

## A ZOOARCHAEOLOGICAL AND TAPHONOMIC PERSPECTIVE OF HOMININ BEHAVIOUR FROM THE SCHÖNINGEN 13II-4 “SPEAR HORIZON”

### *Abstract*

The Schöningen 13II-4 “Spear Horizon” is among the most famous lakeshore archaeological sites dating from the Middle Pleistocene in Europe. Multiple well-crafted wooden spears recovered together with a large assemblage of butchered horse bones at Schöningen stimulated a new outlook of the behavioural capabilities of Palaeolithic hunters. Since these discoveries, a wealth of geological and palaeoecological data have been generated to reconstruct the wider Schöningen interglacial lakeshore environment. Yet, the underlying social and economic behaviours of Middle Pleistocene hominins reflected in the archaeological record itself have received less attention. To address these shortcomings, we began a comprehensive zooarchaeological and taphonomic analysis of the entire large mammalian assemblage from the Schöningen 13II-4 “Spear Horizon”, with the goal of re-focusing attention to the “human component” of this important site. Here we present the preliminary results of our research.

### *Keywords*

Schöningen, Middle Pleistocene, zooarchaeology, taphonomy, bone tools, spatial analysis, site formation

### **Introduction**

The Schöningen 13II-4 site came to prominence in the late 1990s with the discovery of multiple wooden spears preserved alongside a large collection of butchered horse remains and small lithic assemblage (Thieme 1997). Dubbed the “Spear Horizon”, the site represents one of many Middle Pleistocene interglacial localities unearthed from ancient lakeshore sediments at the open cast lignite mine near the town of Schöningen in Lower Saxony, Germany (fig. 1). Geologically, the stacked interglacial deposits within the Schöningen complex of

sites formed within an Elsterian tunnel valley and reflect fluctuations in the levels of the Schöningen palaeolake, which was fed by small streams flowing from the nearby Elm ridge (Lang et al. 2012; 2015). Recent radiometric dating ( $^{230}\text{Th}/\text{U}$ ) yielded an age of  $290 \pm 5$  ka (Sierralta/Frechen/Urban 2012), and thermoluminescence data suggest a maximum age of  $321 \pm 16$  ka (Richter/Krbetschek 2015). Together, these dates place the “Spear Horizon” within Marine Isotope Stage 9. The interglacial character of the deposits is further documented by numerous pa-



**Fig. 1** Map showing the location of Schöningen in Lower Saxony, Germany, and photograph showing an overview of the current excavations at Schöningen 13II with the open cast mine in the background.

lynological (e.g. Urban 2007; Urban/Sierralta/Frechen 2011; Urban/Sierralta 2012; Urban/Bigga 2015) and biogeographical studies (e.g. van Kolfschoten 2012; 2014). Further geological and palaeoecological data collected from various locations across the open cast mine record the development of the wider Schöningen lakeshore landscape over time (see Behre 2012, and references therein; see also Serangeli et al. 2015).

Since the spears were first uncovered, several competing hypotheses regarding their association with the large assemblage of butchered horse remains have been proposed:

a) Single hunting event: *"...Schöningen II is indeed the product of a single event, a successful interception of a complete herd of wild horses that moved along the shoreline of the lake"* (Thieme 2005, 130);

b) Multiple hunting events: *"...multiple horse kill/butchery events are represented in the Schöningen 13II-4 horse assemblage"* (Voormolen 2008, 128); *"The different lines of available evidence indicate... that the fossil assemblage might correspond to an accumulation of multiple events"* (Julien et al. 2015b, 126);

c) Single hunting events and background accumulation: *"The number of [horse] carcasses is be-*

*tween 20 and 25... the minimum number of individuals at the entire site is 46... part of the fossil horse remains should be regarded as natural 'background' accumulation not related to the accumulation of the carcasses of the 20-25 horses"* (van Kolfschoten 2014, 476).

Consistent among these hypotheses is a dual hunting and butchery site situated along the former Schöningen lakeshore. These conclusions, however, are based on observations from a limited sample of the faunal assemblage, with little reference to the cumulative taphonomic factors leading to site formation or spatial arrangements of artefacts across the expansive excavation. The excellent preservation of organic remains within the "Spear Horizon" offers a wealth of possibilities to reconstruct Middle Pleistocene hominin behaviour at a fine scale. A synthesis of Middle Pleistocene hominin activities focusing on the large and extraordinarily well-preserved faunal assemblage recovered from this important site has been lacking until only recently (see Conard et al. 2015, and references therein).

Here we introduce preliminary results of an ongoing investigation of the complete large mammal faunal assemblage from the Schöningen 13II-4 "Spear Horizon" and offer a critical evaluation of the various single and multiple hunting event hypotheses.

Combining a zooarchaeological and taphonomic approach with a GIS-based spatial analysis, we present a holistic view of the site that highlights the “human component” to the Schöningen landscape. With traces of hominin activities as our chief concern, we explore aspects of species representation, bone surface modifications, skeletal part abundances, mortality profiles and seasonality, all from a spatial perspective, to reconstruct the biostratigraphic chain of events that led to the creation and preservation of this unique archaeological record of Middle Pleistocene hominin behaviour.

## Materials and Methods

For the first time a comprehensive zooarchaeological and taphonomic analysis is planned for the entire large mammalian faunal assemblage from the Schöningen 13II-4 “Spear Horizon”. Included for study are all bone specimens excavated between 1994 and 2008 under the direction of Hartmut Thieme and the Niedersächsisches Landesamt für Denkmalpflege. The ca. 3900 m<sup>2</sup> excavation yielded an initial estimate of 25,000 large mammalian faunal remains (Thieme 1997; 2005; 2007; Voormolen 2008), but that total likely reflects conjoinable fragments broken during excavation, processing and storage. Our estimates of the entire faunal assemblage place the total closer to 15,000 specimens, which is in agreement with other assessments (van Kolfschoten 2012; 2014). Taxonomic descriptions and taphonomic summaries of 7946 larger mammal specimens were recently published by van Kolfschoten/Buhrs/Verheijen (2015). Voormolen (2008) provides a more detailed taphonomic analysis, but only studied 4626 remains from a limited spatial extent. The small bone assemblage from the nearby Obere Berme (see Starkovich/Conard 2015), which is thought to represent a southern extension of the “Spear Horizon”, is not included in this analysis.

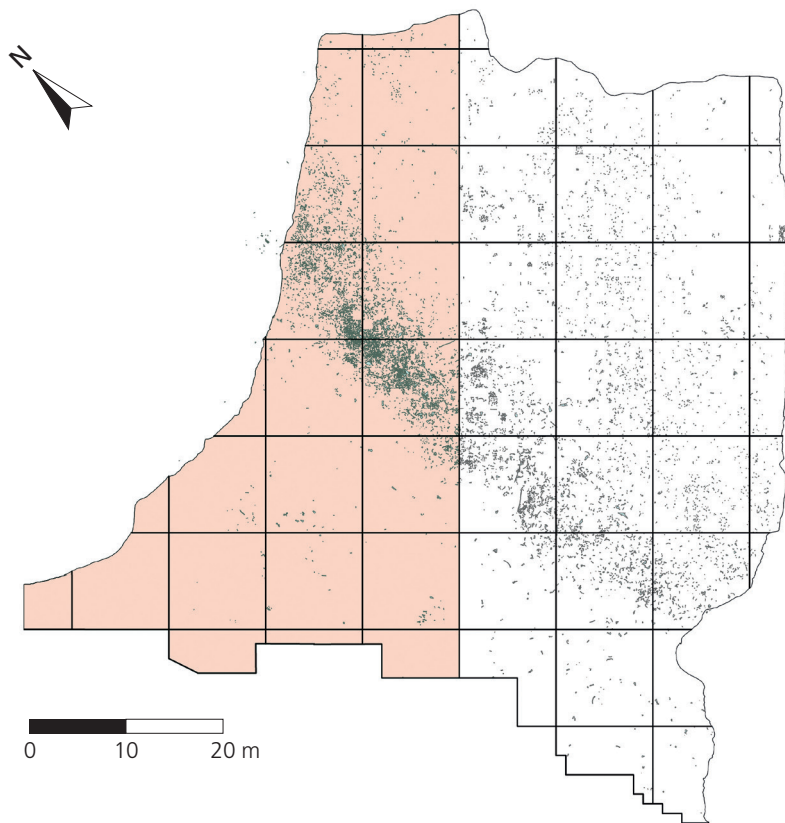
In addition to the material recovered from 1994 to 2008, several dozen bones contained in sediment blocks lifted from the original excavation and transferred to cold storage have been made available for

this study. Efforts to process these blocks are currently underway.

