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“Widely travelled people” at Herxheim? Sr isotopes as indicators of mobility

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+ Translation

Abstract

This paper presents the strontium (Sr) isotope composition of the teeth of Neolithic individuals from the Linearbandkeramik (LBK) pit-enclosure of Herxheim (South Palatinate, Germany). The Sr isotope analyses are vital for the comprehension of the extraordinary site of Herxheim with the abundant human bone modifications found there. The large number of dead individuals, as well as the various exotic styles of high quality

pottery of the latest LBK phase, found with the fragmented human skeletons, support movement from foreign places to Herxheim. Sr isotopes of tooth enamel have been analyzed to establish the possible origins of the individuals at Herxheim. Initial results for individuals found in the regular Bandkeramik burial position and for samples from a concentration of fragmented skeletons indicate the presence of a significant amount of nonlocal individuals, in a proportion higher than reported for other LBK settlements to date. None of the modified skeletal remains from the site investigated thus far belong to indigenous individuals. The observed Sr isotope ratios often indicate basement rock signatures. A subgroup of individuals has high $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of 0.712–0.715, suggesting similarities to a group of five juveniles found in the Neolithic settlement of Nieder-Mörlen/Hesse.

Keywords

Linearbandkeramik, Sr isotopes, ritual, cannibalism

Sr isotopes for LBK settlements in SW-Germany

Sr isotopes have been used for analysing prehistoric movement strategies for Central European communities since the 1990s (Price et al., 1994; Grupe et al., 1997). In the last ten years a number of LBK sites from south-western Germany have been the subject of isotopic research: Flomborn, Schwetzingen (Price et al., 2001), Talheim (Price et al., 2006), Stuttgart-Mühlhausen (Price et al., 2003), Dillingen (Bentley et al., 2002), Vaihingen (Bentley et al., 2003) and Nieder-Mörlen (Nehlich et al., 2009) (Fig. 1). Another LBK project of Sr sampling is still in progress (Bickle and Hofmann, 2007). These sites belong to different phases of the Bandkeramik culture. Samples have been taken from inhumation burials in cemeteries, settlement burials and from the mass grave of Talheim to analyse movement strategies and social relations of early farmers in Central Europe (e. g. Bentley, 2007; Price and Bentley, 2005). Herxheim can be related to and discussed in the framework of all these well-known LBK settlements.

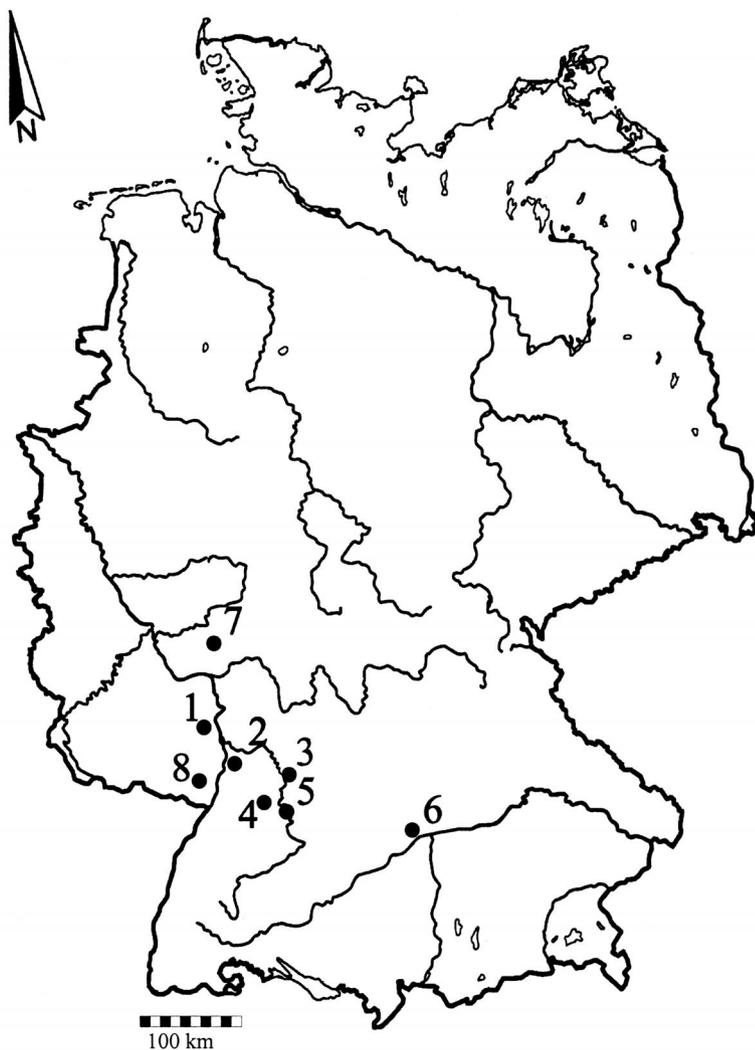


Fig. 1 | Bandkeramik sites with Sr isotope analyses in Southwest Germany. 1 Flomborn; 2 Schwetzingen; 3 Talheim; 4 Vaihingen; 5 Stuttgart-Mühlhausen; 6 Dillingen; 7 Nieder-Mörlen; 8 Herxheim (GDKE Rheinland-Pfalz, Direktion Landesarchäologie, Außenstelle Speyer)

