



Mauer – the type site of *Homo heidelbergensis*: palaeoenvironment and age

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ABSTRACT

The mandible of *Homo heidelbergensis* was found 1907 in the sand pit Grafenrain at Mauer in coarse fluvial sands 24 m below the surface, deposited in a former course of the Neckar River. These 'Mauer sands' are overlain by a series of glacial-climate loess deposits with intercalated interglacial palaeosols, which can be correlated with Quaternary climate history, thus indicating an early Middle Pleistocene age for *H. heidelbergensis*. The 'Mauer sands' are famous for their rather rich mammal fauna, which clearly indicates interglacial climate conditions. The faunal evidence – in particular the micromammals – place the 'Mauer sands' into MIS 15 or MIS 13 although most stratigraphic arguments favour correlation to MIS 15 and therefore to an age of ca 600 ka.

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1. Introduction

The discovery of the mandible of a fossil hominid, known as *Homo heidelbergensis*, on 21st October 1907 in the sand pit 'Grafenrain' at Mauer, a village 16 km southeast of Heidelberg (Germany), was one of the milestones of research into human evolution. This sand pit was renowned for its Pleistocene vertebrate fauna already in the 19th century. The zoologist Heinrich Georg Bronn reported in his 1830 monograph 'Gaea Heidelbergensis', which contains also the first geological map of the area, the find of a fossil elephant tusk (Bronn, 1830).

Convinced by Darwin's descent theory, Otto Schoetensack, a palaeontologist from Heidelberg, began in 1888 to look for hominid remains in the sand pit at Mauer. In particular the find of *Elephas antiquus* in 1887 motivated him for this search, as Schoetensack (1908) noted "The proof of coexistence of man with *E. antiquus*... (at Weimar-Taubach)... made it a duty to search also in the Mauer sands for traces of man". Thus he trained the sandpit workers to recognize fossilized human material by showing them bones from human and apes. The fruits of his far-sighted persistence turned up nearly 20 years later, when the worker Daniel Hartmann noted the mandible on his shovel and immediately recognized the significance of his find, testified by his outcry "Today I found Adam". The following day

Schoetensack arrived at Mauer and found that indeed the discovered fossil mandible was a human one. It was found broken in two parts. A limestone pebble and sand were cemented on the teeth (Fig. 1). In order to dispel any doubts, which later might be raised, Schoetensack had the find verified in a notary's office. This document contains also a surveyor's plan with the exact position of the discovery site. One year later Schoetensack presented his famous monograph "The Lower Jawbone of *Homo heidelbergensis* from the Mauer sands near Heidelberg – A Contribution to the Palaeontology of Man". Schoetensack's approach was very modern. This can be seen from his use of X-ray exposures of the mandible in 1908 in order to study the roots of the teeth and compare them to those of a recent human. Schoetensack had also the courage to address this fossil as 'man' by classifying it into the genus *Homo*, essentially based on the highly evolved set of teeth. By creating the new species *heidelbergensis* he tried to express its morphological distance – apparent from the missing chin and the massive jaw bone, in particular its rising branches – to modern man, the *Homo sapiens*. Under the formal rules of naming species, the Mauer mandible is the type-specimen of the species *H. heidelbergensis*.

In 1909 Schoetensack donated the mandible of *H. heidelbergensis* to the University of Heidelberg, where it is still kept in the Geological Institute. Since its discovery no unequivocal additional human remains have turned up in Mauer despite of intense searching and of the recovery of numerous Pleistocene vertebrate bones and teeth. The sand quarrying at 'Grafenrain' was finally abandoned in the 1960s and the former sand pit is now a protected area, but still accessible for further research.

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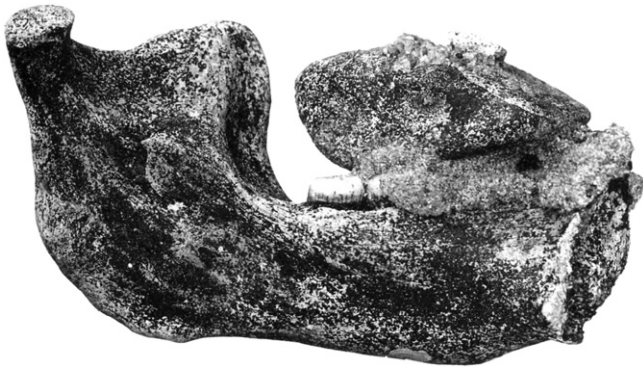


Fig. 1. Medial view of left half of *Homo heidelbergensis* mandible in original find condition with a 60 mm long limestone pebble cemented to the premolar teeth. (from Schoetensack, 1908).

2. Geology and geomorphology

The mandible of *H. heidelbergensis* was found in fluvial gravels and sands, called the 'Mauer sands', which are still exposed at a few places in the former sand pit. The geological succession of the Pleistocene sediments above the Triassic limestone consists essentially of 30 m fluvial sediments (gravel, sand and clay) covered by 12 m of loess with intercalated palaeosols (Fig. 2). The sands were deposited by the former River Neckar although the site is now situated 6 km south of the present day river course. This is evidenced by the petrographic composition of the gravels. Some pebbles are of crystalline nature and their source is securely attributed to the crystalline basement of the Odenwald Mountains, which are located in the catchment area of the Neckar River but not

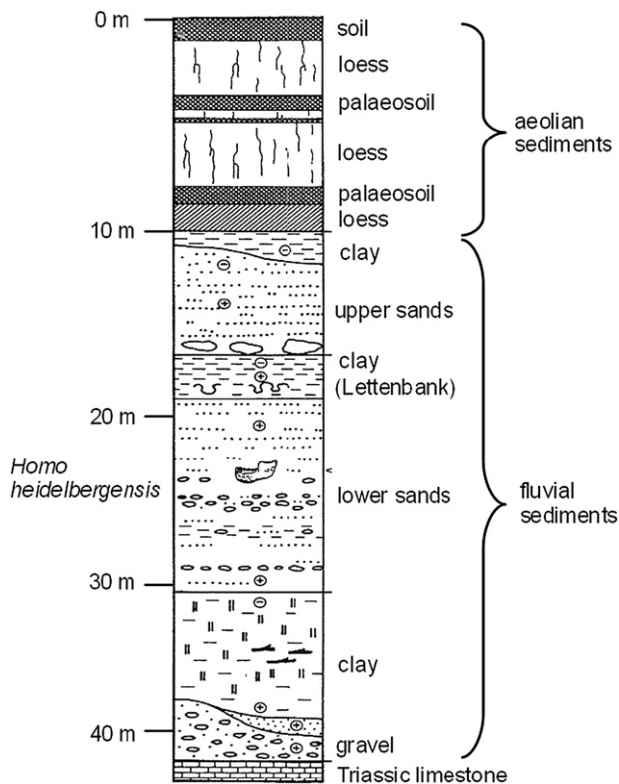


Fig. 2. Stratigraphy of the sand pit Grafenrain at Mauer. The *Homo heidelbergensis* mandible was found in the 'lower sands'.

in the catchment of the Elsenz River, which nowadays flows through Mauer (Sauer, 1898). At the time of deposition the Neckar was flowing through a large meander which later became cut off (Fig. 3). After the Neckar had abandoned the southern part of the meander several layers of loess were deposited during the glacial periods and soils developed on these deposits in the intervening interglacial periods.