The current analysis began in March 2013 with the documentation of specimens selected for exhibition at the Paläon research centre, which has since opened to showcase the finds from the various Schöningen localities. Among the roughly 100 specimens intended for display were numerous complete horse crania and other postcranial remains from a variety of species showing extensive hominin butchery damage. Following that, all specimens listed in the original database as cranial elements and individual teeth (ca. 800 specimens) were analysed and recorded in order to estimate the number of individual animals represented at the site. With those baseline measures established, the bulk of the faunal material has been analysed according to 10 m × 10 m excavation squares. Thus far, our analysis now includes all specimens recovered from the western portion of the Spear Horizon and accounts for roughly half (ca. 8000 specimens) of the estimated bone assemblage from nearly one-third (ca. 1500 m<sup>2</sup>) of the entire excavated surface (fig. 2).

Each specimen has been individually analysed and documented following standard zooarchaeological methods. All bones were recorded by skeletal part according to Gifford/Crader (1977). Taxonomic designations were made at the highest level possible (i. e., species, genus, family), or otherwise ascribed to a size class based on live body weight (Brain 1974; 1981). As the analysis is in progress, quantifications are limited here to number of identified specimens (NISP) and only cursorily to minimum number of individuals (MNI) defined by Grayson (1984) and Klein/Cruz-Urbe (1984). Measures of skeletal part representation were based on minimum number of elements (MNE) of Binford (1978; 1981) and Bunn (1986), but those calculations are only preliminary and limited to skeletal element survivorship relative to bone density (Lam/Chen/Pearson 1999).

To aid in skeletal element quantification, we developed a simple GIS image-based methodology to automate the process (García-Moreno et al. 2015), similar to that described by Marean et al. (2001). All



**Fig. 2** Plan view of Schöningen 13II-4 showing the distribution of faunal remains. All cranial remains from the complete assemblage have been recorded along with the postcranial remains within the shaded portion of the map. Note that each square represents 10 m<sup>2</sup>.

identifiable bone fragments were drawn on standardized templates unique to each skeletal element, and the MNE was automatically counted with GIS software using the number of overlaps between fragments of each skeletal element. All other calculations, including indices of meat and marrow utility (Outram/Rowley-Conwy 1998), are based on NISP values per skeletal element.

Mortality data was assessed for all specimens when possible, and the methods employed here relate only to the equid assemblage. For dental remains, molar and premolar crown heights provided age at death estimates based on the calculations of Levine (1982) and Fernandez/Legendre (2003) for adult teeth and Bignon (2006) for juvenile dentition. Ages for cheek teeth with incomplete crowns and incisors were estimated according to stages of occlusal wear (Levine 1982). The timing of epiphy-

seal fusion provided age estimates for postcranial remains (Habermehl 1975).

Bone surface modifications provide direct evidence for hominin butchery and therefore represent an integral component of this analysis. All skeletal elements were examined with a 10× hand lens or 20-40× handheld digital microscope for traces of modification. Hominin-induced butchery marks, including cut marks, scraping marks, and hammerstone impact damage, in addition to carnivore damage, were identified based on diagnostic macro- and microscopic features (Blumenschine 1988; Capaldo/Blumenschine 1994; Lyman 1994; Fisher 1995; Blumenschine/Marean/Capaldo 1996; Pickering/Egeland 2006; Domínguez-Rodrigo et al. 2009). Limb bone fracture patterns were recorded following the system of Villa/Mahieu (1991) and can be used as reliable indicators of pre- and



post-depositional processes affecting the assemblage. Weathering can obscure traces of bone surface modifications and prolonged exposure on the ground surface can lead to reduced identifiability of bones. The system of weathering stages developed by Behrensmeyer (1978) was used to assess damage caused by exposure of the faunal assemblage.

The exceptional preservation of the archaeological remains, as well as the large extent of the excavated surface, makes Schöningen 13II-4 a unique site to address a number of issues regarding site formation processes and the patterns in the spatial distribution of bones and artefacts that reflect past hominin butchering activities and social actions (Barceló/Maximiano 2013). This preliminary spatial analysis focuses on three different approaches: point pattern analysis, geostatistics, and refitting.

Despite the fact that point plots are usually an oversimplification of events in space and time (Bevan et al. 2013), plotting artefact distributions provides a good visual overview and statistical foundation to infer general patterns in the spatial arrangement of bones and artefacts across the site. This is especially true in the case of small sample sizes, where poorly represented species can highlight spatial patterns otherwise concealed by the large amount of horse remains (Eixea et al. 2011-2012). To better visualize the spatial distributions, we use kernel density estimation (Barceló 1998; Baxter/Beardah/Wright 1997), which calculates the bi-dimensional density of finds given a set of known locations. This function offers a smooth representation of density and an informal estimation of clusters without imposing any structure on the data.

A series of geostatistical tests, including average nearest neighbour analysis and Ripley's K test, were performed in order to establish if the observed patterns were statistically significant (Barceló/Maximiano 2008). The aim of these tests is to quantify whether the analysed sample follows a clustered, dispersed, or random distribution. Both tests were performed using ArcGIS Spatial Statistics toolbox. In general, nearest neighbour analysis measures the significance of non-random distributions in coordinate data (Blankholm 1991). More specifically,

average nearest neighbour analysis compares the average distance between the centroid of each "feature" and its nearest neighbour against the average distance estimated for a hypothetical random distribution. If the observed average distance is smaller or greater than the estimated distance, the distribution can be classified as clustered or dispersed, respectively. Because nearest neighbour analysis is dependent on the extent of the study area (Barceló/Maximiano 2008; Blankholm 1991), a Ripley's K test was performed to measure the type, intensity, and range of a spatial patterning by comparing the observed distances between each "feature" in the sample against a hypothetical random distribution created using a Monte Carlo simulation (Maximiano 2007). This method defines whether a distribution is aggregated or dispersed, the intensity of aggregation (or dispersion), and how that pattern develops with increasing distance.

Finally, the spatial distribution in relation to skeletal element refits was analysed. Refitting has long been used in archaeology, but the adoption of GIS to archaeological applications has allowed for more detailed analyses (Ortiz Nieto-Márquez 2013; Ortiz Nieto-Márquez/Baena Preysler/Chacón 2014). Refitting of skeletal elements is essential to understand the temporal and spatial relationship of features, such as bone clusters, as well as to approach hominin behaviour (i.e., butchering patterns or food sharing) or post-depositional processes (Conard/Prindiville/Adler 1998; Enloe/David 1992). Here, refits include "breakage refits" that consist of two or more conjoining fragments from one original skeletal element, as well as "anatomical refits" where two or more skeletal elements from the same individual articulate. Refitting efforts are in progress, and the data presented here represent only the unsystematic discovery of refits within or between adjacent 10m x 10m excavation units. The spatial analysis of refits entailed calculating the distances and orientations of lines connecting refitting skeletal elements. The orientation pattern of refitting lines was analysed using Rayleigh test (Davis 2002) to check whether a significant mean orientation could be defined for the refits.