Overview: features and findings of Herxheim¹

The site of Herxheim represents an early Neolithic settlement, inhabited from the older Bandkeramik (Flomborn-phase, ca. 5300 BC) up to the end of the culture in Central Europe (ca. 4950 BC). The village was surrounded by an earthwork of two parallel structures which consist of many overlapping oblong pits (Fig. 2). The pits were obviously rather quickly refilled and new pits, cutting the filled ones, were dug continuously (Schmidt, 2004; Haack, 2009). This type of “pseudo-ditch” is called the “Rosheim type” (Jeunesse and Lefranc, 1999). Many of the overlapping pits of the Herxheim enclosure revealed spectacular concentrations of dissected human skeletons, the bones having been smashed into small frag-

¹ Since 2004 the site is examined in the framework of a project funded by the Deutsche Forschungsgemeinschaft (DFG). The project members constitute an international team of specialists: Andrea Zeeb-Lanz (project director), Bruno Boulestin, Anne-Sophie Coupey, Silja Bauer (anthropology), Christian Jeunesse, Anthony De-

naire (pottery analyses), Fabian Haack (feature analyses, bone artefacts), Rose-Marie Arbogast (archaeozoology), Dirk Schimmelpennig (stone artefacts), Rouven Turck (isotope analyses), Nicole Boenke (archaeobotany) and Samuel van Willigen (correspondence analyses of pottery).

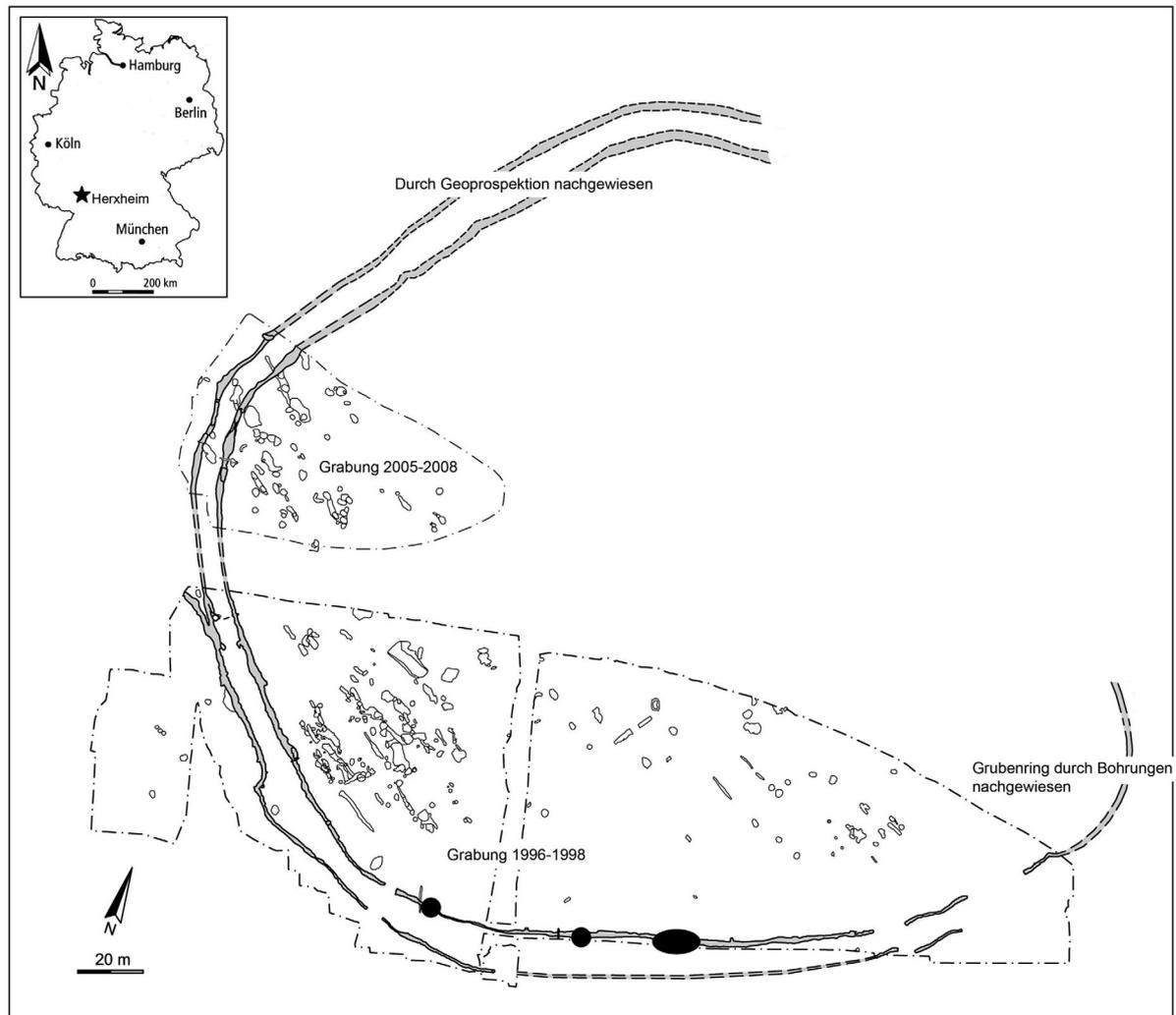


Fig. 2 | Herxheim. Plan of the pit enclosure and the excavated settlement areas with designation of the sampled teeth from Concentrations 2 and 3 (black ellipse) as well as the two “Hocker” burials in their concentrations which were sampled also (black dots) (GDKE Rheinland-Pfalz, Direktion Landesarchäologie, Außenstelle Speyer)

ments (Zeeb-Lanz et al., 2007; Boulestin et al., 2009; Zeeb-Lanz et al., 2009). The skulls of the dead had been subjected to a specific treatment that left only the skull caps intact. In addition to these manipulated human remains, the concentrations contained quite a lot of high-quality pottery with elaborate decoration (Zeeb-Lanz et al., 2006; Jeunesse et al., 2009) from the last phase of the Bandkeramik culture. The pots had obviously also been intentionally smashed before being deposited in the pits (Denaire, 2009). Furthermore the concentrations revealed partly destroyed stone tools, crushed grinding stones and a variety of animal bones, animal bone tools and jewellery made from shells and snails, as well as animal and human teeth (Arbogast, 2009; Zeeb-Lanz et al., 2007).