The 'Mauer sands' are subdivided into the 'lower sands' (ca 10 m thick) and the 'upper sands' (up to 7 m thick) separated from each other by a ca 2 m thick clay/silt layer ('Lettenbank', Fig. 2). The 'lower sands' are composed predominantly of coarse quartz-grains and bear several thin clay layers as well as a few gravel beds. The pebbles of these gravels consist of Triassic sandstone and limestone, Jurassic limestone and, apart from the already mentioned crystalline components, Jurassic and Triassic flints (Löscher, 1997). The mandible of *H. heidelbergensis* was found in a 0.1 m thick gravel layer within the 'lower sands' 4.65 m below the 'Lettenbank' and 24.63 m below the ground surface (Schoetensack, 1908). The pebbles of this gravel layer are slightly cemented by calcium carbonate. At the present time all layers, from the 'lower sands' up to the surface are exposed, but not at the original discovery site of the mandibula. The present site is ca 100 m to the north. The stratigraphic succession and the levelling of the various layers of the 'lower sands' described by Schoetensack (1908) correspond to those exposed in present outcrop and the present site can be correlated with confidence with that described by Schoetensack.

In order to study the hitherto unexposed sediments below the sands two research boreholes were drilled in 1991 from the base of the 'lower sands' down to the bedrock (Middle Triassic limestone = Muschelkalk). They reach a depth of ca 10 m below the base of the quarry. The drill-cores retrieved various layers of clay in the upper part and sand as well as gravel in the lower part. These fluvial sediments provide information on the stratigraphy as well as the climatic and geomorphic history of the Mauer site for a period of ca 800 ka (Zöller and Stremme, 1992). According to this and other studies the Neckar meander underwent several cycles of erosion and sediment filling which reflect the climatic as well as the

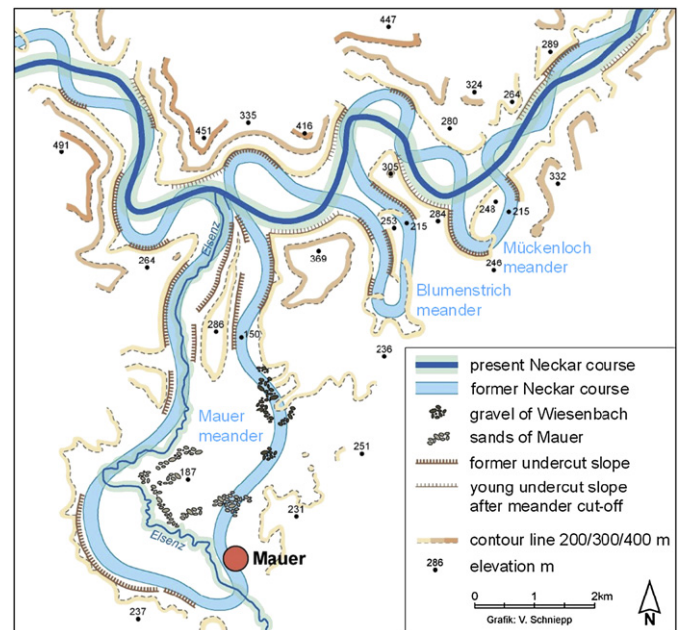


Fig. 3. The large Mauer meander of the former course of the Neckar River became later cut off. The 'Mauer sands' were deposited by the former Neckar around the southern tip of the meander. (after Eitel and Wagner, 2007).

tectonic dynamics of this region during the Quaternary. The final cut-off of the meander occurred between 250 and 150 ka ago (Eitel and Wagner, 2007).

3. *Homo heidelbergensis* of Mauer and its archaeology

Finds of fossil hominids are by nature very rare, and once found, they tend to be fragmentary. This is true for *H. heidelbergensis* at Mauer where only one single remain has been found. The mandible is well preserved (Fig. 4) and is interpreted as representing a male due to the massive size (Condemi and Koenigswald, 1997). Compared to modern man the Mauer mandible is larger and both branches are more widely opened. But this does not necessarily mean that *H. heidelbergensis* was taller in body size. The third molar, which emerges in modern humans around the age of 18 years, is already fully developed and shows traces of use. All teeth are abraded, but less at this molar, so the individual cannot be very old, probably between 18 and 25 years (Kraatz, 1992). Computer tomography revealed a healthy set of teeth, without any signs of caries, and that the Mauer man had suffered a fracture of the right branch of his jaw that later healed up (Kontny et al., 2007). Traces of dental wear are mainly horizontally aligned, possibly indicating a largely vegetable diet (Puech et al., 1982).

In order to assess the phylogenetic position of the Mauer find the mandible has to be compared with the few other Middle Pleistocene findings from Europe, such as, for instance, that from Arago. Condemi and Koenigswald (1997) used the profile of the chin region, the cross-section of the mandibular symphysis and the shape of the *ramus ascendens* for comparisons. Although the Mauer mandible is strikingly massive it shows similarities pointing to a European evolutionary development ending with Neanderthal man (Hardt and Henke, 2007).

Until few years ago, Mauer was known merely as palaeontological and anthropological site. However, with the discovery of various flint-tools Mauer became also an archaeological site. The matter is complicated by the fact that all the archaeology is situated within the context of a fluvial deposit, along with the mandible and other mammal bones. Since complete skeletons are missing, it is likely that the bones have been picked up by the river from the floodplain and the riverbank and transported a limited distance, probably not more than a few kilometres in view of their good preservation, and finally re-deposited. Such transportation would have been accompanied by abrasion, sorting and remixing. The

occasional finds of Palaeolithic flint tools imply that this part of the ancient Neckar meander included the habitat of *H. heidelbergensis*. However it must be stressed that taphonomic difficulties hamper any detailed reconstruction of the behaviour of *H. heidelbergensis*.

