

Ann Forsten
Zoological Museum, Helsinki

The horses (genus *Equus*) from the Middle Pleistocene of Steinheim, Germany

Forsten, A., 1999 - The horses (genus *Equus*) from the Middle Pleistocene of Steinheim, Germany – in: Haynes, G., Klimowicz, J. & Reumer, J.W.F. (eds.) – MAMMOTHS AND THE MAMMOTH FAUNA: STUDIES OF AN EXTINCT ECOSYSTEM – DEINSEA 6: 147-154 [ISSN 0923-9308]. Published 17 May 1999.

The Middle Pleistocene site Steinheim an der Murr, Germany, yielded sparse fossil bone materials representing *Equus hydruntinus*, but a rich sample of the caballoid horse, *E. steinheimensis*. The latter taxon's bones were analysed and are shown here to be similar to other caballoids from the same and later time interval. Its taxonomic position is unclear, as is true for other Middle and Later Pleistocene horses.

De paarden (genus Equus) uit het Midden Pleistoceen van Steinheim, Duitsland – Uit de Midden-Pleistocene vindplaats Steinheim an der Murr, Duitsland, is een gering aantal overblijfselen bekend van *Equus hydruntinus*, en een rijk monster van de caballoide ('echt' paard) *E. steinheimensis*. De botten van deze laatste soort worden bestudeerd en er wordt aangetoond dat ze niet verschillen van de botten van andere caballoide paarden uit dit en uit jongere tijdsintervallen. De taxonomische positie is, zoals gebruikelijk voor Midden- en Laat-Pleistocene paarden, onduidelijk.

Correspondence: Ann Forsten, Zoological Museum, P.O. Box 17, FIN-00014 Helsinki, Finland

Keywords: *Equus*, Steinheim, Middle Pleistocene

INTRODUCTION

The Middle Pleistocene fossil locality Steinheim an der Murr, Württemberg, Germany, is well-known for its hominid finds. The horses from this locality are not as well studied as the hominid, although *Equus steinheimensis* VON REICHENAU has been referred to also in faunas from elsewhere: from Achenheim by Wernert (1957), from Fontéchevade by Arambourg (1958) and Prat (1968), from Chatillon-St.-Jean by Mourer-Chauviré (1962, 1972), from Abimes de la Fage by Bouchud (1972), from Sindomic and Bodoc by Samson (1975), and from Heppenloch by Adam (1975). *Equus steinheimensis* has never been characterized on the basis of the total hypodigm (type

sample) from Steinheim, only on single specimens (Soergel 1911, Reichenau 1915). As a result, there are misconceptions regarding this horse and its position in *Equus* phylogeny. The hypodigm is quite rich as fossil samples go. It is worth an analysis and comparison, aiming at putting *E. steinheimensis* in its proper place among other Middle Pleistocene caballoid or true horses. At the same time, some of the misconceptions regarding this horse may be removed. This is the purpose of my paper. It should be mentioned that the fauna of Steinheim also comprises *E. hydruntinus* REGALIA, not heretofore described from this locality, although Stehlin & Graziosi (1935) referred to *E. hydruntinus*

from the Murr. The fossil sample from Steinheim is kept in the Staatliches Museum für Naturkunde, Stuttgart, Germany.

STRATIGRAPHY

The stratigraphy of Steinheim is complicated (Adam 1954). The fossil elephants of the site would indicate deposition during a long period of time. Thus Adam (1954) recognized four gravel beds, each characterized by its typical elephant, from the lowermost, pre-Holsteinian, 'Ältere Mammut-Schotter' with *Mammuthus trogontherii* (POHLIG) to the uppermost, Würmian, 'Jüngere Mammut-Schotter' with typical *M. primigenius* BLUMENBACH. The two middle beds, the 'Waldelefant-Schotter' with *Elephas antiquus* (FALCONER & CAUTLEY) and the 'Haupt-Mammut-Schotter' with a transitional form *M. trogontherii-primigenius*, corresponding to the Holsteinian interglacial and the Saalian glacial respectively, are the richest in fossils. Presumably the horse material comes mainly from these middle beds, although this is not certain since the specimens are not identified as to their stratigraphic origin. It could be expected from the long period of deposition of the site that the horse material, if deriving equally from all levels, would be metrically and morphologically heterogeneous.

