn period to the later LBK can be contrasted with remarkable continuities. It is striking that the crop spectrum, including the dominance of einkorn among the hulled wheats, persists throughout the sequence, the only new plant introductions, in the Late Flomborn period, being opium poppy and feathergrass, both of which remain restricted to certain parts of the settlement in the later phases. (Dis-) continuities in diet are harder to trace, since most of the human individuals analysed isotopically are crouched burials in the ditch, which belong to the late Flomborn period (see *fig. 5*). Equally, the chronological assignments of isotopically analysed fauna and botanical samples are too sparse to permit an analysis of ecological change through time.

Despite these restrictions, Vaihingen illustrates how the scale of social aggregation affected land use patterns from both a farming and herding perspective, revealing the dynamism of land use and the limitations of simple models. The integrated land use and diet model presented, based on the peak community size in the Flomborn period, demonstrates that an economic system based largely on crops, supplemented by animal and / or foraged foods, is feasible. On the other hand, at its maximum extent in the Flomborn period households belonging to the Middle Neckar tradition evidently retained the most accessible arable land, as reflected by the ecological analysis of weed assemblages associated with this material culture (see also Bogaard et al. 2011). The social mechanisms for equalising land use rights among households in a nucleated settlement appear to have been lacking at Vaihingen, contributing to the departure of certain groups and the establishment of a smaller community that could manage the local landscape intensively. This later pattern was maintained until the abandonment of the site.

The ditched enclosure, unfinished in its southern part, resembles a 'work in progress' (cf. Stäuble 2014), with distinct segments constructed in different ways, perhaps by different 'clan' groups (Strien 2011). Its long-term subsequent use as a burial area suggests commemoration of a significant episode in the community's history linked with levels of nucleation that proved unstable.

2. What was the extent and nature of spatial variation in practice at Vaihingen, and how far does it correspond to the internal divisons of large LBK sites at different scales (farmstead, lineage or 'clan' groups, regional tradition groups)? Are other spatial patterns evident in specific datasets?

The built landscape of Vaihingen, particularly crowded in the Flomborn period, would have accommodated activity zones for individual longhouses of as little as c. 300–400 m^2, and crowding also constrained the orientations of longhouses, which do not show any clear chronological or spatial pattern. A social imperative of nucleation and supra-household identity is clearly implied by the settlement's layout, and dramatically underlined in the Flomborn period by a ditched enclosure that subsequently became an encircling burial ground. If crops were key dietary staples, as suggested by the palaeodietary analysis, it is plausible that a small-scale family would need around a hectare of arable land (Bogaard 2004, tab. 2.2), given that plots were intensively managed and productive as suggested by the archaeobotanical analysis. The ecological implication is that Vaihingen inhabitants placed more emphasis on collective security and supra-household groupings than on household-level territoriality in the productive landscape.

Between the scale of individual residential household and entire settlement, Strien's stylistic analysis of ceramic and lithic material culture has suggested the existence of house groups or 'clans' through the Flomborn period and, in a different configuration, during the later LBK sequence. Stone axe types and ceramic decorative motifs link these 'clan' groups to broader regional traditions: the Middle Neckar and Unterland / Kraichgau.

For an integrated bioarchaeological perspective on the salience of these various social 'scales', we begin at the large-scale end of the spectrum. Aside from material culture traits (stone axe types and ceramic decorative motifs) that link Vaihingen into regional networks, the bioarchaeological evidence discussed here presents remarkable evidence for active linkages and mobility between settlements. While the crop spectrum is generically similar across the western LBK, the astonishing metrical uniformity of cattle at Vaihingen

<table>
<tr><th colspan="2"></th><th></th><th>Wild fauna</th><th>Domestic fauna</th><th>Weeds</th><th>Special plants</th><th>Cattle grazing (Sr+O)</th></tr>
<tr><td rowspan="2">LATER</td><td rowspan="4">Middle Neckar</td><td>I</td><td>red deer</td><td rowspan="2">pig and cattle</td><td rowspan="4">high intensity</td><td>opium poppy</td><td rowspan="4">loess, valley and uplands</td></tr>
<tr><td>II</td><td>aurochs</td><td>feathergrass</td></tr>
<tr><td rowspan="5">FLOMBORN</td><td>A</td><td rowspan="2">red deer</td><td rowspan="2">cattle and pig</td><td rowspan="5"></td></tr>
<tr><td>D</td></tr>
<tr><td rowspan="3">Unterland/ Kraichgau</td><td>B</td><td rowspan="2">wildboar and aurochs</td><td rowspan="2">cattle and sheep/goat</td><td>?</td><td rowspan="3">loess</td></tr>
<tr><td>C</td><td>low intensity</td></tr>
<tr><td>E</td><td>aurochs</td><td>sheep/goat and cattle</td><td>?</td></tr>
</table>