## Results

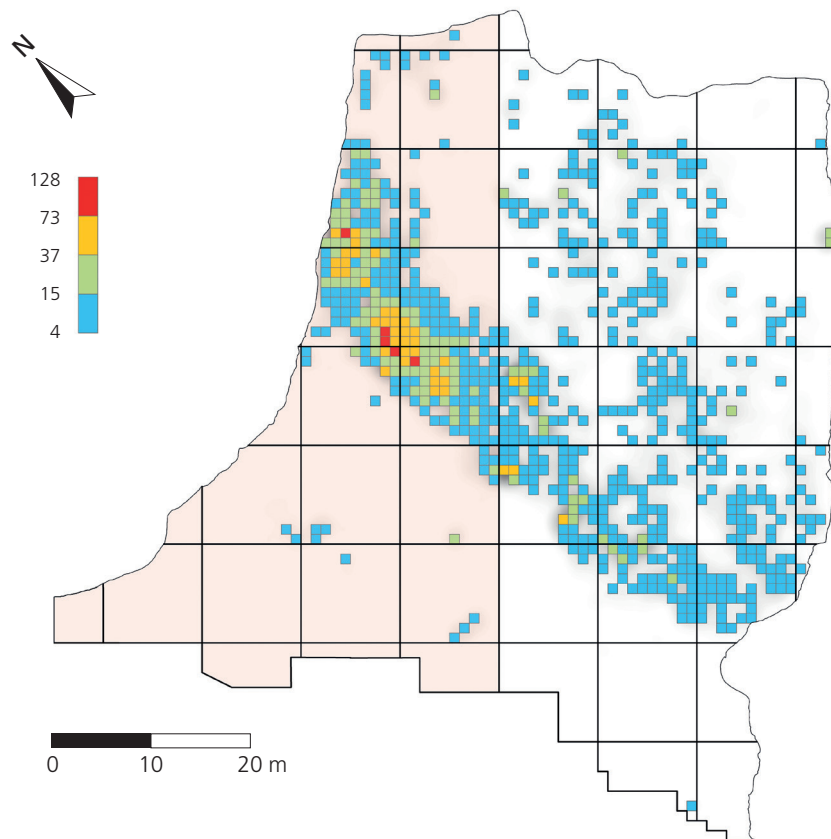
### Species representation

In total, 7816 faunal remains from the “Spear Horizon” have been processed and recorded in detail, amounting to roughly half of the estimated total number of remains. **Table 1** shows all species identified to date, along with NISP for each taxon. This provisional species list is similar to those reported by Voormolen (2008) and van Kolfschoten (2012; 2014; van Kolfschoten et al. 2012; van Kolfschoten/Buhrs/Verheijen 2015), but those analyses included different samples of the large mammalian faunal remains. Clearly, the Middle Pleistocene horse, *Equus mosbachensis*, dominates the faunal assemblage, accounting for 65.5% (5116 of 7816 NISP) of the identified specimens. Add to that bones identified as large ungulate (2337 NISP), most of which are likely large equid based on size, and up to 95% (7453 of 7816 NISP) of the faunal assemblage may be *Equus mosbachensis* remains. According to van Kolfschoten (2014), the *Equus mosbachensis* assemblage represents a minimum of 46 individuals. Based on our own assessment, this estimate is accurate, but the final number of individuals is likely to increase as more of the assemblage is analysed. A second equid species, the more gracile and small-bodied *Equus hydruntinus*, is also represented by several specimens. Apart from equids, at least two cervidae species are present: mostly red deer (*Cervus elaphus*) and a single giant deer (*Megaloceros giganteus*) specimen. Two bovid species have been identified: a sizeable collection of very robust aurochs (*Bos primigenius*) remains and several remains of steppe bison (*Bison priscus*). The remainder of the large mammal assemblage includes two rhinoceros species, *Stephanorhinus hemitoechus* and *Stephanorhinus kirchbergensis*. Carnivores are represented by wolf (*Canis lupus*), badger (*Meles meles*), and a small weasel species (*Mustela* sp.), and beaver (*Castor fiber*) and mole (*Talpa europea*) have been identified among the small mammal remains. The large variety of waterfowl obviously reflects the site’s lakeshore setting, as does the presence of a number of pike (*Esox lucius*) remains.

As a whole, the species list clearly represents a mosaic interglacial environment surrounding the Schöningen palaeo-lakeshore. Most of the large ungulate species identified are grazers typically associated with open habitats, but, based on tooth wear characteristics, cervids and equids are known to adopt variable diets (grazing and browsing) during interglacial time (Rivals/Schulz/Kaiser 2009), which

**Tab. 1** Number of identified specimens (NISP) per taxa and proportion (%NISP) of the total analysed sample.

| Ungulate                                 | NISP | %NISP  |
|--|------|--------|
| Horse, <i>Equus mosbachensis</i>         | 5116 | 65.46% |
| Ass, <i>Equus hydruntinus</i>            | 3    | 0.04   |
| Steppe bison, <i>Bison priscus</i>       | 6    | 0.08   |
| Aurochs, <i>Bos primigenius</i>          | 54   | 0.69   |
| Bovini indet.                            | 84   | 1.07   |
| Red deer, <i>Cervus elaphus</i>          | 58   | 0.74   |
| Giant deer, <i>Megaloceros giganteus</i> | 1    | 0.01   |
| Cervidae indet.                          | 4    | 0.05   |
| <i>Stephanorhinus hemitoechus</i>        | 1    | 0.01   |
| <i>Stephanorhinus kirchbergensis</i>     | 1    | 0.01   |
| <i>Stephanorhinus</i> spp.               | 2    | 0.03   |
| Medium ungulate indet.                   | 53   | 0.68   |
| Large ungulate indet.                    | 2337 | 29.90  |
| <b>Carnivore</b>                         |      |        |
| Wolf, <i>Canis lupus</i>                 | 5    | 0.06   |
| Large carnivore indet.                   | 3    | 0.04   |
| Badger, <i>Meles meles</i>               | 2    | 0.03   |
| Weasel, <i>Mustela</i> sp.               | 3    | 0.04   |
| Small carnivore indet.                   | 1    | 0.01   |
| <b>Small mammal</b>                      |      |        |
| Beaver, <i>Castor fiber</i>              | 3    | 0.04   |
| Mole, <i>Talpa europea</i>               | 1    | 0.01   |
| Small mammal indet.                      | 21   | 0.27   |
| <b>Bird</b>                              |      |        |
| Pintail, <i>Anas acuta</i>               | 2    | 0.03   |
| Teal, <i>Anas crecca</i>                 | 4    | 0.05   |
| Mallard, <i>Anas platyrhynchos</i>       | 3    | 0.04   |
| Tufted duck, <i>Aythya fuligula</i>      | 2    | 0.03   |
| Goldeneye, <i>Bucephala clangula</i>     | 1    | 0.01   |
| Shelduck, <i>Tadorna tadorna</i>         | 1    | 0.01   |
| Swan, <i>Cygnus olor</i>                 | 1    | 0.01   |
| Water rail, <i>Rallus aquaticus</i>      | 1    | 0.01   |
| Bird indet.                              | 15   | 0.19   |
| <b>Fish</b>                              |      |        |
| Pike, <i>Esox lucius</i>                 | 10   | 0.13   |
| Fish indet.                              | 14   | 0.18   |
| <b>Insect</b>                            |      |        |
| Beetle, Coleoptera sp.                   | 3    | 0.04   |



**Fig. 3** Plan view showing the number of bones within each 1 m<sup>2</sup> excavation unit.

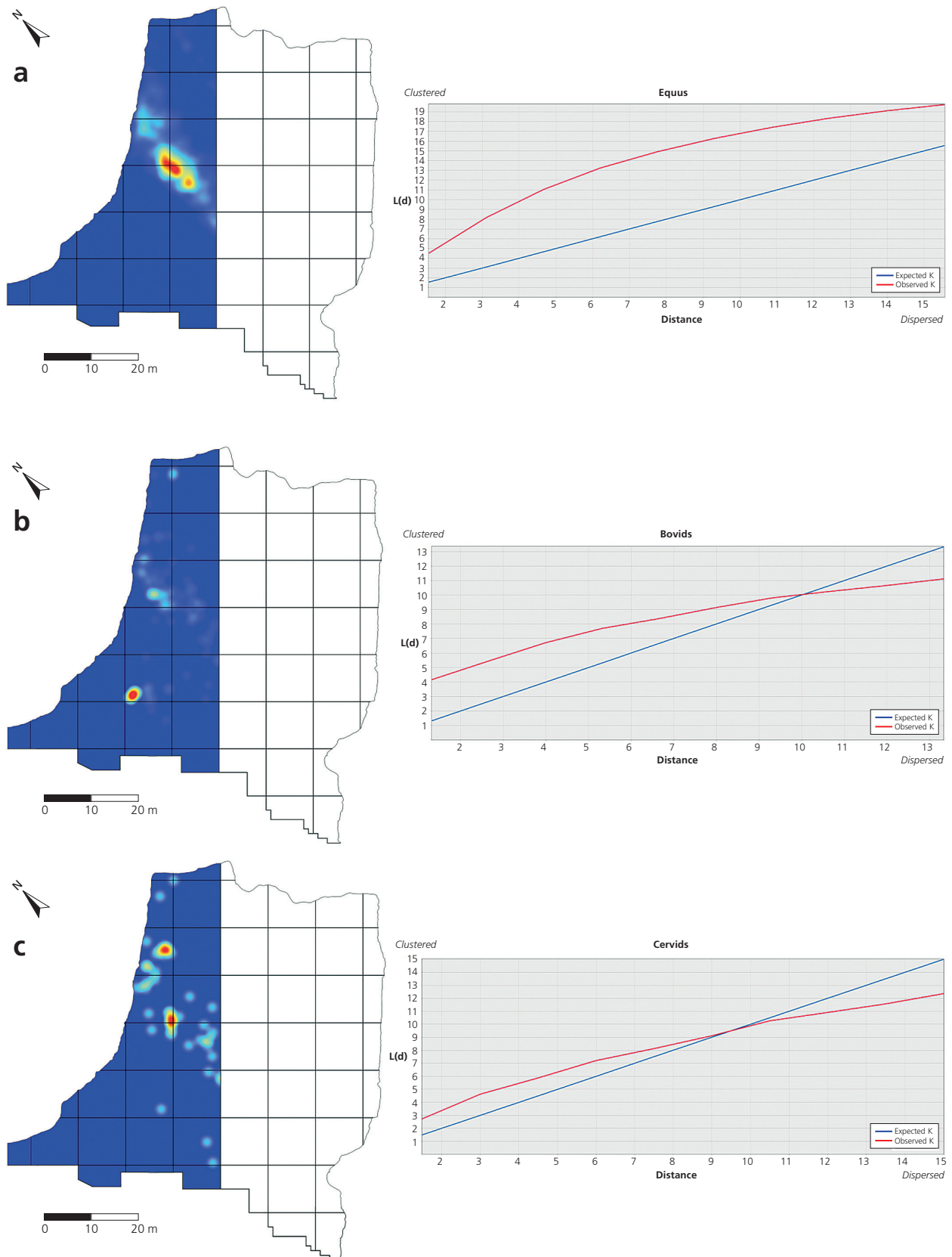
also appears to be the case with segments of the Schöningen horse population (Rivals et al. 2015). These dietary signatures imply a grassland habitat with a significant woodland component in the immediate vicinity of the Schöningen palaeo-lakeshore. This mosaic environment is corroborated by numerous palynological studies that show an abundance of grass and arboreal pollen, dominated by pine and birch (e.g. Urban 2007; Urban/Sierralta/Frechen 2011; Urban/Sierralta 2012; Urban/Bigga 2015).