These extraordinary concentrations, comprising the battered remains of hundreds of human individuals, have given rise to much speculation and various hypotheses about their origin. The violent destruction was initially interpreted as an indicator of mass murder and warfare at the end of the LBK culture (e.g. Spatz, 1998; Golitko and Keeley, 2007). An economically critical situation, resulting from

climate aggravation, hunger and diseases, was discussed as a possible reason for such a crisis. Initial examinations of diet and bones at Herxheim (Dürrwächter et al., 2003, 2006; Haidle and Orschiedt, 2001; Orschiedt and Haidle, 2009) disproved these ideas: there were no indicators of hunger, diseases and malnutrition or regular injuries of violence leading to death detected. The concentrations in the double pit enclosure of Herxheim are associated with a previously unknown extraordinary and violent ritual. It is possible that that ritual was triggered by a specific form of socio-cultural crisis which might perhaps be described as a “crisis of mind” (Zeeb-Lanz, 2009). The manipulation of the human bones attests to a systematic dismemberment of the bodies in a fresh state. This standardized treatment has recently been interpreted as an indicator of a special form of cannibalism integrated into the mysterious rituals (Boulestin et al., 2009); a specific ceremony including the strict dissociation of the perishable and nonperishable parts of the dead bodies has also been considered (Zeeb-Lanz et al., 2009).

Altogether, the remains of about 500 or even more individuals have been excavated. This extremely high number of dead individuals contrasts with the situation in normal LBK burial grounds (Nieszery, 1995). The estimate is based on the number of skulls, skull caps or fragments of skull. Various studies (c.f., Lüning, 1991) have shown that such an extraordinary number of people cannot have lived at the site in the small span of 50 years estimated from the dating of the pottery.

In addition to the human bones, the pottery deserves special attention. All the decorated ceramic from the concentrations dates to the final phase of the LBK – but it is unlikely that all of the vases come from the site itself or the vicinity (Zeeb-Lanz et al., 2006). The vessels exhibit eight different regional styles of decoration, e.g. the Rhine-Main hatching style, some from as far away as the Elbe valley (Šarka style) or the Elster-Saale region (Houbre, 2007). Recent attempts to fit together fragments of pots found in the same pit or from different concentrations (Denaire, 2009) revealed that the pottery was destroyed on site, probably as part of the supposed ritual. In some cases, sherds which could successfully be re-fitted were found in concentrations that lay rather far apart (up to 120 m).

The range of decorative styles hints at origins of the pottery in quite a lot of different regions north and east of Herxheim.

Some years ago, investigations of stable isotopes (C, N) of bone material from the pit enclosure at Herxheim were carried out by C. Dürrwächter and colleagues (2003, 2006), who were investigating diets. Those authors discussed the origin of the Herxheim individuals in the context of migration from distant places (Dürrwächter et al., 2003; Dürrwächter et al., 2006).

Basically N and C isotopes do not directly pertain to mobility but instead shed light on dietary variation. But in the case of Herxheim it might be possible that the varying N isotope ratios reflect differences in nutrition due to the derivation of deposited individual from varying macroregions. Thus the data might be seen as indirectly pointing to people originating in different regions.

There are several arguments for the origin of quite a number of the Herxheim individuals in foreign places:

1. At least 500 individuals were deposited in the concentrations of the pit enclosure within a rather short time span.
2. The area of the settlement is not large enough to have housed hundreds of people in the short time span of about 50 years (latest phase of the LBK; the pottery in the concentrations dates the events leading to the concentrations to this phase).
3. The associated pottery exhibits decorations in many regional styles, some of which clearly derive from distant geographical areas.
4. Some of the measured nitrogen-isotope ratios may not be compatible with indigenous diets.

The suggested migration of so many Neolithic individuals to Herxheim leaves the question of their specific places of origin open. The use of Sr isotopes represents a promising approach to set limits on the range of possible geographical districts involved. Sr isotope ratios of the skeletal remains may help to provide evidence of the presence of strangers in Herxheim; it can tell us whether local people were also deposited in the pit system, and it may help to identify different places of origin among the individuals studied.

A small number of regular Bandkeramik graves in the settlement area inside the pit enclosure which follow the usual pattern of LBK inhumation burials have been documented (Orschiedt, 1998). In those cases, the dead were placed in rectangular grave pits in a crouched position, the legs flexed – the so-called “Hocker” burial (Fig. 3). In a few cases, pits dug into the sides of some of the enclosure features revealed additional regular inhumation burials. A small number of skeletons in different concentrations of the pit enclosure constitute torsos, still showing vertebrae of the spinal column in articulation and connected to the skull. In other cases parts of the spinal column are still in the anatomical position and linked to the pelvis. Whole extremities like arms with hands or legs with feet exist as well. There are also various states of bone preservation represented in the concentrations. Some concentrations revealed “nests” of skulls, others consisted of mostly unbroken long bones, but the predominant picture is that of massively fragmented bone material. Jawbones and their fragments are relevant for Sr investigations, as tooth enamel is needed for the isotope analyses.