HISTORY OF TAXONOMIC WORK

Soergel (1911) differentiated *Equus* sp. from the 'older beds' and *E. cf. germanicus* NEHRING from the 'younger beds' of Steinheim, mainly based on the morphology of the teeth; a single jaw was identified as *E. cf. germanicus*. Soergel believed that he had found some important characters showing gradual evolution during *Equus* phylogeny, viz. decrease in relative length of the premolar row and increase in length of the lobus tertius (= talonid) of m3. Increase in m3 length in the stratigraphically younger representatives of *Equus* would increase the length of the lower molar row, m1-m3, in relation to the premolar row, p2-p4. Soergel did not discuss similar changes in the upper tooth row,

which for functional reasons must change in a corresponding way. My data on fossil and recent horses do not support Soergel's conclusions (Forsten, 1982). A long M3/m3, particularly a long talon/talonid of M3/m3, is a senile feature typical of the much worn dental battery of the hypsodont horses. Due to the curved shape of the crown of M3/m3, the trigon/trigonid of this tooth begins to wear well before the talon/talonid, which only gradually comes into wear. M3/m3 is also the only tooth in the cheek tooth battery, which becomes longer towards the base of the crown, thus increasing in length with wear. All the other cheek teeth taper towards their base and become shorter when worn down. Although the premolars, irrespective of wear, are always larger, i.e. longer and broader, than the molars, in the much worn cheek tooth battery the molar row may almost equal the premolar row in length solely due to the increase in M3/m3 length. The size of M3/m3 depends on the horse's individual age and the over-all size of the teeth. This character has no taxonomic or phylogenetic value (see also Hay 1915: 566-567).

Reichenau (1915) erected a new species and subgenus *E. (Euhippus) steinheimensis* for the horse from Steinheim. In his brief description he stressed the short protocone, the weak styles of the premolars, and the weak grooving of the mesostyle. The subgeneric name he used for the first time on p. 131 without a diagnosis. He then repeated *Euhippus* on p. 150 as a collective name for 'Die Edelpferde' (the noble horses), including for instance the Arabian domestic breed, mainly characterized on their skull. Reichenau's sample from Steinheim consisted only of teeth and was very small. It is evident that he was not familiar with the range of morphological variation in the total dental material.

Soergel's (1911) and Reichenau's (1915) descriptions and their choice of specimens illustrated in their plates have left the impression that *E. steinheimensis* has upper cheek

Table 1 Occlusal measurements on the cheek teeth, enamel to enamel; *E. steinheimensis*. Measurements in cm.

tooth	N	M ± mean error	s.d.
P ² length	22	4.01 ± 0.04	0.174
breadth	31	2.71 ± 0.03	0.150
P ³⁻⁴ length	92	3.12 ± 0.02	0.174
breadth	76	2.90 ± 0.02	0.156
M ¹⁻² length	85	2.78 ± 0.01	0.129
breadth	70	2.72 ± 0.01	0.118
M ³ length	16	2.88 ± 0.05	0.197
breadth	26	2.32 ± 0.03	0.132
protoc. l.	163	1.40 ± 0.01	0.129
plicat.n.	123	9.22 ± 0.23	2.550
P ₂ length	10	3.58 ± 0.05	0.148
breadth	13	1.59 ± 0.02	0.060
P ₃₋₄ length	46	3.04 ± 0.02	0.161
breadth	43	1.72 ± 0.02	0.101
M ₁₋₂ length	32	2.78 ± 0.03	0.162
breadth	33	1.55 ± 0.01	0.074
M ₃ length	14	3.34 ± 0.04	0.158
breadth	21	1.40 ± 0.02	0.083

teeth with a short protocone and weakly grooved labial styles (Gromova 1949a,b, but see Soergel 1911: taf. 33/34: 5,1, for grooved styles of P3-4). Both characters are considered primitive. *Equus steinheimensis*, although a truly caballoid horse, has been characterized as 'a slowly evolving branch of *Equus*', more primitive than its predecessor *E. mosbachensis* REICHENAU, and closer to the Pliocene non-caballoid *E. stenorhis* COCCHI (Gromova 1949a,b, Prat 1968).