Fig. 30. Summary of contrasts in land use practice between regional traditions and 'clan' groupings of longhouses at Vaihingen an der Enz.

and elsewhere attests to regular contacts and exchanges among LBK settlements. Given that the predominace of cattle keeping, most pronounced in the earlier part of the settlement's history, posed ecological challenges, it seems plausible that their value was at last partly linked to these exchanges among communities. The diet of Vaihingen inhabitants appears to have been heavily reliant on crops. Integrated stable carbon and nitrogen isotope analysis of humans, fauna and crops (cereals and pulses) at Vaihingen, plus internal analysis of the food chain based on amino acid compound-specific stable nitrogen isotope ratios, suggests that crops were a more important source of protein than meat / milk. Consumption of cattle and other livestock probably had a predominantly social and cultic importance, for example through sharing of meat among 'related' households or across the community (cf. Halstead 2007).

Figure 30 summarises the major strands of bioarchaeological evidence for differences between regional traditions and / or 'clan' groups at Vaihingen. In terms of hunted fauna, domestic fauna and arable ecology, there is clear evidence of cohesion at the level of the regional tradition. Thus, Clan groups A and D, of the Middle Neckar tradition, are linked with a preponderance of red deer hunting, pig as well as cattle keeping and well worked (proximate?) cultivation plots on basic soils. The Unterland / Kraichgau households of Clans B and C, by contrast, are linked especially with aurochs hunting and keeping of small ruminants alongside cattle. In terms of cattle grazing patterns, the Middle Neckar households made more use of river valleys and uplands bordering the local loess than the Unterland / Kraichgau families. The clear implication is that land use patterns – from cultivation to herding and hunting – were shaped by regional affiliation, and that the Middle Neckar households had some clear ecological advantages. It seems possible that these rights were linked with the founding of the settlement by Middle Neckar households. It is also notable that all of the human burials in the ditch appear to belong the 'local' Middle Neckar tradition (Bogaard et al. 2011).

Additionally, *figure 30* shows that Strien's Flomborn 'clan' groups had economic salience in some areas but not in others. 'Clan'-specific practice is evidenced by subtle differences in weed flora, which distinguish, for example, Clans A and D of the Middle Neckar tradition (see Bogaard 2011; Bogaard et al. 2011). On the other hand, Clan E of the

Unterland / Kraichgau tradition, originally defined by Strien in terms of an absence of distinguishing material culture traits, is associated with a distinctive emphasis on keeping of small ruminants. Clan E also differs from the other two Unterland / Kraichgau 'clans' in hunting practice, being linked with an emphasis on aurochs but not on wild boar.

Turning to the post-Flomborn 'clan' groups I and II, they are indistinguishable in terms of (high) cultivation intensity and keeping of pigs and cattle, but were linked with hunting of red deer and aurochs, respectively, as well as with opium poppy versus feathergrass, which were newly introduced plants in the late Flomborn.

The broad implication is that *both* affiliation to regional traditions *and* 'clan' grouping helped to shape subsistence practice at Vaihingen. Independent lines of bioarchaeological evidence converge on this conclusion and lend weight to Strien's original identification of sublte but persistent variations in material culture. More targeted sampling and analysis of Sr isotopes in cattle and human teeth from distinct house (and burial) groupings are needed to explore inter-group variability further.

In terms of sub-'clan' groupings and individual households, the scope for exploring bioarchaeological variation is limited by overlapping of features, such that only 11 out of 229 structures excavated at the site can be clearly delineated *(fig. 9)*. Nevertheless, archaeobotanical analysis has traced subtle differences in weed flora and hence arable growing conditions among households within Clan A (Bogaard 2011; Bogaard et al. 2011).