It must be emphasized that overall the features in the pit enclosure present a consistent picture. Human bones, as well as artefacts like pottery and stone tools, were systematically destroyed and deposited in the enclosure. But neither the amounts of bones and artefacts and their distribution nor the size of the concentrations follow a discernible pattern with respect to associations of finds. Moreover, the degree of destruction of the human bones varies markedly (Zeeb-Lanz et al., 2007). In the face of the above mentioned facts, two concentrations which have already been published (Zeeb-Lanz et al., 2007) were chosen for this paper. They act as representatives for the much larger number of sampled individuals from the site. They provide a representative cross-section with respect to the finds and exhibit good preservation of the tooth material.

The archaeological features

A total of five individuals could be sampled from the human remains in two concentrations, from the excavations in 1996–1998 (Fig. 4). An additional individual (HXM 14) cannot definitely be assigned to a specific concentration. Two of the samples presented in this paper were taken from the only two intact skeletons in flexed position which can, due to their association with pottery sherds, skull caps and battered human bones, chronologically be connected to the “concentration horizon”. Two recent radiocarbon dates from these skeletons (Zürich ETH-39377: 5220–4930 cal BC; Florida Beta-265223: 5220–5000 cal BC) confirm this assumption. The remainder of bone material of the concentrations to which these skeletons can be linked has not yet been analyzed in detail.

Concentrations 2 and 3, which provide most of the isotope ratios discussed here, lie in the southern part of the inner pit ring and have already been published in detail (Zeeb-Lanz et al., 2007; Haack, 2009). Concentration 2 lies approximately 0.20 m above the base of a long pit, containing the remains of at least four individuals. Among these are the mandible of an adult and the fragmented lower jaw of a child, both of which could be used for sampling (HXM 16, HXM 17). In the concen-



Fig. 3 | Complete skeleton in flexed position (“Hocker”) in a concentration (Sample HXM 39) GDKE Rheinland-Pfalz, Direktion Landesarchäologie, Außenstelle Speyer

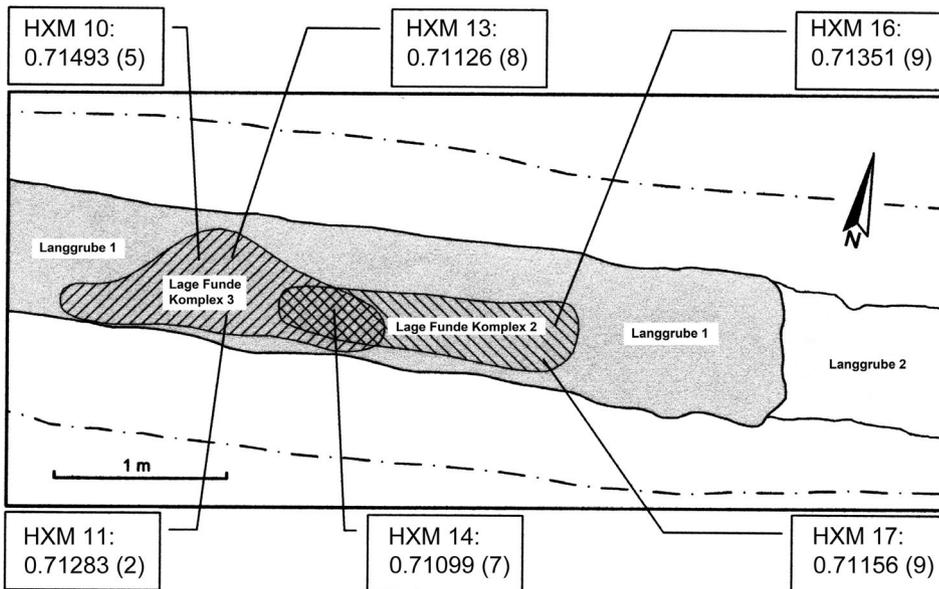


Fig. 4 | Graphic rendering of the main level of the find situation in Concentrations 2 and 3 (after Zeeb-Lanz et al., 2007)

tration, which lies in a conglomeration of soil reaching a thickness of up to 0,25 m, some articulated human remains are also present, including the bones of a hand, a foot and the lower part of a spinal column attached to the pelvis. In general the skeleton parts appear to be less degraded in this concentration than in other areas of the pits, as a few larger segments of long bones and completely intact bones were excavated.

Also found in the concentration with the human remains were three small fragments of decorated pottery of indeterminate regional style, the larger part of a vase ornamented in the style of the Palatinate

and, especially conspicuous, two refittable fragments from the bottom of a pot ornamented in the Rhine-Moselle style (Fig. 5). In addition to these pottery sherds, Concentration 2 revealed six flint artefacts, two fragments of grinding stones and part of a bone tool. The mottled skull of a dog and piece of deer antler are further proof that the established pattern of the animal bones in the concentrations is not part of the normal butchery waste (Arbogast, 2009).