ANALYSIS AND COMPARISON

The caballoid horse (*Equus steinheimensis*)

I measured the permanent cheek teeth at the tooth base and at the occlusal surface excluding cement; the measurements are given in cm (Table 1). The limb bones (Table 2) I measured mainly following Gromova (1949a,b). I first analysed the horse sample from Steinheim for homogeneity by doing scatter plots and frequency diagrams on the measurements of the teeth and limb bones. In spite of the evidently long period of deposition, as reflected in the evolution of the fossil elephants, the horse sample is not strongly heterogeneous, indicating that it derives from only a limited part of the sequence of the site. Alternatively there was little evolutionary change in the horses, in spite of evolution in the elephants. Among the teeth a few specimens are large and fall outside or at the upper limit of the main scatter when plotted for breadth to length or for protoconal length to occlusal length; a few specimens may be 'small', but overlap with the main scatter. There are no morphological differences. Among the limb bones different size categories cannot be distinguished. In calculating the statistical parameters for the teeth, I discarded clearly large specimens (right and left P3-4 nos.32803-160 and 33074-2, right M2 no.32803-52), but included 'small' ones (right M1-2 no.32917-16 and left P3-4 no.32917-12, both from the Murr, and right P3-4 no. 32803-67) since not clearly aberrant.

The analysis and the morphological and metrical comparison of the sample of the caballoid horse from Steinheim show that it fits well into the sequence of Pleistocene caballoids of Eurasia. Nothing indicates that this horse is more primitive than its predecessors or successors. The protocone mean length (1.40 ± 0.01 cm, n=163) is comparable to that in other caballoids of equal size. The labial styles of the upper premolars are grooved or, in rare cases, flattened. The styles in the upper molars are often simple or grooved only basally, but this is the case also in other caballoids.

Table 2. Measurements in cm on the limb bones; *E. steinheimensis*.

bone/variante	N	M ± mean error	s.d.
MC III l.	7	24.3 ± 0.22	0.601
prox.br.	11	5.42 ± 0.05	0.158
prox.diam.	10	3.68 ± 0.05	0.163
dist.art.	12	5.48 ± 0.05	0.178
dist.prot.	12	5.38 ± 0.06	0.197
keel diam.	11	4.01 ± 0.05	0.158
mid-shaft	3	3.93 ± 0.05	0.133
MT III l.	13	29.3 ± 0.32	1.139
prox.br.	20	5.59 ± 0.06	0.266
prox.diam.	17	5.03 ± 0.06	0.239
dist.art.	13	5.47 ± 0.06	0.204
dist.prot.	18	5.44 ± 0.05	0.199
keel diam.	10	4.10 ± 0.07	0.234
mid-shaft	12	3.87 ± 0.03	0.121
Phalanx 1 l.	25	9.13 ± 0.08	0.378
mid-shaft	42	3.99 ± 0.03	0.176
Phalanx 2 l.	5	5.10 ± 0.14	0.310
mid-shaft	6	4.98 ± 0.09	0.228
Astragalus			
dist.art.	12	5.83 ± 0.10	0.346
height	15	6.71 ± 0.08	0.302
Calcaneum			
height	4	12.09 ± 0.22	0.448
tuber a-p.	6	4.90 ± 0.04	0.091