#### *Spatial distribution*

The spatial distribution of all faunal remains with accurate horizontal coordinates shows a dense concentration of bones oriented north-to-south across the entire central portion of the site (fig. 3). This roughly linear cluster likely represents some aspect of the former lakeshore, with dry land to the west and the deeper part of the lake located to the east. At its widest, the main bone concentration meas-

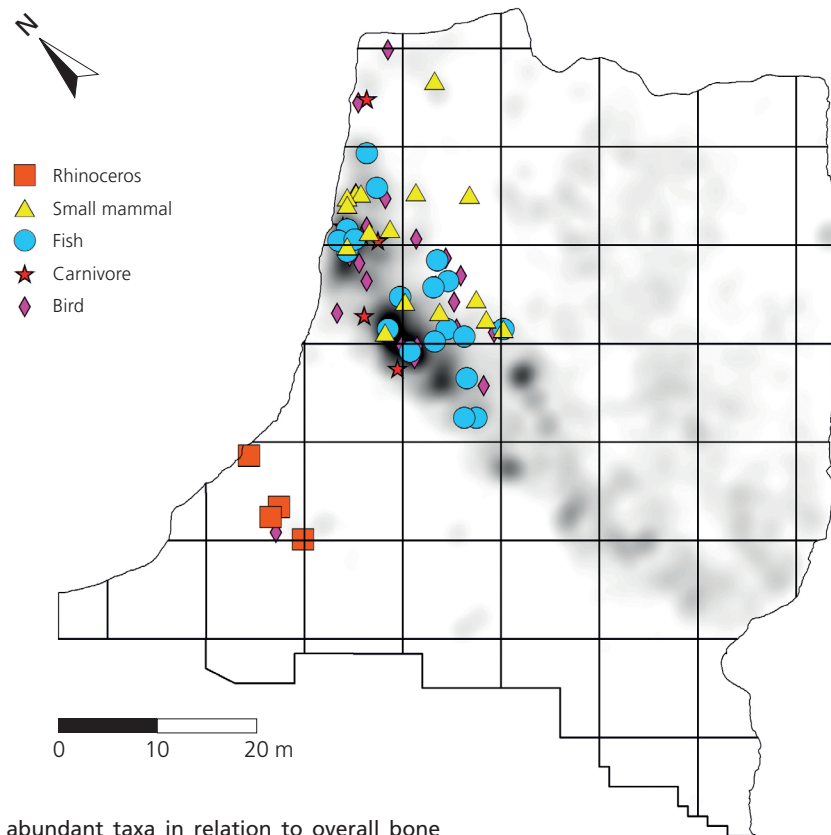
ures roughly 10m (E-W) wide, and may indicate advancing and receding lake levels during site formation. Regardless of the exact position, a majority of the faunal remains and other artefacts likely accumulated very close to the lakeshore, on dry land or in shallow water, although an accumulation in deeper water cannot be excluded at present (see Stahlschmidt et al. 2015a). Within the main concentration, two distinct clusters appear (denoted by red squares in fig. 3): a small cluster located at the northern edge of the excavated area, and a larger cluster positioned just to the south. These two clusters show higher density of bones, in some cases with more than 100/m<sup>2</sup>.

Regarding the abundance of large mammal species, horse bones are by far the most abundant, 85% (4345 of 5116) of which are distributed within the main bone concentration. Both nearest neighbour analysis and Ripley's K test indicate that those remains are significantly clustered (fig. 4a). The remains of bovids and cervids show slightly



**Fig. 4** Kernel density estimation (left) and Ripley's K test (right) of the distribution of equid (a), bovid (b) and cervid (c) remains.





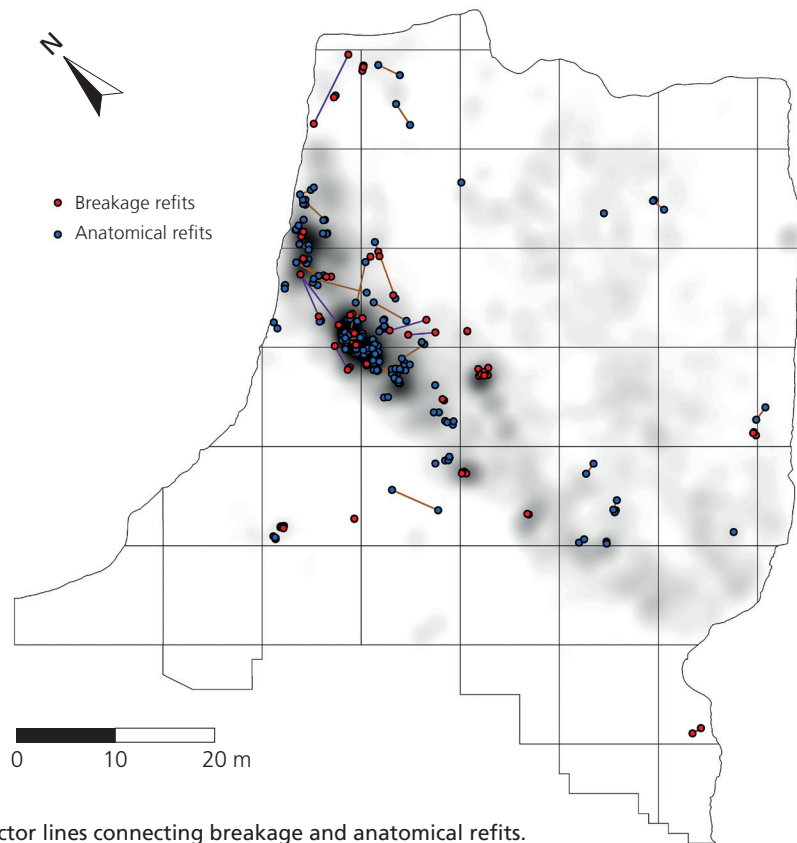
**Fig. 5** Distribution of less abundant taxa in relation to overall bone concentration shown as black shaded areas.

different distributions than horses. Bovids are well represented within the main concentration, but occur in higher frequency to the west (fig. 4b). Ripley's K function shows that bovid remains are also clustered, but to a lesser extent than horse bones, and up to a certain point become dispersed. On the other hand, cervid bones appear primarily along the main concentration, but are more dispersed than horse remains (fig. 4c). A nearest neighbour analysis indicates cervid bones are randomly distributed within the surface area covered here.

Other taxa, such as carnivores, fish, birds, small mammals, and rhinoceros are represented by only a few remains (fig. 5). With the exception of rhinoceros, all were recovered within the main concentration, although they are either randomly distributed (birds, fish, small mammals) or dispersed (carnivores, rhinoceros). It is noteworthy that fish remains appear only within the main concentration, but not to the east, an area supposed to represent the deeper part of the lake during the occupation of the site, al-

though taphonomic factors may have led to the absence of fish remains elsewhere. The distribution of rhinoceros bones is also interesting, appearing not in the main concentration, but in a secondary cluster to the west, next to a concentration of bovid remains. Since the spatial analysis presented here only includes the western portion of the site, we can only offer the preliminary hypothesis that large mammals are differently distributed across the site. Thus, the site must include a number of death events occurring over an extended period of accumulation.