Concentration 3 is situated 0.40 m higher than Concentration 2 and runs further to the east; it is separated from Concentration 2 by a massive layer of charcoal. Seven human individuals could be identified in this concentration (Zeeb-Lanz et al., 2007), three of which provided teeth adequate for sampling (HXM 10, HXM 11, HXM 13). Fragments of skulls represent nearly half of all the human remains in this concentration and are thus explicitly overrepresented. Two skull caps, characteristic finds in the concentrations of Herxheim, are included in the human remains. In addition to two pottery sherds decorated in the Palatinate style and two undecorated fragments from storage pots, two pieces of a pot ornamented in the “Leihgestern” style, common in the Hessian region north of the Main, belong to the corpus of finds from Concentration 3 (Fig. 5).

Concentration 3 also featured a flint blade and two flint flakes, a grinding stone and a bone scraper. At least four cattle are represented by a small number of vertebrae, skull fragments and parts of a few long bones.

The two whole human skeletons were also found in concentrations in the inner pit ring (see Fig. 2). Sample HXM 39 was taken from the tooth of a human individual found lying on its back with extremely bent legs (Fig. 3). The skeleton lay along the long axis of the pit ring in an east–west direction, face to the north.

The second complete skeleton (HXM 40) was excavated around 50 m east of the first. The skeleton, likewise placed in the concentration in a flexed position, also followed the orientation of the pit enclosure. While similar in orientation to the individual from Concentration 2, with the head in the east, this skeleton lay on the other side, face to the south. Both of the skeletons represent men over 30 years of age at death.

Samples and methods

The samples discussed in this article were taken from dental enamel. It is generally accepted that dental enamel is the most reliable archive and best suited for the identification of bioavailable Sr components. The series of selected samples focuses on the first molars of various individuals. The first molar is developed during the early infancy. The composition of the enamel does not change during the lifetime of the individual, which means that the Sr isotope values of the first molars reflect the environments of the individuals during the first two years of their life (Knipper, 2004; Bentley, 2006). The differentiated analysis of the teeth led to the exclusion of some individuals as their teeth did not preserve any suitable enamel. The loss of tooth enamel due to chewing abrasion as well as to diagenetic phenomena after burial excluded further individuals from sampling. In the end only six of the ten fragmented jaws from the two concentrations could be analyzed (see Zeeb-Lanz et al., 2007).

Routine procedures were applied for Sr isotope analysis using thermal ion mass spectrometry (TIMS). To avoid the mixing of enamel with dentine, we used a new method of tooth cutting and drilling. This modified procedure of sample preparation yields high precision and accuracy of analysed Sr isotope ratios. More details of the procedures will be published shortly (Kober et. al., submitted paper).

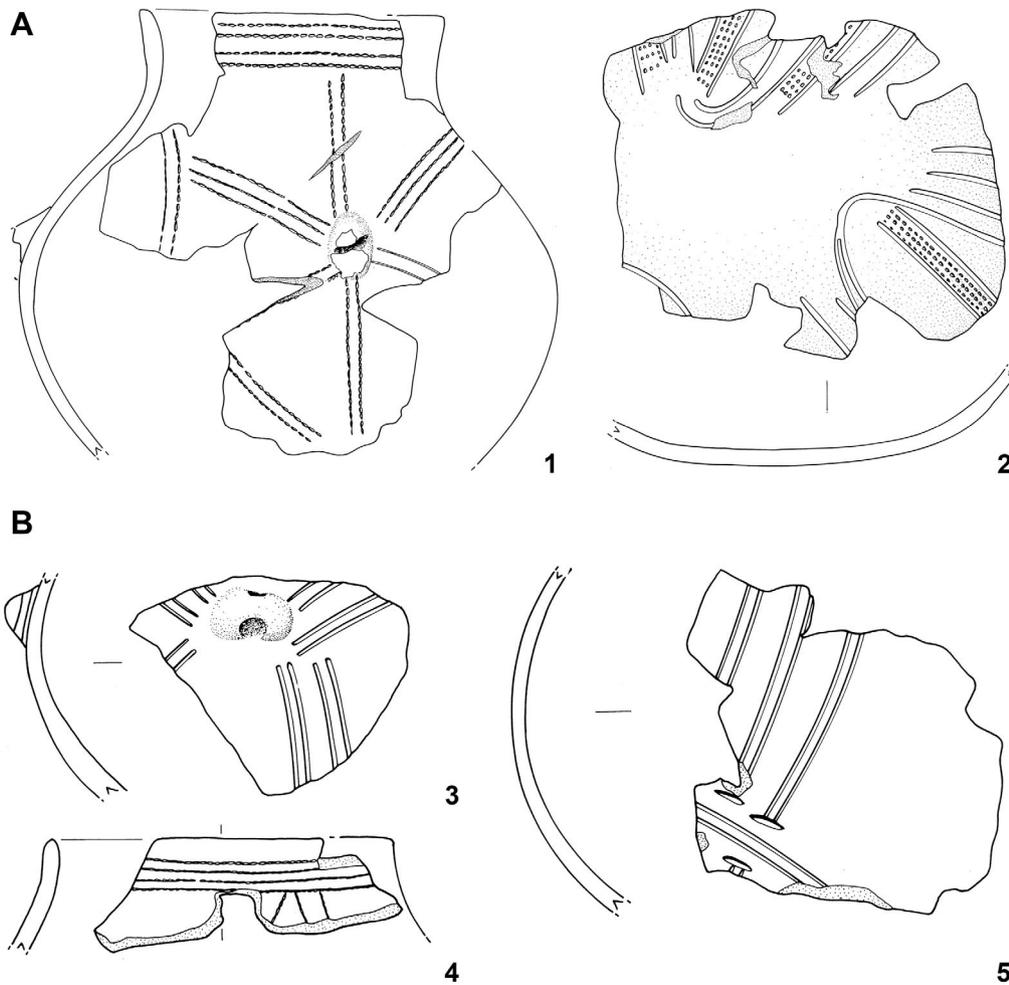


Fig. 5 | Pottery from Concentration 2 (A) and Concentration 3 (B). 1, 4 local style of the Palatinate; 2 Rhone-Moselle-style; 3, 5 Style "Leihgestern". 1, 2 scale 1:3; 3-5 scale 1:2 (GDKE Rheinland-Pfalz, Direktion Landesarchäologie, Außenstelle Speyer; after Zeeb-Lanz et al., 2007)