I compared the main sample of the teeth (Fig. 1) and the limb bones (Fig. 2) from Steinheim with dental and/or limb bone samples from Mosbach (dental occlusal measurements according to Eisenmann 1980, 1981), Mauer, Frankenbacher Sande, Pfrimm bei Kriegesheim, Bilzingsleben, and Vertesszöllös, iden-

tified as *E. mosbachensis* (Reichenau 1915, Thies 1926, Weiler 1931, Kretzoi 1990, Musil 1991), and from Ehringsdorf, called *E. taubachensis* FREUDENBERG (Musil 1968), and with limb bone samples from Achenheim, called *E. achenheimensis* NOBIS (Nobis 1971, data Crégut 1979), from Chatillon St.Jean, called *E. cf. steinheimensis* (Mourer-Chauviré 1972), from Arago, called *E. mosbachensis tautavelensis* (Crégut 1979), and from Lunel Viel I and IV, called *E. mosbachensis lacustris* (Bonifay 1980). Both the limb bones and the teeth (measured at the base as well as occlusally excluding cement) from Steinheim are smaller than in the classical samples of *E. mosbachensis* (Figs. 1, 2). For a comparison in the phenograms there are not enough limb bones from Bilzingsleben and Vertesszöllös, but the single MT III (Hungarian National Museum, V69-798) and metapodial fragments from Vertesszöllös II ('Janossy's locality') are as large as those from Mosbach, although proximally very flat; the single MC III (no. 174.114) from Bilzingsleben is very massive. The teeth from Bilzingsleben are large, while those from Vertesszöllös are relatively small, similar to those from Steinheim (Fig. 1). The limb bones from Ehringsdorf are like those of *E. mosbachensis*, as are the teeth occlusally (Figs. 1, 2). Measured at the base, the teeth from Ehringsdorf are relatively small, resembling those from Steinheim and Vertesszöllös.

The horse from the Holsteinian of Heppenloch, although referred to as *E. steinheimensis* (Adam 1975), differs from the latter in being much larger. The left MT III (Naturmuseum Stuttgart no. 7590) is comparable only to those of *E. mosbachensis* from the classical localities and from Vertesszöllös. The astragali and phalanx 2 fall in the upper range of or beyond those from Steinheim.

I did not compare the French samples for their dental data, since the published occlusal measurements appear to include the cement, but used data on the limb bones (Mourer-Chauviré 1972, Crégut 1979, Bonifay 1980).