Regarding refits within the analysed sample, 37 breakage refits and 118 anatomical refits have been documented (fig. 6). Breakage refits primarily include conjoinable limb bone shafts and shaft fragments with ancient breaks indicative of fracture from marrow extraction. Most anatomical refits paired two or more articulating elements from the vertebral column and among carpals and tarsals. A few individual teeth with no associated maxilla or mandible, but with matching wear facets are also counted



**Fig. 6** Plan view with vector lines connecting breakage and anatomical refits.

among the anatomical refits. The mean distance for breakage refits is  $1.03 \pm 1.82$  m (range: 0-7.79 m) and  $0.81 \pm 1.27$  m (range: 0-7.48 m) for anatomical refits. A histogram of refit distances shows that most occur within less than 1 m (**fig. 7a**), likely due to the fact that no refits between distant squares have been considered at this preliminary stage in the zooarchaeological analysis. Considering orientation, the mean vector for breakage refits is  $98.51^\circ \pm 58.34^\circ$  and  $28.84^\circ \pm 59.82^\circ$  for anatomical refits (**fig. 7b**). Rayleigh's tests show that orientation is significant for breakage refits, but no significant preferential orientations is evident among anatomical refits. These different patterns in refit orientations may indicate two different processes involved in the dispersion of the assemblage, one shaped by regularities in hominin butchery practices in the case of breakage refits, and the other reflecting the natural and random processes of *in situ* disarticulation involved with anatomical refits. But again, our refitting efforts are ongoing and this hypothesis will be tested within a more rigid analytical framework in the future.

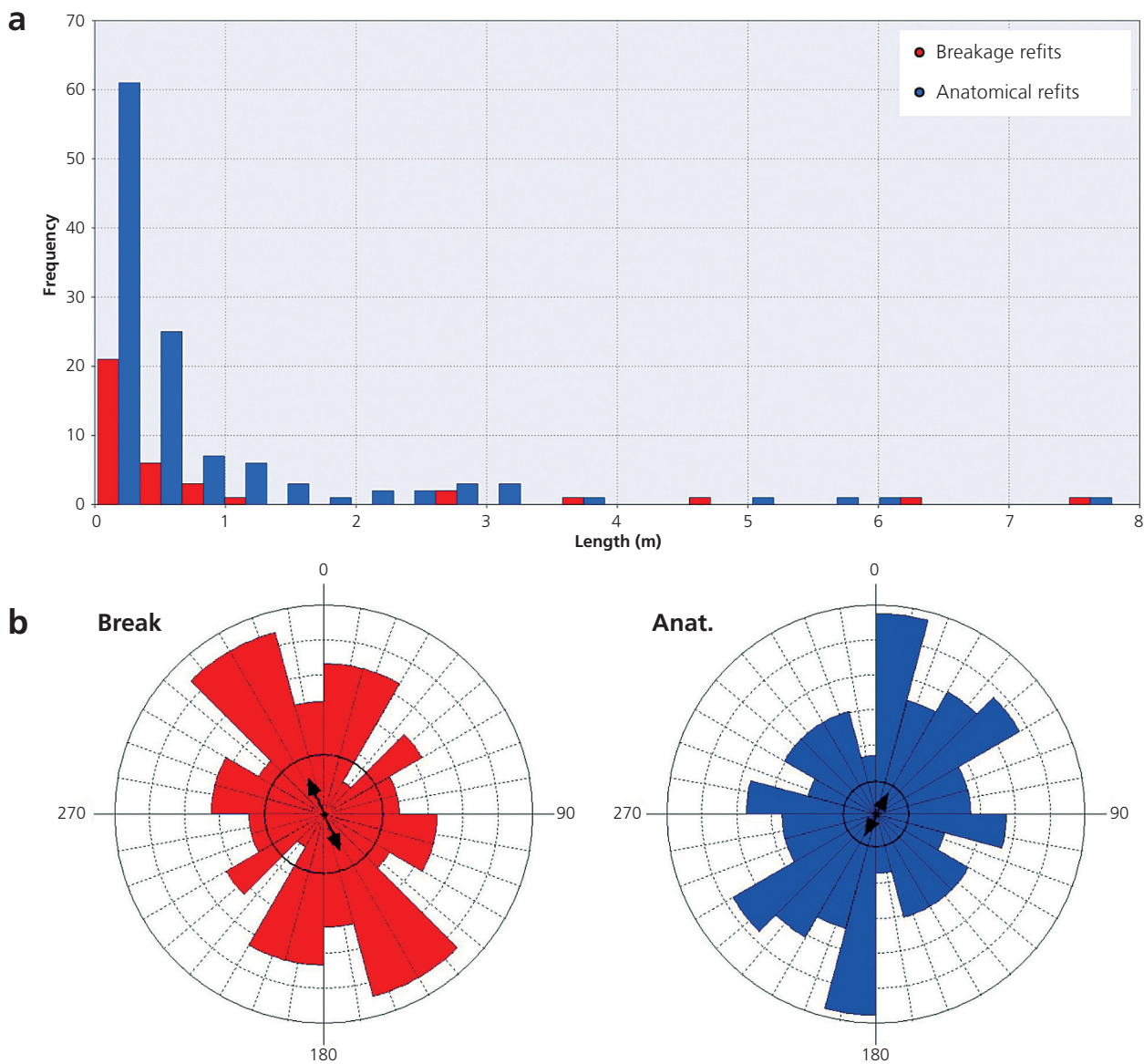
#### *Bone surface modification*

A wide array of bone surface modifications has been recorded in the faunal assemblage, providing critical information for reconstructing site formation processes and the role of hominins in the accumulation of the faunal assemblage. Taken together, bone surface modifications indicate primary access to carcasses by hominins, likely through active hunting along the Schöningen palaeo-lakeshore.

Among the horse remains, the entire sequence of hominin butchery activities is preserved, from filleting of meat to disarticulation and marrow extraction. Overall, cut and scraping marks are concentrated on limb elements along the midshafts and epiphyses, corresponding to the removal of meat, dismemberment, and preparation of bones to facilitate access to marrow. Similar marks on some non-meat-bearing skeletal elements (crania and lower limbs) suggest skinning activities (Binford 1981; 1984), but most hominin-induced damage is focussed on the major meat- and marrow-bearing elements of the appen-

dicular skeleton. Vertebrae show comparatively few butchery traces, along with most other elements of the axial skeleton. A high incidence of cut-marked ribs has been recorded; however, this observation is less relevant to the overall treatment of carcasses when considering the relative abundance of ribs in

a single horse skeleton (ca. 36 per individual). Numerous bovid and cervid bones also show butchery traces, indicating horses were not always the primary focus of hominin hunters along the Schöningen lakeshore, but systematic butchery of those species is likely masked by the small sample size.



| Refit type | Min. distance | Max. distance | Mean distance | Mean vector     | Concentration | Circular variance | Rayleigh's z | p     |
|------------|---------------|---------------|---------------|-----------------|---------------|-------------------|--------------|-------|
| Breakage   | 0.02 m        | 7.79 m        | 1.03 + 1.82 m | 98.51° ± 58.34° | 1.49          | 0.40              | 13.12        | 0.000 |
| Anatomical | 0.02 m        | 7.48 m        | 0.8 + 1.27 m  | 28.84° ± 59.82° | 0.23          | 0.44              | 1.50         | 0.222 |

**Fig. 7** Histogram of refit distances (a) and rose diagram of refit vectors (b), with statistical comparisons between breakage and anatomical refits.

Impact notches and other associated damage related to marrow extraction are common on horse limb bones and mandibles. Fresh bone fracture characteristics are abundant, providing solid evidence for breakage while bones were still fresh and greasy. Many of these notches occur repeatedly in the same locations on limb shafts, suggesting a systematic process of bone breakage. **Figure 8** shows damage to femora shafts on the anterior surface adjacent to the third trochanter, a relatively thin area on an otherwise very dense limb shaft. Tibiae, humeri, and radio-ulnae also show similarly consistent locations of bone breakage. Often impact notches are paired with damage to the opposite side of the limb shaft, indicating the possible use of anvils in the fracturing process. Whereas impact notches on limb bones occur regularly in the same locations, impact damage does not follow a standardized pattern related to food utility. More specifically, there is no correlation between the frequency of impact marks and the amount of marrow within a particular limb bone. If maximum returns were the only goal of the Schöningen hominins, bones containing the most marrow would be broken more often and should preserve more traces of impact. In general, femora and humeri contain the most marrow among horse limb bones (Outram/Rowley-Conwy 1998), but impact damage is preserved more frequently on tibiae and radii fragments (based on NISP). Furthermore, impact damage is almost as frequent in metatarsals as femora despite the lowest marrow content for metatarsals among the major limb bones. Reduced frequency of damage to the highest-ranking limb bones may simply reflect the large amounts of trabecular bone in the marrow cavities of equid femora and humeri, which can pose difficulties for marrow removal (Blumenschine/Madrigril 1993).

On the other hand, perhaps such maximizing behaviours should not always be expected among Middle Pleistocene hominins. In the case of Schöningen, patterns of impact damage to limb bones and the lack of butchery marks on much of the axial skeleton do not follow predictions for the maximization of food resources. With so many horse carcasses present at the site, maximizing returns may

have been unnecessary, and the resulting patterns reflect a strategy to meet short-term subsistence needs. Clearly meat yields, marrow content, and the like, have some influence over butchery, but as we analyse the entire assemblage and begin to form a clearer picture of the overall pattern of modification, we must look beyond quantitative comparisons to food utility and explore alternative explanations for the observed butchery patterns and measures of skeletal part representation.