The Mauer area offered many resources for early man, including plants for food and tools, game for food as well as for clothing and pebbles for making stone implements. Although the pebbles in the 'lower sands' consist mainly of Triassic sandstone and limestone, the Triassic and Jurassic flint among them – despite of their small size of less than 5 cm – are suited for tool making. Altogether 36 artefacts – 31 close to the original discovery site of the mandible and 5 at the present outcrop – have been discovered, many directly in the find layer of *H. heidelbergensis*. Due to their small size they were not, for several decades, generally accepted as artefacts, but subsequently their archaeological origin has become accepted (Löscher et al., 2007). Some of them have very sharp cutting edges (Fig. 5). This implies that they were not transported by the river and probably were worked or used on the spot, that is on the sand bar, in which the mandible and the other bones were buried (Löscher et al., 2007). It is possible that *H. heidelbergensis* hunted with wooden spears, such as those discovered in Schöningen – a somewhat later Early Palaeolithic site in Lower Saxony (Thieme, 1997). Experimental studies have demonstrated that it is possible to cut functional spears from young spruce trees with replicas of the Mauer flint tools (Rieder and Eibner, 2007).

4. Fossil mammal fauna

The 'lower sands' – in particular the layers close to the find horizon of *H. heidelbergensis* – are famous for their rich mammal fauna. By now 5142 identifiable specimens of large mammals are documented (Schreiber, 2007, for an updated faunal list cf. Table 1, and a bibliography has been provided by Schreiber, 2006).

Relative to the study of the large mammals much less attention has, until now, been paid to the micromammals from Mauer (per definition here including the orders Eulipotyphla, Lagomorpha and Rodentia). The first remains of rodents to be recorded were the rather large mandibles and teeth of beavers (Freudenberg, 1922/23; Rüger, 1928; Mai, 1979). It was then Heller who started systematic collecting of micromammals in the 1930s. However, only 10 identifiable remains belonging to moles, voles and to a beaver were found (Heller, 1934, 1939a,b). Koenigswald (1973a, 1992, 1997) included Heller's finds in his analyses, along with new material subsequently found at Mauer. In his proposed stratigraphic succession Koenigswald (1973a) referred Mauer to 'Arvicola-Fauna type 1' (*Arvicola-Pliomys* Faunas).

With further studies new micromammal material has been found due to an intense sieving programme (Löscher and Unkel, 1997). Currently more than 3000 micromammal specimens are available comprising postcranial elements, fragments of jaws and isolated teeth. Ca 50% of this material can be identified as belonging to rodents and 5% to insectivores. Most of these finds have a length of between 2 and 10 mm. Ninety percent of all remains have been found in the 2–6 mm (fine gravel) grain size fraction with the other 10% in the 6–60 mm size fraction (middle and coarse gravel). The fraction <1.5 mm contains only tiny fragments of fossils, if any. The micromammal remains originate from a 1.2 m thick layer including the find level of the mandible (147.8 m ü. NN) and the sand and gravel bed directly above the mandible layer (Fig. 2).

5. The new micromammal material

In the new micromammal material (Fig. 6), remains of moles (Talpidae) are frequent (1/5 of specimens identifiable to species level). They belong to the dwarf mole *Talpa minor* and to *Talpa* cf.



Fig. 4. The present condition of the *Homo heidelbergensis* mandible. The two left premolars were lost in the 1940s. (photo: K. Schacherl).

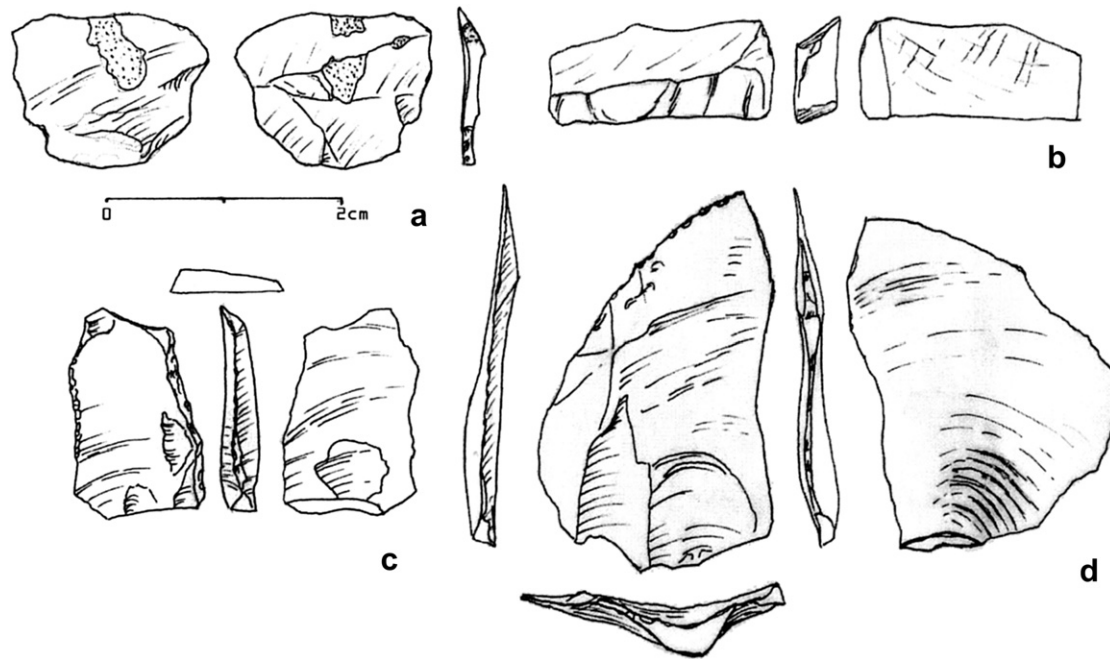


Fig. 5. Recently found flint artefacts from the *Homo heidelbergensis* horizon in the sand pit Grafenrain at Mauer. The cutting edges are still very sharp. (from Löscher et al., 2007).

europaea. Moles are indicators of loose ground (e.g., Rabeder, 1972) – neither too hard nor too moist. Shrews (Soricidae) are represented by few toothless mandible fragments, the sizes of which are similar to that of members of the red-toothed shrews of the genus *Sorex*. One

fragment can be determined as *Sorex* sp., whereas the fragmented mandible of another shrew can be referred to as *Sorex* (*Drepanosorex*) *savini* based on its size and the shape of the articular facets (Reumer, 1984). Due to the coarse surface of the molars, known from other sites, Reumer (1984) concluded an aquatic habitat and feeding on freshwater molluscs.