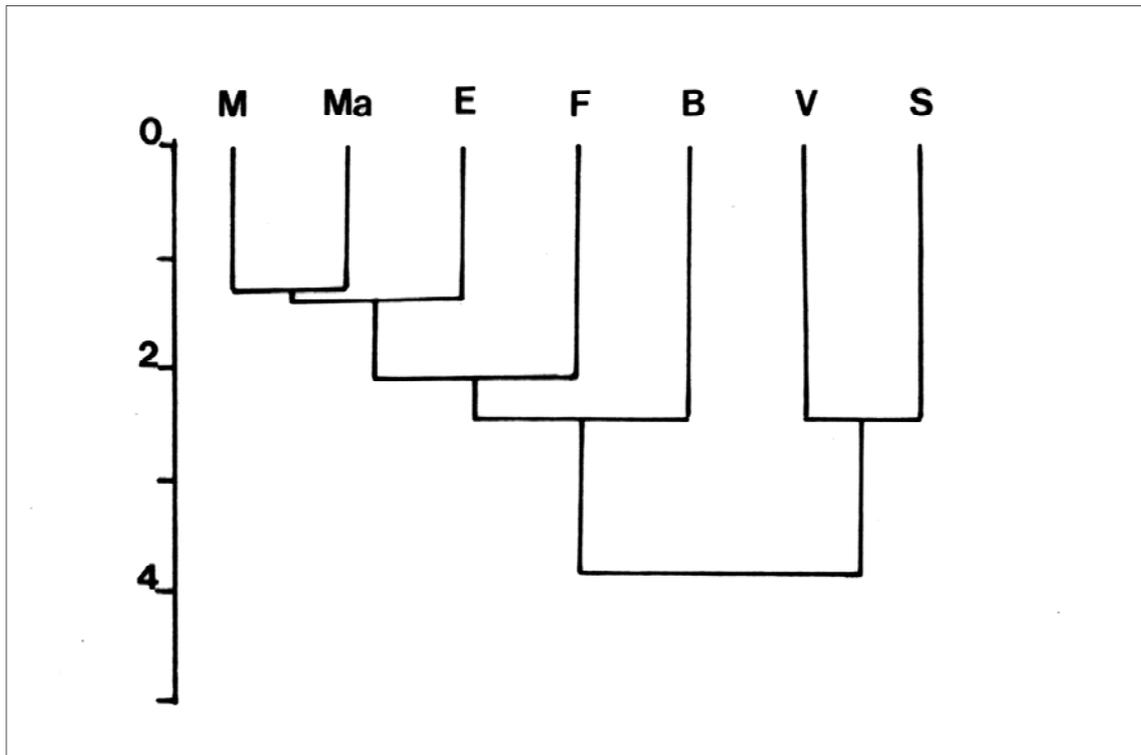


Figure 1 Phenogram constructed using 18 dental occlusal measurements: Steinheim (**S**) compared with Vertesszöllös (**V**), Bilzings-leben (**B**), Frankenbacher Sande (**F**), Ehringsdorf (**E**), Mauer (**Ma**), and Mosbach (**M**). Scale to the left is in standard

The horse from Chatillon is similar to that from Steinheim (Fig. 2), as recognized by Mourer-Chauviré (1972). The Achenheim horse resembles the samples of classical *E. mosbachensis* and that from Arago resembles Ehringsdorf. The horse from the Holsteinian of Lunel Viel is not a *mosbachensis*; it is smaller than the latter and similar to the one from Chatillon and Steinheim. The horse from Steinheim is not primitive. For its morphology and size it occupies a place among the caballoid horses of Eurasia fully in accord with its age. Although it is tricky to predict the ancestor(s) of a fossil form, nothing contradicts *E. mosbachensis* as the ancestor of *E. steinheimensis* (see also Nobis 1971, contra Samson 1975), nor the latter as the ancestor of later caballoids.

Equus hydruntinus

Equus hydruntinus is represented from Steinheim by two cheek teeth, in addition to

four teeth from the Murr; there are no limb bones. It is not known from which beds the teeth derive, but according to Stehlin & Graziosi (1935: 47, citing Berkhemer) the age of three specimens from the Murr, described by them, is Saalian/Rissian. The teeth do not in any way differ from those of *E. hydruntinus* in numerous European localities from the Holsteinian (possibly already Cromerian) to the Copper Age.

DISCUSSION

Can the size and morphology of the horses from Steinheim be used for determining their relative age and origin within the stratigraphic sequence of the site? The few teeth of *E. hydruntinus* do not differ from those from the Holsteinian of Lunel Viel (Bonifay 1991) on the one hand or from those from the Würmian of Roter Berg on the other. For its teeth *E. hydruntinus* is not stratigraphically useful. Some early forms may have had small limb