In addition to the identification of several carnivore remains in the assemblage, carnivore presence is also indicated by numerous tooth scores, pits, punctures, and other related damage on the horse bones. Bovid and cervid bones also preserve the distinct traces of carnivore gnawing, but considerably less than in the horse assemblage. Several lines of evidence indicate carnivore access to horse carcasses was secondary to that of hominins. In general, hominin butchery marks are most common on horse limb elements (477 of 1130 NISP, 42.2%), but large portions of the axial skeleton were completely ignored (203 of 2171 NISP with butchery marks, 9.4%). Carnivore damage is present on some horse limb bone shafts and epiphyses (110 of 1130 NISP, 9.7%), but slightly more abundant on ribs, vertebrae, and other axial elements (241 of 2171 NISP, 11.1%). This contrast between the locations of hominin and carnivore damage is statistically significant ( $\chi^2=119.34$ ;  $p < 0.0001$ ), and suggests early access to carcasses by hominins followed by carnivore scavenging. Furthermore, 71 horse bones include both cut marks and carnivore damage, and in a few cases tooth pits or scores are preserved directly on top of cut or scraping marks. No cut or scraping marks occur directly on top of carnivore damage.

In addition to cut, scrape, and impact marks that clearly identify a systematic pattern of hominin butchery, the Schöningen faunal assemblage also includes a large collection of bones interpreted as bone retouchers and soft hammers used in the manufacture and maintenance of lithic tools. Eighty-eight such bone tools have been reported by van Kolfschoten et al. (2015). We have identified additional retouchers and soft hammers not previ-





**Fig. 8** *Equus mosbachensis* right femur shaft fragments showing consistent patterns of breakage.

ously reported. The Schöningen retouchers are most frequently made from limb bone shaft fragments and display characteristic pits and scores indicative of forceful percussion applied to the edges of stone flakes or tools (Chase 1990; Patou-Mathis 2002; Mallye et al. 2012; Daujeard et al. 2014; Abrams et al. 2014). A few rib shaft fragments also show similar damage along the dense portion of the medial shaft at the neck. Some examples made from limb bones also include small stone flakes imbedded within the bone surface. Consistent with the dominance of horse bones in the overall assemblage, most retouchers are made from horse remains, and only a

few are fashioned from bovid and cervid bone. Specifics regarding the gross morphology of retouching marks and associated breakage patterns (Mallye et al. 2012) indicate that most retouchers appear to have been used in a relatively fresh state, with only a few possible specimens showing evidence of use while dry, or at least defatted (fig. 9). We are currently analysing these implements in greater detail in order to differentiate the markings from other biotic and abiotic modifications and confirm their use as retouchers. In the end we expect the total number of bone retouchers to exceed 100, a remarkable number considering the age of the site.

An additional collection of limb bones preserve damage to the epiphyses related to use as soft hammers (fig. 10), primarily on the proximal and distal ends of horse metapodials. Based on our own limited experimental studies, we hypothesize that the bone retouchers were used in light-duty tasks of trimming tool and flake edges, while the soft hammers were better served as heavy-duty implements, either for working stone or breaking other bones for marrow, as suggested by van Kolschoten et al. (2015).

With such a wide variety of bones used to shape and modify lithic tools, bone was a useful resource for Middle Pleistocene hominins at Schöningen. Furthermore, the relative scarcity of metacarpals and metatarsals in the overall assemblage may indicate the selective removal of metapodials for later use at other locations across the landscape. As the lithic assemblage at Schöningen is relatively small – only 1500 fragments of chert, mostly retouching debris (Thieme 2007; Serangeli/Conard 2015) – it is possible that bone retouchers and soft hammers supplanted stone hammers in the manufacture and maintenance of lithic tools or as hammerstones used to process the numerous animal carcasses. Substantial variability in form and damage produced implies a variety of functional uses for these implements during different stages in the lithic reduction and butchery process. Such diversity also indicates the use of bone as a raw material was a well-established behaviour by 300,000 years ago.

### *Skeletal part representation*

As the analysis of the Schöningen 13II-4 faunal assemblage is still progressing, interpretations of skeletal part representations are only preliminary. Thus far, all of cranial remains listed as such in the original database have been analysed, but only the postcranial remains from the western portion of the site have been processed (see fig. 2). Because many statistical correlations rely heavily on the differential survival of skeletal elements, i.e., the relationship between the number of observed bones and the number of expected bones, meaningful calculations cannot be made in reference to the analysed sample. The minimum number of elements (MNE) can be calculated from the number of identified specimens (NISP), but it would be misleading to compare those totals against the expected totals from an unknown minimum number of individuals (MNI). However, certain trends of skeletal part representation can be evaluated in terms of NISP and MNE, without reference to MNI or other derived measures of abundance.

In general, all elements of the horse skeleton are preserved in various quantities, from the most dense teeth and limb bone shafts to the very thin and fragile hyoid bones and sternebrae. Although all elements are represented, the survival frequency of different skeletal elements and portions of skeletal elements is highly influenced by density, at least for the postcranial skeleton. From a sub-sample of



**Fig. 9** Retouch damage on large mammal limb shaft fragments. Specimen on the left was likely used as a fresh bone; specimen on the right was likely used in a relatively dry or defatted state.



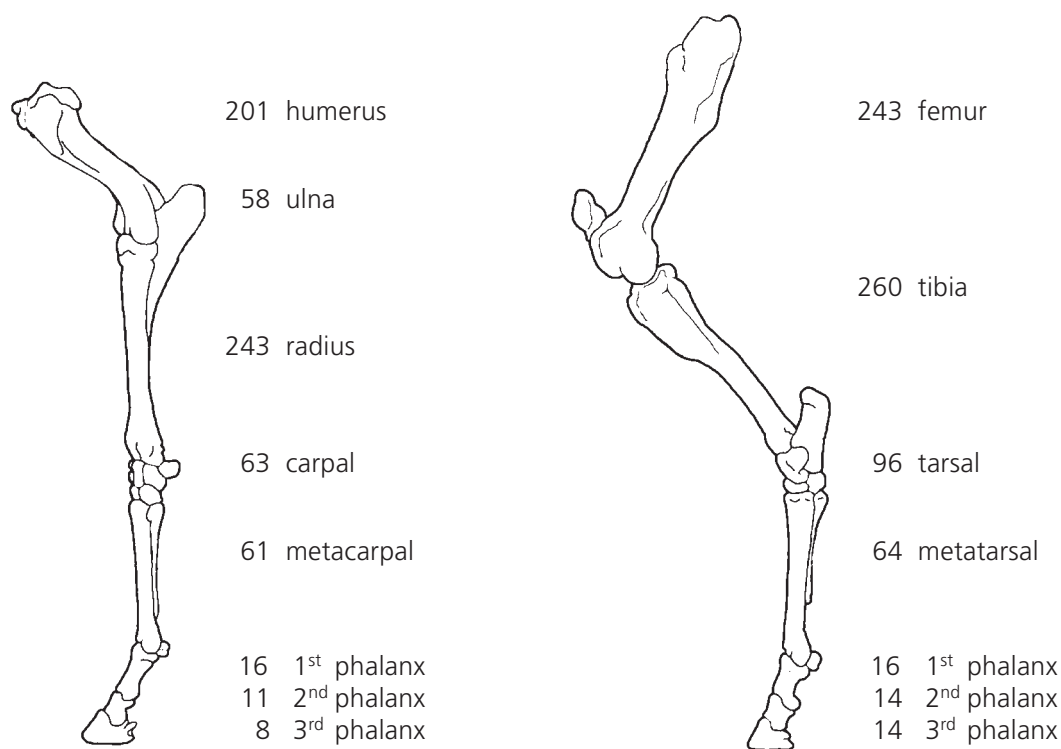
**Fig. 10** *Equus mosbachensis* metapodial with damage to distal condyles from use as a soft hammer.

1857 adult horse postcranial remains (estimated MNE=765), survivability is highest among the densest portions of the skeleton and lowest in the least dense skeletal elements. For example, humerus midshafts, with a calculated bone mineral density of  $1.10\text{g/cm}^3$  (Lam/Chen/Pearson 1999), are represented by 38 MNE, while only seven proximal humeri ( $0.23\text{g/cm}^3$ ) were preserved based on MNE. This pattern is repeated in nearly all of the limb bones, as well as other elements of the appendicular and axial skeleton. From a different sample of bones, Voormolen (2008) found no correlation between survivorship and bone density; however, those calculations were based on average density for each bone rather than individual bone portion.