Local loess from the site was analyzed in order to estimate the biologically available Sr isotope ratio (e.g. Bentley et al., 2004) in the Herxheim area. In addition, some animal teeth found in the pits were analysed. In addition to the animal teeth, human teeth were selected for analysis from places situated in the southern part of the enclosure. Some of the human teeth were sampled from isolated jaws, a few others from whole skeletons found in the normal crouched burial position, but integrated in concentrations with skull caps and smashed long bones.

First results of Sr data

The results from animal teeth indicate local $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of about 0.7095 which are interpreted as the bioavailable Sr isotope ratio in the Neolithic Herxheim environment. The mean enamel $^{87}\text{Sr}/^{86}\text{Sr}$ value from animal teeth is 0.70953 ± 0.00008 (1 σ). The local range is defined using the 95% confidence level

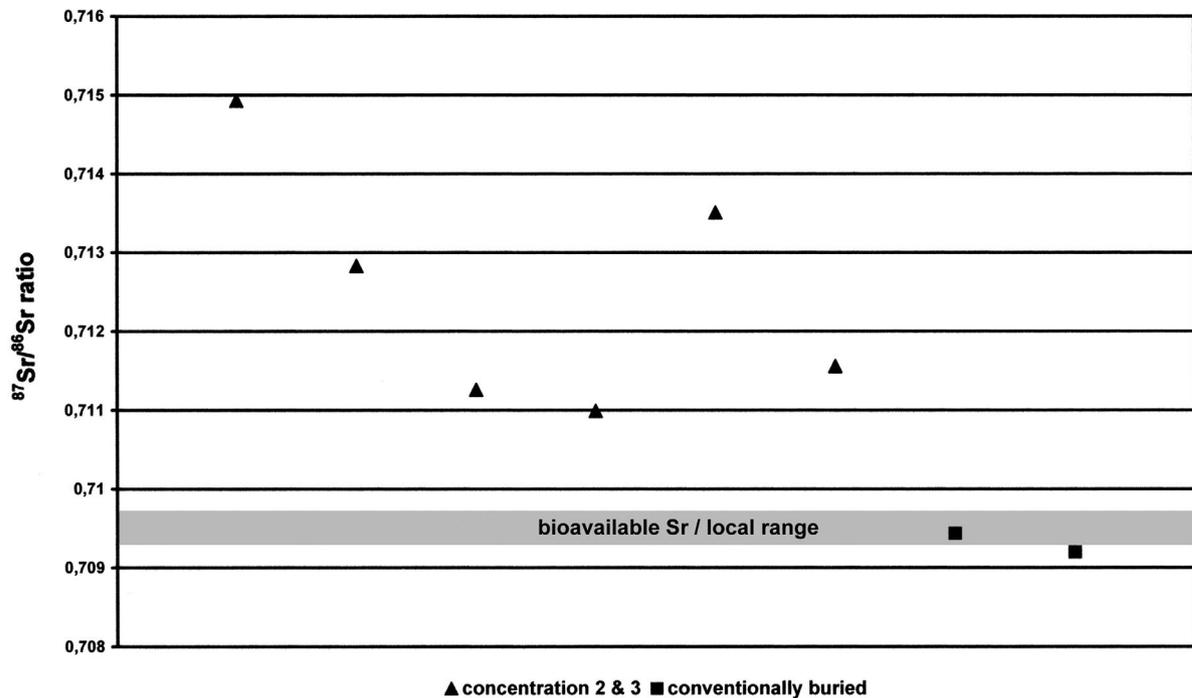


Fig. 6 | Plot of $^{87}\text{Sr}/^{86}\text{Sr}$ values of Herxheim individuals (GDKE Rheinland-Pfalz, Direktion Landesarchäologie, Außenstelle Speyer)

Table 1 | $^{87}\text{Sr}/^{86}\text{Sr}$ values from enamel samples of the first molar (M1) of the individuals from the Concentrations 2 and 3 from Herxheim and from two whole skeletons in flexed position in the upper level of two further concentrations (GDKE Rheinland-Pfalz, Direktion Landesarchäologie, Außenstelle Speyer & Institut für Geowissenschaften Universität Heidelberg [B. Kober, J. Kontny])

Sample	Jawbones	$^{87}\text{Sr}/^{86}\text{Sr}$ ratio	Context	Age	Sex
HXM 10	Mandible	0.71493 (5)	Concentration 3	infans	?
HXM 11	Mandible	0.71283 (2)	Concentration 3	adult	?
HXM 13	Maxilla (fragment)	0.71126 (8)	Concentration 3	juvenile	?
HXM 14	Mandible (fragment)	0.71099 (7)	Concentration 2 or 3	infans	?
HXM 16	Mandible	0.71351 (9)	Concentration 2	adult	?
HXM 17	Mandible (fragment)	0.71156 (9)	Concentration 2	infans	?
HXM 39	Mandible	0.70944 (9)	Complete skeleton, Concentration	adult +30 years	male
HXM 40	Maxilla (fragment)	0.7092 (1)	Complete skeleton, Concentration	adult +30 years	male

(20): 0.70937 to 0.70969 (Fig. 6). These values are consistent with data from Schwetzingen and Flomborn though wider local ranges were determined (Price et al., 2001), and with a few single data collected by Bentley and Knipper (2005) in the vicinity of the Rhine Valley.