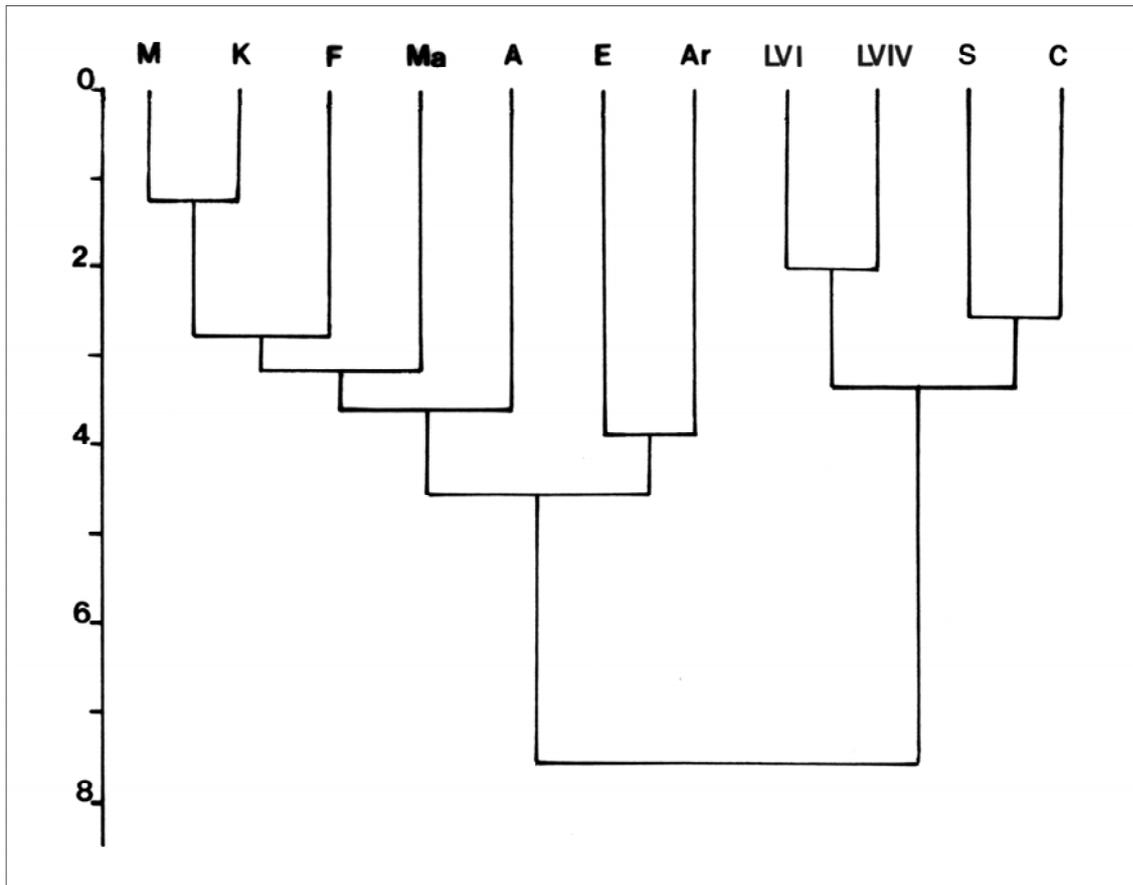


Figure 2 Phenogram constructed using 17 limb bone measurements: Steinheim (**S**) compared with Chatillon St. Jean (**C**, data Mourer-Chauviré 1972), Lunel Viel I and IV (**LV**, data Bonifay 1980), A rago (**Ar**, data Cregut 1979), Ehringsdorf (**E**), Achenheim (**A**, data Cregut 1979), Mauer (**Ma**), Frankenbacher Sande (**F**), Pfrimm bei Kriegesheim (**K**), and Mosbach (**M**). Scale to the left is in standard deviation units.

bones (Bonifay 1991), but unfortunately limb bones are lacking from Steinheim. The metrical and morphological homogeneity of the sample of the caballoid horse may indicate that it comes from a temporally limited part of the sequence, with the few 'large' teeth deriving from either younger or older beds. If this sample derives from the middle beds of Steinheim together with the majority of the fossils, a Holsteinian or Saalian age (Adam 1954) comes into question for the caballoid horse, as well as for *E. hydruntinus*.

In the phenograms on the teeth and bones (Figs. 1, 2) the Steinheim caballoid horse is clearly separated from, being smaller than, classical *E. mosbachensis*. Dentally it does

not differ from that from Vertesszöllös, also referred to as *E. mosbachensis* and considered Holsteinian in age (Kretzoi 1990, Schwarcz & Latham 1990). Compared for several limb bones, the horse from Steinheim resembles the one from Chatillon, aged Saalian (Mourer-Chauviré 1972), and Lunel Viel, aged Holsteinian (Bonifay 1980). Compared for the metapodials alone (Fig. 3), it resembles Late Pleistocene medium to large horses of the *E. germanicus* group, and only more distantly those from Chatillon and Lunel Viel. The Saalian horses from Ehringsdorf, Achenheim, and Crayford, and *E. insulidens* Samson from Romania, have larger limb bones and teeth.