Density-mediated attrition is pervasive in the fossil record (e.g. Brain 1967; 1969; Lyman 1984; 1993; Grayson 1989), and carnivore feeding behaviour has also been shown to follow this same pattern of density-mediated survival of skeletal parts (e.g. Faith/Marean/Behrensmeyer 2007; Marean/Spencer 1991; Marean et al. 1992). In fact, many of the carnivore tooth pits, scores, punctures, etc., are concentrated at the least dense limb bone epiphyses

and portions of the axial skeleton. Thus, a combination of pre- and post-burial taphonomic processes likely account for the resulting skeletal part representation at Schöningen, wherein the diagenetic effects of prolonged burial have amplified the effects of carnivore ravaging following hominin discard of the bone assemblage.

Despite the apparent density-mediated survival of skeletal parts, a clear pattern in the representation of horse limb bones appears to have endured the effects of burial and carnivore ravaging. This pattern, coupled with the high frequency of hominin-induced modifications to the bones, provides critical insight into the carcass acquisition strategies, butchery practices, and possible transport decisions of Middle Pleistocene hominins. **Figure 11** depicts the representation of horse front and hind limb bones with corresponding NISP values per element. In both front and hind limbs the upper limbs (humerus and femur) are abundant, and the highest NISP values are shown in the tibia, followed by radius. Representation of the lower limbs substantially decreases in sequence from the metacarpals and metatarsals through to the phalanges. The data



**Fig. 11** Horse front and hind limb bone representation based on number of identified specimens (NISP).

presented are only based on NISP values, but this representation of front and hind limb bones does not fit the pattern of a strictly density-mediated assemblage. Among limb bones, metapodial midshafts rank as the most dense bone portions at 1.10g/cm<sup>3</sup> (Lam/Chen/Pearson 1999), equal to that of humerus midshafts. While humeri are quite abundant, metapodials are comparatively scarce. Metapodial midshaft fragments may be more difficult to identify to side, portion, and segment than humerus midshafts, and therefore may not be counted in the analysed sample with the same reliability, but the overall pattern of limb bone representation appears more pervasive than a simple matter of identifiability.

Experimental results of carnivore feeding on simulated hominin-created bone assemblages shows that phalanges of small ungulates (sheep) are often completely consumed when present (Marean et al. 1992). This could explain the scarcity of phalanges in the assemblage. However, metapodials were only rarely consumed by carnivores in the experiments, which would argue against their absence as a result

of carnivore ravaging. These simulated assemblages involved hyena consumption of sheep bones, which may not be exactly relevant to the taphonomic history of the Schöningen assemblage since horse phalanges are significantly more robust than those of sheep. Carnivores with a comparable ability to completely destroy or consume entire bones or bone portions like hyenas are absent from the Schöningen site, and similar experiments to determine the effects of carnivores on horse limb bones are not available. Additionally, only a low percentage of identified metapodials (6 of 125 NISP) and first phalanges (4 of 32 NISP) in the Schöningen assemblage show any damage from carnivores. As density and carnivore ravaging do not fully explain the resulting pattern of limb bone survival, it is probable that skeletal part representation reflects the butchery and transport decisions of Middle Pleistocene hominins.

The open-air, lakeshore setting at Schöningen is not a likely place for a residential site. There are no indications for long-duration occupations, but shorter-term encampments could be possible given the range of artefacts recovered. The most likely sce-



nario is that the site represents an overlapping series of hunting episodes followed by intensive butchery activities. In such a case, the hominin discard of the bone assemblage potentially came with the selective removal of skeletal parts away from the site for nutritional purposes or otherwise. As a number of proximal and distal metapodials show damage related to their use as heavy-duty implements, Middle Pleistocene hominins certainly recognized the utility of these specific bones as soft hammers. Other skeletal parts do not show such consistent use as tools. It is possible that metapodials, along with the attached phalanges, were separated from the carcasses and transported away from the site for use as tools at other locations across the landscape. In fact, of the 443 bones recovered from nearby site 12II-2 (stratigraphically above the "Spear Horizon"), only one bone was identified as large cervid (likely *Megaloceros*) – a metapodial shaft fragment with traces of use as a retoucher at both ends (Julien et al. 2015a). Neither the proximal or distal epiphyses of the bone are present, but its singularity and its use as a tool suggest that the bone may have been transported to the site.

### *Mortality Profiles*

From the cranial remains, van Kolfschoten (2014) identified a minimum of 46 *Equus mosbachensis* individuals; we expect this total to increase as our analysis progresses. Breaking down the available sample into age classes according to broad life history stages, the horse population includes an abundance of prime age adults, numerous subadults, and few old adults based on tooth crown heights and tooth wear characteristics. Comparing the resulting mortality profile against theoretical models there is a strong correspondence between the Schöningen horse assemblage and a pattern of catastrophic mortality (see Lyman 1987; Stiner 1990) or the Juvenile-Prime-Old (JPO) model described by Discamps/Costamagno (2015). This suggests that the cumulative age at death mirrors the living structure of a stable horse population. In other words, horse mortality at Schöningen occurred independently of

age. Such a pattern is most easily imagined as resulting from any number of large-scale catastrophic events – floods, fires, volcanic eruptions, disease, etc. – where the probability of death is equal across the population regardless of age. Catastrophic mortality can also result from the additive effects of predation, when prey animals are killed according to their proportional live abundance (Stiner 1990). There is no indication of a natural, catastrophic event at Schöningen, and the presence of individuals distributed across all age classes likely rules out a single, mass-kill event. In terms of hominin hunting preferences, the horse population at Schöningen does not appear to be selectively hunted, but rather killed in accordance to their live abundance during multiple hunting events along the lakeshore. Furthermore, the Schöningen horse population includes a minimum of five prime adult males, the presence of which would suggest multiple bands of horses. A typical horse herd usually includes a single prime adult male over the age of five or six, a harem of 2-6 breeding adult females, and their offspring (Klingel 1974; Levine 1983; Berger 1986). Bachelor herds can consist of 2-15 males aged 2-4.5 years; older males may remain solitary after 4.5 years of age, but most leave the bachelor group to form their own family groups. Several bands may join to form one large herd at certain times of year, but it is more likely that the horse population reflects multiple individual bands, portions of which were killed along the Schöningen lakeshore during chance encounters with Middle Pleistocene hominins.

Looking to the seasonality of death among the subadult horses (**fig. 12**), a slight drop in deaths occurred in spring, during and following the birthing period in May, but in general, all seasons are equally represented. No deaths are recorded for November, but overall autumn deaths are equal to those occurring during the winter and summer. No distinct seasonal pattern was found in  $^{18}\text{O}$  and  $^{13}\text{C}$  isotopic variations of adult horse teeth (Julien et al. 2015b). The exact month of birth and death is not entirely relevant, but the wide range of crown heights and wear stages recorded in the teeth of the subadult horse population suggests that individuals died at

the Schöningen lakeshore at a relative consistent rate throughout the seasonal cycle (assuming a constant rate of tooth wear among different individuals). This age distribution suggests a year-round presence of horses in the vicinity of the lake. Additional  $^{87}\text{Sr}/^{86}\text{Sr}$  isotope studies are aimed, in part, to determine if segments of the horse population were resident or migratory. This has important implications for inferring Middle Pleistocene hominin mobility. If the horse assemblage was drawn from an entirely resident, non-migratory population, it can be reasoned that there was also a consistent, perhaps year-round, presence of hominins in the vicinity of the Schöningen lakeshore during the Middle Pleistocene.