One lower molar can be attributed to a leporid, and is identified by its dimension as belonging to the genus *Lepus*. It remains unclear whether we deal here with the European (*Lepus europaeus*) or the Snow Hare (*Lepus timidus*) or another extinct species (*Lepus terraerubrae*) of that genus. Members of this genus are all more or less adapted to open habitats.

Petauria helleri is recorded from Mauer on the basis of three molars. Remains of this gliding squirrel are extremely rare in European Pleistocene sites and were known hitherto only from the German sites of Schernfeld (Dehm, 1962), Voigtstedt (Kretzoi, 1965) and Husarenhof 4 (Koenigswald, 1973b) as well as from the Polish locality Kozi Grzbiet (Black and Kowalski, 1974). *Petauria* was much bigger than the extant Eurasian species *Pteromys volans*. However, all gliding squirrels require trees to climb and are therefore indicators of wooded environment.

Beavers (Castoridae) are frequent in the 'Mauer sands'. *Castor fiber* is represented with 31 and *Trogotherium cuvieri* with 6 remains. Kretzoi (1969) recognized an evolutionary tendency in that the lateral incisions (striae and striids) of the cheek teeth grow deeper into direction of the crown base. According to Heinrich (1989) the most distal incisions (metastriid; Mtsd in Fig. 6s) on the lower p4 are the most indicative striids. Based on this argument, the specimens from Mauer are more evolved and therefore younger than the specimens from Süssenborn and older than those from Mosbach 2 and Bilzingsleben 2 (Maul and Heinrich, 2007). Also in *Trogotherium* morphological changes on the lower p4 can be traced during the Pleistocene. In faunas that are older than the Brunhes/Matuyama boundary only three lingual and one buccal re-entrant fold are developed (Heinrich, 1998). In younger faunas the percentage of premolars with an additional lingual fold (lingual anteroflexid resp. anterostriid; LAfd, LAsd in Fig. 6T, t) increases successively. This can be observed in the early Middle Pleistocene

Table 1
Mammal taxa recorded at Mauer.

Large mammals	Carnivora	<i>Canis lupus mosbachensis</i>	
		<i>Ursus thibetanus</i>	
		<i>Ursus deningeri</i>	
		' <i>Pliocrocota perrieri</i> '	
		<i>Panthera pardus sickenbergi</i>	
		<i>Panthera leo fossilis</i>	
		<i>Felis cf. silvestris</i>	
		<i>Felis issiodorensis</i>	
		<i>Homotherium latidens</i>	
		<i>Elephas antiquus</i>	
		Proboscidea	<i>Stephanorhinus hundsheimensis</i>
			<i>Stephanorhinus kirchbergensis</i>
		Perissodactyla	<i>Equus mosbachensis</i>
<i>Sus scrofa mosbachensis</i>			
Artiodactyla	<i>Hippopotamus amphibius</i>		
	<i>Cervalces latifrons</i>		
	<i>Cervus elaphus acoronatus</i>		
	<i>Capreolus suessenbornensis</i>		
	<i>Bison schoetensacki</i>		
	Micromammals	Eulipotyphla	<i>Talpa cf. europaea</i>
			<i>Talpa minor</i>
<i>Sorex</i> sp.			
Lagomorpha		<i>Sorex</i> (<i>Drepanosorex</i>) <i>savini</i>	
		<i>Lepus</i> sp.	
		<i>Petauria helleri</i>	
		<i>Castor fiber</i>	
		<i>Trogotherium cuvieri</i>	
		<i>Cricetus cf. runtonensis</i>	
		<i>Myodes acrorhiza</i>	
		<i>Pliomys episcopalis</i>	
		<i>Pliomys coronensis</i>	
		<i>Arvicola mosbachensis</i>	
<i>Microtus arvalinus</i>			
<i>Microtus arvalidens</i>			
<i>Apodemus cf. sylvaticus</i>			
Rodentia			