There is a systematic difference in the analyses between tooth samples from concentrations of skeletal remains which had been smashed and fragmented and tooth material from conventionally buried individuals. The tooth enamel from individuals with skeletal modifications yielded $^{87}\text{Sr}/^{86}\text{Sr}$

values above 0.711 (Fig. 6; Table 1). Some of the samples even showed values of 0.7128 to 0.715. These high values indicate that the respective individuals must have passed their childhood and youth on geological contexts different from loess and lowland areas like the Rhine valley. Most of the data are compatible with highland areas and outcropping crystalline basement rocks (e. g. Aubert et al., 2002; Kober et al., 2007; Ufrecht and Hölzl 2006; Tichomirowa et al., 2010). Three measurements (HXM 10, 11, 16) yield significantly higher $^{87}\text{Sr}/^{86}\text{Sr}$ ratios than nearly all other published Sr data for Bandkeramik individuals (e.g. Price and Bentley, 2005). Lower $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (HXM 13, 14 and 17) may also be compatible with Sr components released from Triassic sandstones. Taken as a whole, the rather high but variable Sr isotope ratios, all of them above the bioavailable Herxheim value of 0.71, indicate that these individuals migrated to Herxheim from distant places. However, further data are needed to identify the different groups among the migrants based on the Sr isotopes on a more detailed level.

Mountainous regions are so far not known as Bandkeramik settlement areas. This appears to be in contradiction to the observed high $^{87}\text{Sr}/^{86}\text{Sr}$ ratios of the teeth from the Bandkeramik individuals of Herxheim. However, recent studies (Valde-Nowak and Kienlin, 2002; Ramminger, 2006; Knipper et al., 2007) have indicated a possible LBK presence in these terrains. Further intensive surveys to monitor possible mountainous Bandkeramik sites are required. Our current knowledge about LBK settlements is that most of the villages lie on – or at least on the border of – areas with loess substrate. The idea of fields for agriculture situated far away from the settlements – and in totally different geographical areas – does not appear convincing at the present time (Lüning, 2000; Bogaard, 2004). A. Heier and colleagues (2009) have shown that carbonized grain Sr isotope analyses may have a high potential for the determination of the areas of agriculture and for the discussion as to whether the prehistoric settlements were supplied with local field crops or with grain from distant areas.

One might speculate that groups of LBK people (among them children and juveniles) left their lowland settlements seasonally, e.g. for pasture in mountainous regions (e. g., Bentley et al., 2004; Knipper, 2009). In the uplands, they would have ingested highland diets with basement-type isotope signatures and elevated $^{87}\text{Sr}/^{86}\text{Sr}$ ratios. This hypothesis has important implications; for example, long term transhumance would have had to include very young children and childbearing women, as the analyzed teeth derive from the earliest childhood of the sampled individuals.

It is an important fact that one individual (HXM 39), who was buried “regularly” in a “Hocker” position, revealed Sr data that is compatible with the Sr isotope composition we have identified as Herxheim local reference value (~ 0.7095). The second one (HXM 40) is also compatible with sediments of the Rhine Valley but probably not from Herxheim. However, this is not yet a database sufficient for the conclusion that the conventionally buried individuals in Herxheim were generally indigenous persons. But definitely the present set of available Sr isotope data supports the thesis that the individuals who migrated to Herxheim had different places of origin – and it suggests a systematic pattern: it seems that all individuals whose skeletons have been modified were nonlocals.

Various available Sr isotope data sets for LBK sites in southwest Germany (see above and Fig. 1) can be used to discuss the data from Herxheim. A direct comparison of cemeteries and settlement burials with the situation in Herxheim is difficult and has to be done with care, due to differences of local development and functions of the various places and their dating. However, from the available data in the literature it is evident that in nearly every investigated LBK settlement or cemetery there were some potentially nonlocal individuals with $^{87}\text{Sr}/^{86}\text{Sr}$ ratios elevated compared to the typical local Sr isotope compositions (e. g. review of Price and Bentley, 2005).