### Forthcoming studies

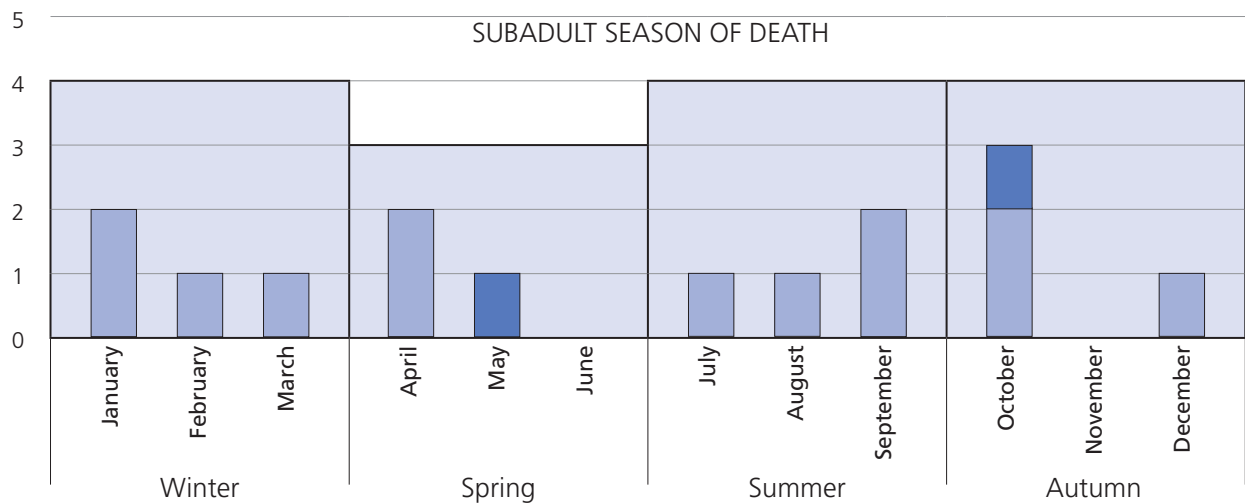
In the future, we will further evaluate these and other patterns once the complete faunal assemblage is analysed. Our immediate objectives are to finish the zooarchaeological and taphonomic documentation of the eastern portion of the site. Numerous multidisciplinary studies will help to further define the local depositional environment. Stable isotope and 3D-micro-texture analyses of horse teeth will provide additional data on the paleoecology of the main prey species. Additionally, these studies will also be useful in identifying different horse populations within the accumulation, providing a possible route to distinguish between multiple death events. Micromorphology thin sections and palynological samples taken from sediment blocks stored under deep freeze since the original excavations are currently being analysed to provide precise depositional contexts immediately preceding and following burial. A comprehensive bone refitting programme is also underway to identify potentially distinct activity loci within the main bone concentration and other areas across the site. With an in-depth spatial analysis that incorporates all of these various analyses, we can reconstruct hominin activities at the site on a fine scale. This holistic approach aims to highlight the “human component” to the Schöningen 13II-4 “Spear Horizon”.

### Discussion

These preliminary findings offer a view into the complex archaeological record of the Schöningen 13II-4 “Spear Horizon”. Although our analysis is ongoing and the data presented here are only a portion of what is planned for the overall project, we are beginning to assemble a more clear understanding of hominin behaviour preserved within the Schöningen 13II-4 deposit. While we reserve our final interpretations of the site until the full analysis is complete, we can evaluate several existing hypotheses regarding the events leading to accumulation of the site: a single mass kill (Thieme 2005); multiple kill/butchery episodes (Julien et al. 2015b; Voormolen 2008); and, a mass kill event among a natural background accumulation of bones (van Kolfschoten 2014).

Alone, the quantity of butchered horse individuals all but excludes a single mass kill event. Add to that the butchered remains of bovids and cervids and the different spatial arrangements among these main prey species, the notion of a single hunting and butchery event can no longer be supported. All evidence presented here suggests multiple hunting events over an extended period of time, during all seasons of the year. While we do not deny the possibility exists for one mass kill of 20-25 horses described by van Kolfschoten (2014), we cannot support this hypothesis based on the available taphonomic and spatial evidence. With the horse bones so densely concentrated within a relatively restricted area along the relict shoreline, we make no claims as to being able to distinguish one butchered horse carcass from another. Nor are we currently able to differentiate between horse carcasses (or portions thereof) butchered during a possible single mass kill event from those representing a supposed background accumulation. In fact, we feel the use of the term “background accumulation” should be avoided as it implies little or no active hominin involvement with the faunal accumulation apart from one mass kill event.

Despite strong indications for an extended period of accumulation, there are regularities in the treatment of horse carcasses across these multiple hunting and butchery episodes. The entire butchery



**Fig. 12** Seasonality (astronomical) of death among juvenile horses with the birthing season modeled to begin in may. Light blue bars represent young juvenile horses 0-1 years of age; dark blue bars represent juvenile horses 1-2 years of age; shaded blue background represents the total deaths according to season (Winter = 4, Spring = 3, Summer = 4, Autumn = 4). Age in months based on crown height measurements of Bignon (2006).

sequence is preserved, from filleting, disarticulation, marrow processing, and perhaps skinning. Butchery was focused toward the removal of meat from the appendicular skeleton and processing of limb bones for marrow. Impact damage to the same locations on limb bone elements suggests an efficient and systematic approach to obtaining marrow. Overall, elements of the axial skeleton were only minimally processed by hominins, but have been more frequently damaged by carnivores. In all instances of hominin butchery traces coinciding with carnivore damage to bones, hominins had early access to the carcasses, followed by carnivore scavenging. However, that does not preclude the possibility that some animals were killed by carnivores or died naturally along the Schöningen palaeo-lakeshore.

The use of bone as a raw material to manufacture and maintain lithic tools at the site is clearly evident in the numerous bone retouchers identified in the assemblage. Indications for the fashioning of these implements from both fresh and dry bones suggest some previous knowledge of available raw materials at the site, further reinforcing the possible connections between the multiple hunting events. Bone retouchers were an important complement to the Middle Pleistocene hominin tool-kit at Schöningen, especially considering the very small and rather expe-

dient lithic assemblage. Damage to the proximal and distal ends of metapodials in the assemblage implies their use as soft hammers, likely for more heavy-duty purposes. The scarcity of metapodials relative to other limb bones underscores their utility, some of which may have been transported away from the "Spear Horizon" for use at other locations across the landscape.

The Schöningen lakeshore was undoubtedly an attractive location on the landscape for horses both as a source of water and for feeding. Likewise, the Schöningen lakeshore was the focus of hominin hunting activities. The abundance of horses, together with the presence of other large mammals, birds, fish, and a variety of plants, certainly could have supported a modest population of resident hominins throughout all seasons of the year, as implied by the timing of individual deaths among the subadult horse population.

Particularly intriguing is how the Schöningen hominins were able to cope with the challenges of living at northern latitudes during the winter. Even during interglacial periods, low temperatures, snow cover, and reduced resource availability during winter would have posed serious threats to survival. These problems could be eased by a variety of technological buffers, cultural insulators, and other

adaptive strategies (Gamble 1987; Hosfield 2016; White 2006). The spears certainly attest to the technological prowess of the Schöningen hominins; add to that the use of bone tools, and it is clear that they possessed a broad knowledge of useful raw materials beyond stone. Based on the quantity and dense concentration of butchered horse bones, it is probable that multiple horse individuals were killed during each hunting episode. Such large quantities of meat may imply some level of food sharing and storage, which would have been a beneficial strategy during times of resource scarcity. Despite the excellent preservation at the site, various forms of cultural insulation, including fire, shelter, clothing, etc., are absent. Evidence of hearths in the “Spear Horizon”, once heralded as among the earliest indications of the controlled use of fire in Europe, has since been rejected (Stahlschmidt et al. 2015b). Indications for shelters and clothing are rare, if not entirely absent, at Middle Pleistocene archaeological sites, including the “Spear Horizon”. This could simply reflect the limited range of activities performed at the site and its lakeshore location. The Schöningen 13II-4 “Spear Horizon” likely represents a hunting and butchery site, thus providing only a glimpse of Middle Pleistocene hominin activities on the landscape. The prospect of a resident hominin population holds potential for identifying a variety of different activities and types of sites among the various Schöningen lakeshore localities.

## Conclusion

The Schöningen 13II-4 “Spear Horizon” discoveries reframed how archaeologists and paleoanthropologists viewed the physical and cognitive capabilities of Middle Pleistocene hominins, and hopefully informed the perceptions of pre-modern humans among the general public. As it stands, the “Spear Horizon” is anything but a simple Palaeolithic hunting and butchery site; rather, Schöningen preserves a very rich and complex record of Middle Pleistocene hominin adaptive behaviours. The Schöningen lakeshore was undoubtedly a dominant feature on the

interglacial landscape, a location with predictable resources that were exploited throughout the year by a variety of animal species, including hominins. Yet, like any other, the site only reflects a particular suite of behaviours at one point in space and time. Combined with the other high-resolution archives of hominin behaviour contained in this volume, a clear focus toward lakeshore environments is evident across much of Europe during Pleistocene interglacial periods and into the Holocene (Gaudzinski-Windheuser/Roebroeks 2010). Particularly intriguing are comparisons between Schöningen and the Eemian interglacial lakeshore site at Neumark Nord 2. The sites are analogous in their topographical lakeshore settings and associated interglacial fauna, but the level of carcass processing by hominins and subsequent carnivore activity is strikingly different. At Neumark Nord 2, the bones from all portions of mammal skeletons are more thoroughly processed than at Schöningen, and carnivore involvement with the faunal assemblage is minimal (Kindler/Smith/Wagner 2014). Despite broad environmental similarities between the sites, carcass processing strategies of Middle Pleistocene hominins, i.e., the time and energy expended to satisfy their nutritional needs, was clearly different. From such comparative studies of lakeshore sites, we can begin to appreciate the various ways in which our hominin ancestors viewed and adapted to similar interglacial environments over time.

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