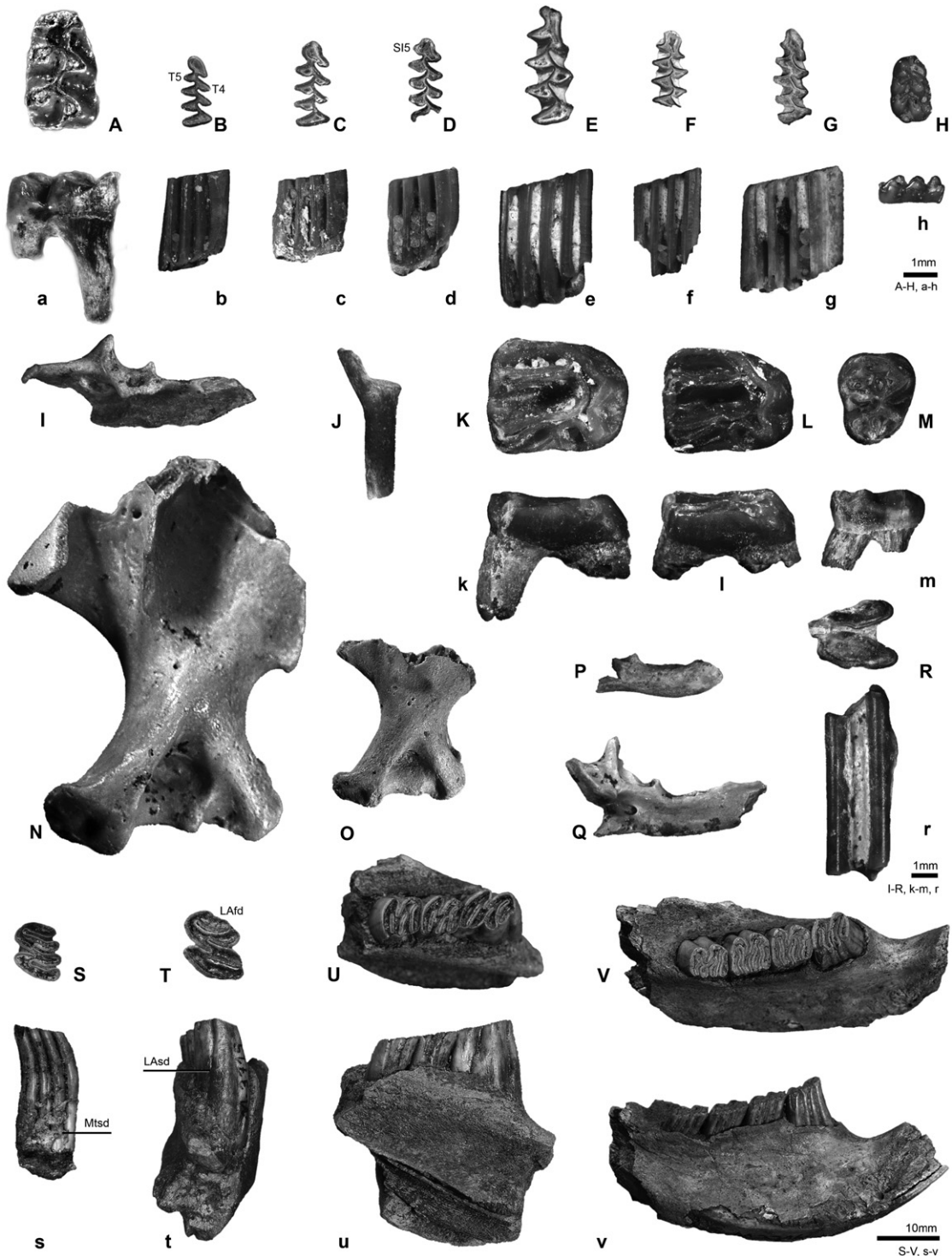


Fig. 6. New micromammal material from Mauer. A, a – *Cricetus cf. runtonensis*, B, b – *Myodes acrorhiza*, C, c – *Pliomys episcopalis*, D, d – *Pliomys coronensis*, E, e – *Arvicola mosbachensis*, F, f – *Microtus arvalinus*, G, g – *Microtus arvalidens*, H, h – *Apodemus cf. sylvaticus*, I–J – *Talpa* sp., K–M, k–m – *Petauria helleri*, N – *Talpa cf. europaea*, O – *Talpa minor*, P – *Sorex* sp., Q – *Sorex (Drepanosorex) savini*, R, r – *Lepus* sp., S, s, V, v – *Castor fiber*, T, t, U, u – *Trogontherium cuvieri*. A–H, a–h – lower m1, I – ulna fragment, J – radius fragment, K–L, k–l – upper M1/2, M, m – lower m3, N, O – humerus fragments, P, Q, U, V – mandible fragment, R – lower molar, S–T, s–t – lower p4. A–H, K–M, R–T – occlusal view, a–h, k–m, r–s, u–v – lateral view, t – mesial view. Abbreviations: LAfd – lingual anteroflexid, LAsd – lingual anteroincid, Mtsd – Metastrid, SI5 – 5th lingual syncline (re-entrant angle), T4, T5 – 4th and 5th dental field.

sites of Voigtstedt and Miesenheim 1, Mosbach 2 (Heinrich, 1998) and also in Mauer. Parallel to these changes the premolars increase in size. According to this value the specimens of Mauer are more developed than those from Voigtstedt, but more primitive than the remains from Bilzingsleben 2 (Heinrich, 1998; Maul and Heinrich,

2007). Fossil remains of beavers are generally considered as indicators of aquatic conditions (streams and lakes), although *Trogontherium* is less adapted to water bodies than *Castor* (Mayhew, 1979).

The hamster that is recorded in Mauer, *Cricetus runtonensis*, is slightly larger than the recent *Cricetus cricetus* but smaller than late

Middle and Late Pleistocene large hamster *Cricetus major* that was found in many remains, e.g., at Petersbuch 1 (Fahlbusch, 1976). Hamsters are adapted to open habitats.

Arvicolids are represented in Mauer by 6 species. *Myodes acrorhiza* is the phylogenetic ancestor of the extant *Myodes glareolus*. Typical for *M. acrorhiza* is that in lower m1 the dental fields T4 and T5 (Fig. 6B) are not completely separated (Carls and Rabeder, 1988). In central Europe bank voles are the only voles that live in wooded areas.

Pliomys has rooted molars that lack crown cementum in the re-entrant angles and possesses cutting edges thicker in the anterior part of each dentin field. In Mauer, *Pliomys episcopalis* and *Pliomys coronensis* are represented by 25 molars. Typically, the m1 of *P. coronensis* is characterized by the presence of a 5th lingual re-entrant angle (SI5 in Fig. 6C, D), whereas in *P. episcopalis* this element is lacking. Both *Pliomys* species became extinct in central Europe before the Elsterian glaciation (Koenigswald and Heinrich, 1999). Some 50 molars, most of which are fragmented, can be referred to as the fossil water vole *Arvicola mosbachensis* (for taxonomic reasons this name should be used instead of *Arvicola cantianus* resp. *Arvicola cantiana* or *Arvicola terrestris cantiana* – extended discussion see Maul et al., 2000). The ancestor of *Arvicola* with rootless molars is *Mimomys savini*, which has still roots on its cheek teeth. The members of the water-vole lineage display a tendency in which for the enamel thickness between the posterior and anterior edges to change successively (Koenigswald, 1973a; Heinrich, 1978). Differences in the enamel thickness have long been recognized as a property by which it is possible to distinguish species and the geological age of water voles (Hinton, 1926; Heller, 1933; Koenigswald, 1973a). Heinrich (1978) has quantified this trend and introduced the SDQ ratio (enamel differentiation quotient), which is the thickness of the posterior expressed as a percentage of the thickness of the anterior cutting edges of the lower molars. This ratio has enabled a precise chronological order to be applied to populations of water-vole populations, while molars with an SDQ >100 are referred to as *A. mosbachensis*, such with values <100 to as *Arvicola terrestris* (for Central Europe, Heinrich, 1978). In samples from the early Middle Pleistocene these values range from 130 to 140, at the end of the Upper Pleistocene and Holocene they are clearly below 100. *Arvicola* from Mauer has an SDQ of 140, confirming the early Middle Pleistocene age of this site. Due to the abundance of fossil remains of *M. savini* in aquatic sediments of various sites (e.g., Budakalász in Hungary, Voigtstedt in Germany) Jánossy (1962) concluded a general adaptation for all members of the water-vole lineage to a semiaquatic habitat. It is also possible that *A. mosbachensis* from Mauer can be considered as a semiaquatic animal.