Consequently, the observation of Early Neolithic people with high mobility seems to be rather typical, especially for early LBK people (Bentley, 2007). Obviously these strangers were integrated into Bandkeramik communities and also buried in accordance with the local traditions. Herxheim definitely differs from other sampled sites insofar as here, nonlocals were the subject of violent ritual actions, possibly even cannibalism (Boulestin et al., 2009). High maximum $^{87}\text{Sr}/^{86}\text{Sr}$ ratios comparable to the ones at Herxheim (especially samples HXM 10, 11, 16) are reported for only one of the reference sites, Nieder-Mörlen in Hesse (Nehlich et al., 2009). Isotope studies in Central Europe have so far revealed only a small number of individuals with very high radiogenic data. Usually either an origin from mountainous areas is supposed or the diet of these individuals is interpreted as having had a specific relation to such regions (e. g. Schutkowski, 2002; Müller et al., 2003; Heyd et al., 2005; Price and Bentley, 2005; Schweissing, 2005; Haak et al., 2008). All other places show $^{87}\text{Sr}/^{86}\text{Sr}$ ratios between 0.7083 and 0.710, with only a few values in the range of 0.710–0.712. The observed range of $^{87}\text{Sr}/^{86}\text{Sr}$ values in Herxheim is markedly higher. The data sets of Nieder-Mörlen and Herxheim are unique among the rest of the Neolithic locations. Nieder-Mörlen dates from the older to the youngest phase of the LBK (e. g. Schade-Lindig 2002; Schade-Lindig 2003). The concentration of the maximum $^{87}\text{Sr}/^{86}\text{Sr}$ values from Herxheim verified to date, at about 0.7128–0.715, appears very similar to values for a subgroup of five Nieder-Mörlen individuals (Nehlich et al. 2009), buried in the settlement. It suggests that certain groups of individuals who lived during their childhood in areas with similar crystalline rock-type isotope signatures can be identified in both sites. These subgroups can be classified as nonindigenous individuals for both sites on the basis of their similar and rather well-defined homogeneous Sr isotope composition ($^{87}\text{Sr}/^{86}\text{Sr} \sim 0.714\text{--}0.715$) and from archaeological arguments (Nehlich et al. 2009). Nehlich and colleagues report that all five members of this subgroup of Nieder-Mörlen were juveniles and children, meaning that they were far away from their original living space when they died in Nieder-Mörlen – none of them surviving to adulthood. Nehlich et al. discuss possible places of origin of these nonlocal adolescent individuals, proposing areas like the Bavarian Forest and the Black Forest (Bentley and Knipper, 2005; Schutkowski, 2002), as well as North and South Tyrol (Hoogewerff et al. 2001; Müller et al. 2003) where there are outcroppings rocks with Sr isotope ratios that match the human enamel Sr isotope compositions.

Nehlich and colleagues also discuss the possibility of transhumance for these juveniles. Following this hypothesis, even small children – presumably with their mothers – would have been taken to the mountains for herding. Naturally there is also the possibility that these children and adolescents came from mountainous regions (Taunus area?) to Nieder-Mörlen and died there (Nehlich et al., 2009). Whether they might have been slaves or war prisoners or whether friendly reasons were responsible for their residence in Nieder-Mörlen cannot be determined either by archaeological or from natural science methods. The individuals from Nieder-Mörlen were obviously integrated in the community as they were buried in the usual way for LBK people. Obviously, the possibility of certain groups of Bandkeramik people who lingered for longer periods in the mountains – or even had their domiciles there – during different phases of the LBK must be considered. Apparently these groups left few or no material traces. At least we can conclude from the available LBK isotope analyses that a higher proportion of younger people seem to have come from foreign, mountainous places to Bandkeramik settlements and died there.

For Herxheim, these implications raise the question whether the Neolithic migrants belonged to the LBK, to some other Neolithic/Mesolithic population or instead to LBK subgroups that have not yet been detected. The observed pottery styles suggest source areas which do not fit with the upland-type Sr

isotope signatures. These signatures cannot be attributed to the Sr isotope compositions that have been reported for various LBK settlements so far.

Conclusions

The first set of investigated teeth, collected from animal remains found in the enclosure and in settlement pits, were suitable to estimate the average Sr isotope composition of bioavailable strontium in the palaeoenvironment of Herxheim. This reference isotope composition agrees well with data reported for other Neolithic settlements in the Rhine valley. The currently available Sr isotope data are adequate to distinguish between remains of local and nonlocal individuals. Our first series of Sr isotope data shows a clear distinction between tooth material from individuals with modified skeletons from the concentrations of the pit enclosure and tooth material from conventionally buried individuals.

The Sr isotope composition of tooth enamel from two individuals who were buried in regular LBK fashion matches the local Herxheim composition and lowland areas well, although their skeletons were found in close vicinity to concentrations of fragmented human remains. All of those individuals investigated whose bones were fragmented could be identified as nonlocal persons. Their native places are characterised by sandstone or crystalline rock in upland areas. This rather large group of Early Neolithic people with clear associations with mountainous homelands is yet unknown for LBK times, with the exception of Nieder-Mörlen and a very few individuals from regular cemeteries. We suspect that during Early Neolithic times there may have been people who continuously have resided in mountainous areas – e.g. for herding or mining. In the majority of cases these people were not buried in the cemeteries or settlements that have been investigated thus far, or their skeletal remains were generally not preserved at their home areas for other reasons.

We have found significant variation of the enamel Sr isotope ratios, which we interpret as indicators of different native places of the dead who were deposited in the concentrations of Herxheim. This observation would seem to be compatible with the various latest LBK pottery styles documented at the location. On the other hand, the individuals represented by manipulated skeletal remains in the concentrations definitely grew up in highland areas. A mountainous origin, however, cannot be assumed as the source of the richly ornamented pottery found with the fragmented skeletons. In fact there is an obvious discrepancy between the Sr isotope values of the dead and the ornamented LBK pottery. At the moment it would seem that the manipulated dead are not connected to the ceramic finds in the concentrations. It will be necessary to consider the various possible explanations for these contradictions and followed them up during the further analysis of the site, its features and findings.

Prospects

It is essential that more data be collected – including data from stable isotopes – from a variety of geological formations, biologically available local strontium and different sites, in order to reach a point where widespread and reliable comparison can give us the chance to formulate more definite hypotheses concerning the origin of inhabitants of LBK settlements as well as those who are found in cemeteries of this culture.

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