3. What light is shed by late LBK practices at Vaihingen on the ending of its occupation? Is there evidence of 'crisis'?

The combined evidence from Vaihingen suggests diachronic change in the social landscape without an ecological 'crisis'. The Vaihingen data attest to the existence of differentiated use of the landscape by contemporary longhouse groups, as well as to expansion and contraction of herding and arable catchments as the settlement grew rapidly in the Flomborn period and subsequently shrank in the later LBK. While the limited chronological resolution of the data could obscure short-term shifts in subsistence practice as documented in dendrochronologically dated Neolithic lakeshore sequences (for example Jacomet / Schibler 2010), it is apparent that no particular phases are associated with increased levels of hunting, which instead remain remarkably consistent throughout the occupation. The implication is that there were no lasting episodes of subsistence shift in response to climatic deterioration, notwithstanding wider regional evidence for change and perhaps collapse. The strains of increased nucleation in the Flomborn period were resolved by the departure of the Unterland / Kraichgau groups, while the existence of house groups with differentiated identities and activities throughout the occupation likely reflects particular 'communities of practice' that pooled resources to some degree. The latest features on the site are the very latest in the current Württemberg seriation (Strien 2011); there is no evidence to suggest an ecological cause for the end of the occupation.

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Abstract: The Bandkeramik settlement of Vaihingen an der Enz, Kreis Ludwigsburg (Baden-Württemberg): an integrated perspective on land use, economy and diet

In this paper we develop an integrated perspective on land use, economy and diet at the LBK site Vaihingen an der Enz, an extensively excavated settlement and cemetery of the early Neolithic (later 6th millennium cal BC). We synthesise the results of primary and stable isotope analysis of fauna, humans and botanical remains, interpreted in light of material culture variation across the settlement and through the occupation sequence. Our integrated approach reveals a dynamic relationhip between the changing scale and social geography of the community, on the one hand, and land use, on the other.

Zusammenfassung: Die Siedlung der Linearbandkeramik von Vaihingen an der Enz, Kreis Ludwigsburg (Baden-Württemberg): Eine Gesamtsicht auf Landnutzung, Wirtschaftsweise und Ernährung

Dieser Beitrag integriert diverse Ansätze zur Untersuchung der Landnutzung, Ökonomie und Ernährung des linearbandkeramischen Fundplatzes Vaihingen an der Enz, einer extensiv ausgegrabenen Siedlung mit Bestattungen des Altneolithikums (spätes 6. Jahrtausend cal BC). Wir synthetisieren die Resultate primärer und stabiler Isotopenanalysen an Fauna, menschlichen und botanischen Resten, die im Licht der Unterschiede in der materiellen Kultur innerhalb der Siedlung und im Verlauf der Nutzungszeit interpretiert werden. Dieser integrierte Ansatz lässt eine dynamische Beziehung zwischen der wechselnden Größe und sozialen Geographie der Siedlungsgemeinschaft einerseits und ihrer Landnutzung andererseits erkennen.

Résumé: L'habitat Rubané linéaire de Vaihingen-sur-l'Enz, Kr. Ludwigsburg (Bade-Wurtemberg): Une synthèse intégrative de l'exploitation du sol, de l'économie et de l'alimentation

Cet article intègre différents angles d'étude de l'occupation du sol, de l'économie et de l'alimentation du site de Vaihingen-sur-l'Enz, un habitat fouillé sur une grande surface avec des sépultures du Néolithique ancien (fin du 6e millénaire cal BC). Nous synthétisons les résultats des analyses isotopiques primaires et stables faites sur de la faune, des restes humains et botaniques. Ceux-ci sont par la suite interprétés à la lumière des différences qui se manifestent dans la culture matérielle de l'habitat et tout au long de l'occupation. Cette approche intégrative révèle un lien dynamique entre la grandeur fluctuante et la géographie sociale de la communauté d'une part et l'occupation du sol d'autre part.

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References of figures:
Figs 1–4: after Krause 2011. – *Fig. 5*: after Strien 2011, personal communication. – *Fig. 6*: after Bogaard et al. 2011. – *Figs 7–8*: after Strien 2011. – *Figs 9–10*: Ch. Krahn. – *Figs 11–19*: M. Schäfer and R.-M. Arbogast. – *Figs 20–21*: after Bogaard 2011. – *Figs 22–25*: after Knipper 2011. – *Figs 26–27*: after Fraser et al. 2013b. – *Fig. 28*: R. Ebersbach. – *Figs 29–30*: A. Bogaard.