In *Microtus* an increased complexity and elongation the anterior portion (anteroconid complex) of the lower m1 can be observed in the course of evolution. The increase of relative length of the anteroconid complex was documented first by van der Meulen (1973) who devised the so called A/L-Index. On the basis of this ratio a relative order of *Microtus*-finds of different age is possible. The remnants of *Microtus arvalinus*, the ancestor of the recent field mouse (*Microtus arvalis*), are recorded at Mauer. They differ from the recent related forms because of smaller dimensions and lower (therefore more primitive) A/L-values. On the other hand, *M. arvalinus* from Mauer is less evolved than the material from Mosbach 2 and Petersbuch 1. In principal, the same is true for *Microtus arvalidens*, the second *Microtus*-species recorded from Mauer. This species leads to the extant European Pine vole (*M. subterraneus*). Here the A/L-values are also more primitive than those from the site of Petersbuch 1. Species of the genus *Microtus* are mostly adapted to open habitats.

Muridae are recorded in Mauer with several incisor fragments and one lower first molar. The latter is within the range of size and morphology of both *Apodemus sylvaticus* and *A. flavicollis*. However, the m1 length (1.82 mm) better fits the range of *A. sylvaticus* (Maul and Parfitt, 2009). Therefore the molar is assigned to *Apodemus* cf. *sylvaticus*. Wood mice are recorded from sites throughout the Pleistocene and therefore have little stratigraphic meaning. Ecologically the species of *Apodemus* are typically inhabitants of wooded areas, although *A. sylvaticus* is associated with forest margins.

6. Palaeoenvironment

Due to their stratigraphic association with the mandible of *H. heidelbergensis* the analysis of the mammal fauna from the 'lower sands' allows – within limits – the reconstruction of his palaeoenvironment. In the large mammal fauna several taxa are climate-sensitive and indicate the presence of temperate-climate conditions. These are hippopotamus (*Hippopotamus amphibius*), wild boar (*Sus*), roe deer (*Capreolus*), straight tusked elephant (*E. antiquus*), forest rhino (*Stephanorhinus hundsheimensis* and *Stephanorhinus kirchbergensis*) and red deer (*Cervus*). The presence of hippopotamus indicates open waters that did not freeze permanently in wintertime and therefore the existence of higher mean annual temperature or other factors, which cause milder winters than today. The finds of deer, stag and elk point to a wooded landscape with open spaces. Bison (*Bison schoetensacki*) and especially horses (*Equus mosbachensis*) indicate open habitats.

As discussed above, the micromammal fauna from Mauer also contains taxa such as *Petauria*, and *Myodes* that can be interpreted as forest dwellers, and others indicating open areas (*Lepus*, *Cricetus*, *Microtus*). Representatives of aquatic habitats are *Drepanosorex*, *Castor*, *Trogontherium* and possibly also *Arvicola*. Cold and/or continentally adapted species are completely missing among both large and small mammals. Therefore, the environment can be described as a forest-covered floodplain, forest at the hillside slopes and more open wooded areas on the hills. Thus, *H. heidelbergensis* lived apparently in a warm-temperate climate, with a mean annual temperature only little above that of the present day (Koenigswald, 1997). The landscape, accessible to *H. heidelbergensis* at Grafenrain, was a wide river plain near the southern tip of a meander. In the meandering riverbed there were active sand bars that would occasionally become flooded. As the artefact finds indicate, humans inhabited and used the floodplain, probably for hunting and fishing as well as for manufacturing tools from flint pebbles (Löscher et al., 2007). At the riverbank, in the forests and in the open areas, habitats were available with their rich game and wood resources. Contemplating also the mild climate conditions it appears that the site was quite a favourable environment for early humans.

There have been also attempts to reconstruct the climatic conditions before and after the period represented by the 'lower sands', whereby faunal, pollen-analytical, sedimentological and pedological data have been taken into account. Based on pollen in the clays below the 'lower sands', Zöller et al. (2007) concluded that this period had been preceded by climatic changes from a cool-temperate forest period, through a cooler steppe period and to a temperate forest period again.

After the deposition of the 'lower sands' the climate turned to cooler conditions. The Lettenbank contains in its lowest part spruce-pollen probably from a temperate forest period (Urban, 1992) developing into a cool steppe-climate indicated by cryoturbation-like structures and grass-phytoliths (Zöller and Stremme, 1992). Traces of soil formation within the top of the Lettenbank may represent a succeeding interglacial period. The lowest horizon of the overlying 'upper sands' with ice-rafted