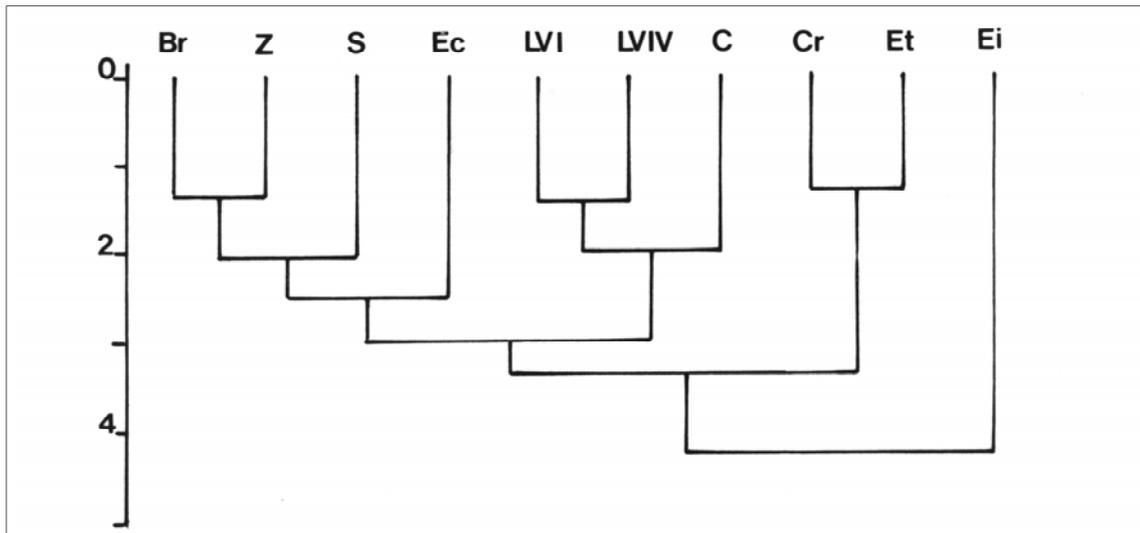


Figure 3 Phenogram constructed using 9 metapodial measurements: Steinheim (**S**) compared with Brundon Pit (**Br**), Zemst (**Z**, data Gernonpré 1993), *Equus chosaricus* (**Ec**, data Gromova 1949), Lunel Viel I and IV (**LV**, data Bonifay 1980), Chatillon St.Jean (**C**, data Mourer-Chauviré 1972), Crayford (**Cr**), *E. transsylvanicus* and *E. insulidens* (**Et** and **Ei**, data Samson 1975). Scale to the left is in standard deviation units.

The Steinheim caballoid horse, thus, is smaller than typical *E. mosbachensis*, but also tends to be smaller than the compared Saalian forms, except that from Chatillon. Some Holsteinian horses were smaller than their predecessors and successors, others were large, e.g. those from Bilzingsleben (see Musil, 1991) and Heppenloch. Thus the 'large' teeth from Steinheim could be either from the pre-Holsteinian 'Ältere Mammut-Schotter' or from the Saalian 'Haupt-Mammut-Schotter', from whence dentally large horses can be expected, but neither is a Holsteinian age excluded. Size does not settle the age of the main horse sample, however.

Is the Steinheim horse, *Equus steinheimensis*, a good species and can it be differentiated from other Mid- to Late Pleistocene forms? On the morphological criteria given by Reichenau (1915) it cannot. The Steinheim horse clearly differs in size from classical *E. mosbachensis*, but approaches, because of size decrease, later caballoids. It belongs in a taxonomically poorly defined category of middle and late Pleistocene horses, including

also *E. taubachensis* FREUDENBERG, *E. pive-teaui* DAVID & PRAT, *E. chosaricus* GROMOVA, *E. insulidens* SAMSON, and large *E. germanicus* NEHRING. The status of these horses has still to be clarified.