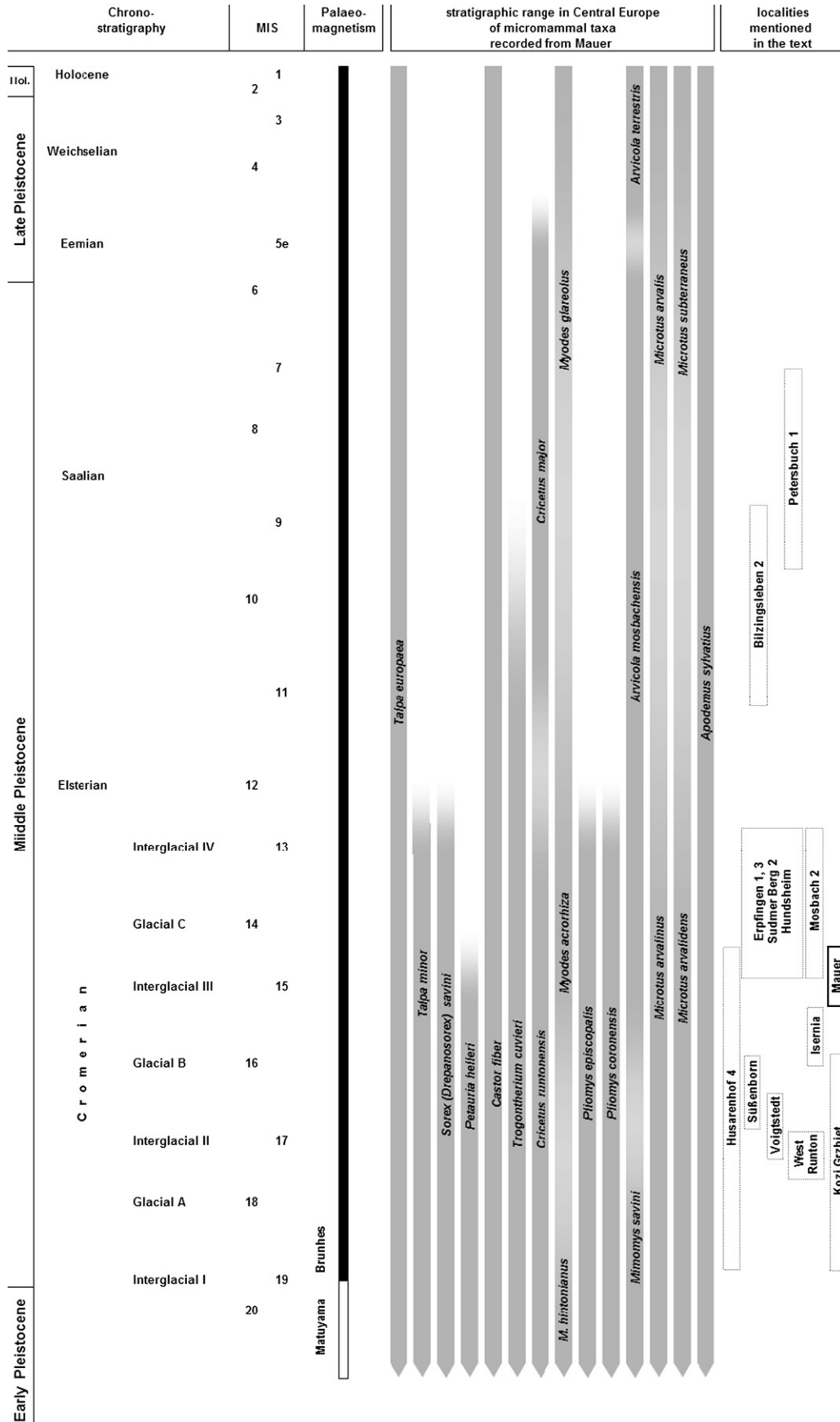


Fig. 7. Stratigraphic ranges of the micromammal taxa recorded from Mauer (for references cf. Schreiber et al., 2007).

sandstone-boulders probably represents a cold climate (Zöller and Stremme, 1992). The climatic conditions that existed during the deposition of the ‘upper sands’ may reveal a climatic change to a warmer period similar to the ‘lower sands’, because of the persistence of some faunal elements (like *E. antiquus*, *S. hundsheimensis*, *B. schoetensacki*, *Cervalces latifrons*) and traces of soil formation in the top.

7. Chronology

Several attempts, both stratigraphic and radiometric have been undertaken to date *H. heidelbergensis* at the sand pit Grafenrain at Mauer. Based on the mammal fauna of the ‘lower sands’, Schoetensack (1908) already correlated Mauer with the ‘preglacial Forestbeds’ of Norfolk, England and thus concluded – in recent terminology – an early Middle Pleistocene age. Although desirable, the direct radiometric dating of the mandibula is not possible, and the accompanying fossils as well as the embedding sediments have to be employed instead.

Palaeomagnetic results on all suitable argillaceous sediments of the former Neckar in Grafenrain show normal polarity, thus they belong to the Brunhes chron and are younger than 780 ka (Hambach, 1996). Since the ‘lower sands’ are underlain by normally magnetized clays, they must be preceded by at least one cool period, based on pollen analysis, and thus their maximum age is MIS 17.

The 40 m thickness of sediments at the Grafenrain section – excluding the uppermost loess – belong to the Middle Pleistocene. The ‘Mauer sands’ are overlain by a series of glacial-age loess deposits intercalated by interglacial palaeosols which can be correlated with the Quaternary climate changes. Together with the climatically and tectonically driven development of the former Neckar meander, an early Middle Pleistocene age can be derived for the ‘Mauer sands’. In this scheme the climatostratigraphic minimum age of the ‘lower sands’ is MIS 13, since the overlying sediments, in particular the loess/palaeosol sequences, represent at least five glacial/interglacial cycles (Zöller, 1997).

A biostratigraphical age is considered to provide only a relative order. However, in most cases fossils – in particular those of micromammals – are indicators for palaeoclimatological succession and therefore can provide important information for chronological inferences. In this way, the minimum age of Mauer can be inferred from known last occurrence dates of particular taxa (Fig. 7). According to the present knowledge, in central Europe *P. episcopalpis*, *P. coronensis*, *Sorex (Drepanosorex) savini* and *Petauria* all predate the Elsterian, which is correlated with MIS 12 (Gibbard et al., 2007). Therefore an age not younger than MIS 13 can be concluded for Mauer. This confirms the minimum age estimation by above mentioned climatostratigraphic arguments.

The maximum age of Mauer can be inferred from the presence of *A. mosbachensis*. The first appearance of *Arvicola* is defined by its transition from its rooted phylogenetic ancestor *M. savini*. Koenigswald and Kolfshoten (1996) inferred the date of the transition from *M. savini* to *A. mosbachensis* in central Europe from records of *Mimomys* in the site of Kärlich F, which is referred to Cromerian Interglacial II (correlated with MIS 17, Gibbard et al., 2007) and Kärlich G with *Arvicola*, which is dated into Interglacial III (correlated commonly with MIS 15, Koenigswald and Kolfshoten, 1996). This inference was confirmed by the dating of the fossiliferous layer at Isernia, southern Italy, (Fig. 8) that also includes *Arvicola* and is placed by Ar–Ar-dating of sanidine into MIS 15 (610 ± 10 and 606 ± 2 ka, Coltorti et al., 2005). Moreover, both the sites of West Runton Freshwater Bed in East Anglia (England) and Voigtstedt in Thuringia (central Germany) yielding *M. savini* are placed into the palaeomagnetic Brunhes chron and therefore are

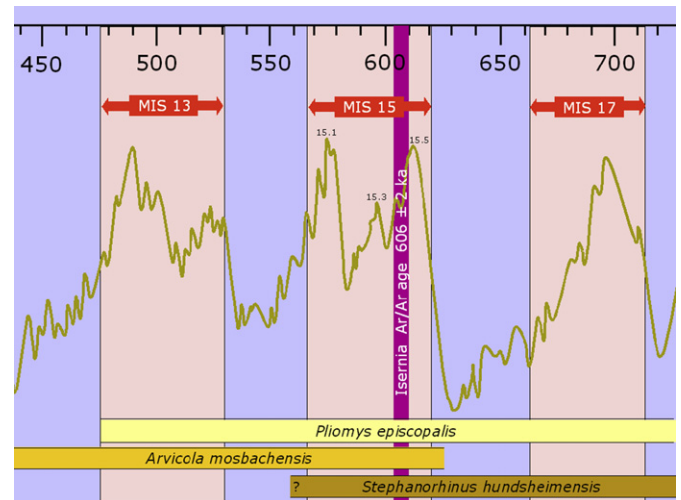


Fig. 8. Ar/Ar-ages (610 ± 10 , 606 ± 2 ka, Coltorti et al., 2005) of the palaeolithic site Isernia/Italy and the marine isotope curve in the section from 720 to 440 ka (numbers at the top). The numeric dating assigns this site with the overlapping occurrence of the moles *Pliomys* and *Arvicola* clearly to MIS 15, likely even to the end of substage MIS 15.5. (from Wagner, 2007).

not older than the upper part of MIS 19 (Maul and Parfitt, 2009). Since West Runton represents an early stage of an interglacial, it is most likely to be correlated to MIS 17 (Maul and Parfitt, 2009). Thus, the transition from *Mimomys* to *Arvicola* seems to occur consistently after MIS 17. However, it must be noted that this transition was possibly not synchronous in all Europe, e.g., at least in eastern Europe it seems to have been later (Maul and Markova, 2007).

The faunal spectrum alone is not sufficiently indicative for a decision between interglacials MIS 15 and MIS 13. Micromammal taxa as *A. mosbachensis*, *Pliomys* and *Drepanosorex*, recorded at Mauer, are also known from other sites: Mosbach 2 (Heller, 1933; Maul et al., 2000), Erpfingen 1 and 3 (Heller, 1936, 1958), Sudmer Berg 2 (Koenigswald, 1972) and Husarenhof 4 (Koenigswald, 1973b) in Germany, Hundsheim (Frank and Rabeder, 1997) in Austria, Brasov (Kormos, 1933) in Romania and Isernia (Maul et al., 1998a) in Italy. Although the species spectra from the various sites are similar, the age referral of Isernia serves only within limits to date the other faunas. Judging from the species content, all these faunas might be included in MIS 13 or 15.

Nevertheless, a correlation of the micromammal fauna of Mauer with MIS 15 is more likely than with MIS 13 (Maul and Heinrich, 2007; Schreiber et al., 2007). As discussed above, some of the micromammal species underwent continuous evolutionary changes. In particular the continuous decrease of the SDQ in *Arvicola* is indicative for the relative order of faunas. The SDQ value from Mauer is 140, from Isernia 130 (Maul et al., 1998b) and from Mosbach 2 it is 133 (Maul et al., 2000). The more primitive values of Mauer in comparison to Mosbach 2 might indicate a slightly older age. Regional differences may be the reason why Isernia has lower values despite of its greater age. *Arvicola* from both Mauer and Isernia are very primitive. Some specimens of the sample still display incipient root creation. Also other micromammal taxa suggest a reference rather to MIS 15 than MIS 13: according to the evolutionary level of the remains of *Castor* and *Trogotherium* Mauer would be older in comparison to Mosbach 2. Also the occurrence of *Petauria* leads to the conclusion of a rather close relation in age with Voigtstedt, thus being older than the other mentioned faunas.

Among large mammals, *E. antiquus* and *S. hundsheimensis* occur in Mauer as well as in Mosbach 2 (Koenigswald and Heinrich, 1999).

However, in Mauer *S. hundsheimensis* is much more abundant in comparison to only few remains of *S. kirchbergensis* (Schreiber, 2005). In Mosbach 2 they occur in equal numbers. The differences in abundance could be due to a somewhat older age of Mauer (cf the hypothesis that during evolution species populations start with smaller numbers, Vrba and DeGusta, 2004). However, differences could also confirm the assumption that Mosbach 2 represents a longer time interval than Mauer.

Summarising the evidence of both the micro and large mammals, the time interval of the origin of the 'Mauer sands' can be limited to MIS 13 or 15, with the higher probability to the older age. When allocated to MIS 15, the age of the 'lower sands' of Mauer are thus astronomically dated to between 568 and 621 ka (Fig. 8).

There have been a number of attempts at radiometric dating, work is still in progress. ESR and $^{230}\text{Th}/^{234}\text{U}$ dating of an elephant tooth gave ages of >300 ka, and TL-dating of potassium feldspar grains from the 'Mauer sands' gave age estimates of between 400 and 700 ka (Wagner et al., 1997). Current studies involve the application of the combined ESR/U-series technique on mammal teeth and infrared radiofluorescence on feldspar grains from the 'Mauer sands'.

8. Conclusion

One century of research at Mauer has revealed that 600,000 years ago *H. heidelbergensis* was already present on the European stage. Other well known fossil occurrences of *H. heidelbergensis* in Europe are Caune de l'Arago (France), Sima de los Huesos (Spain) and Boxgrove (England), but it is not yet clear whether they are contemporaneous with Mauer, and indeed it is more likely that they are younger. However, the *H. heidelbergensis* from Mauer certainly is not any more the earliest human in Europe – as was believed for a long time. Earlier human fossils are now known from Spain (Atapuerca) and also from Italy (Ceprano). But so far, it still is the earliest individual discovered north of the Alps and the Pyrenees.

Most scholars agree on a speciation event in Africa about 800 ka ago when *Homo erectus* gave rise to a new species (e.g., Hardt and Henke, 2007). Some call this new species *H. heidelbergensis* (Rightmire, 1998), while others have proposed *Homo rhodesiensis* (McBrearty and Brooks, 2000) or archaic *H. sapiens* (Bräuer, 1984). The new species expanded around 700–600 ka ago to Europe, and its first definite fossil evidence is the type-specimen from Mauer, where it was already in 1908 named *H. heidelbergensis*.

It is generally believed that this Middle Pleistocene species is the ancestor to the Neanderthal lineage in Europe, whereas in Africa *H. rhodesiensis* evolved into *H. sapiens*. Apparently after about 500 ka ago the two lineages evolved separately from each other (Hublin, 1998). The fact that the genetic exchange between the European and the African lines apparently became largely interrupted might have been caused by severe climatic changes. Starting with MIS 12 the glacial periods became colder and large continental ice-sheets repeatedly covered northern and central Europe. Glaciers from the Alps moved into the forelands leaving only narrow ice-free corridors in central Europe from time to time. *H. heidelbergensis* had to develop his own survival strategies that probably isolated him. In any case, *H. heidelbergensis* plays a prominent role in the conceptions of man's past. In this sense, the Mauer find belongs, not only for historic reasons, together with those of Neanderthal and of Trinil in Java to the classical hominid finds.

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