REFERENCES

- Adam, K.D., 1954 - Die mittelpleistozänen Faunen von Steinheim an der Murr (Württemberg) - Quaternaria 1: 131-144
- Adam, K.D., 1975 - Die mittelpleistozäne Säugetier-Fauna aus dem Heppenloch bei Gutenberg (Württemberg) - Stuttgarter Beiträge zur Naturkunde, Ser. B Geologie. & Paläontologie 3: 1-247
- Arambourg C., 1958 - Les gros mammifères des couches tayaciennes - La Grotte de Fontéchevade - Archives de l'Institut Paléontologique Humaine, Memoire 29: 185-229
- Bonifay, M.-F., 1980 - Le cheval du Pléistocène moyen des grottes de Lunel Viel (Hérault), *Equus mosbachensis palustris* n. sp. - Gallia Préhistoire 23: 233-281
- Bonifay, M.-F., 1991 - *Equus hyduuntinus* Regalia *minor* n. ssp. from the Caves of Lunel-Viel (Hérault, France) - in: Meadow, R.H. & Uerpman, H.-P. (eds.) - Equids in the Ancient World, Volume 2 - pp. 178-

216. Dr. Ludwig Reichert Verlag, Wiesbaden
- Bouchud, J., 1972 - Les grands herbivores Rissiens des 'Abimes de la Fage' en Corrèze (Cervidés, Bovidés, Capridés, Ruplicaprines, Suidés et Équidés) - *Nouvelles Archives du Muséum d'Histoire Naturelle de Lyon* 10: 33-59
- Crégut, E.T., 1979 - La faune de mammifères du Pléistocène moyen de la Caune de l'Arago à Tautavel, Pyrénées Orientales - Unpublished Ph.D. Thesis (Thèse pour obtenir le grade de Docteur de spécialité en géologie des formations sédimentaires), l'Université de Provence
- Eisenmann, V., 1981 - Étude des dents jugales inférieures des *Equus* (Mammalia, Perissodactyla) actuels et fossiles - *Palaeovertebrata* 10: 127-226
- Eisenmann, V., 1980 - Les chevaux (*Equus sensu lato*) fossiles et actuels: Crânes et dents jugales supérieures - *Cahiers de paléontologie*: 1-186
- Forsten, A., 1982 - Equidae - in: Kozłowski, J. (ed.) - Excavations in the Bacho Kiro Cave (Bulgaria). Final Report (in English), pp. 56-61. Panstwowe Wydawnictwo Naukowe, Warszawa
- Germonpré, M., 1993 - Osteometric data on Late Pleistocene mammals from Flemish Valley, Belgium - *Studiedocumenten van het Koninklijk Belgisch Instituut voor Natuurwetenschappen* 72: 1-135
- Gromova, V.I., 1949a - Istoriya loshadei (roda *Equus*) v Starom Svete. Cast 1 (in Russian) - *Trudy Paleontologicheskogo Instituta Akademii Nauk SSSR* 17: 1-374
- Gromova, V.I., 1949b - Istoriya loshadei (roda *Equus*) v Starom Svete. Cast 2 (in Russian) - *Trudy Paleontologicheskogo Instituta Akademii Nauk SSSR* 17: 1-162
- Hay, O., 1915 - Contributions to the knowledge of the mammals of the Pleistocene of North America - *Proceedings of the U.S. National Museum* 48: 515-575
- Kretzoi, M., 1990 - Vertebrate fauna of the archaeological site - in: Kretzoi, M. & Dobosi, V.T. (eds.) - *Vertesszöllös. Man, Site and Culture* - pp. 231-238. Akademia Kiado, Budapest
- Mourer-Chauviré, C., 1962 - Les gisements fossilifères quaternaires de Chatillon-Saint-Jean (Drôme) - Unpublished 'Thèse 3e cycle', Lyon
- Mourer-Chauviré, C., 1972 - Étude de nouveaux restes de vertébrés provenant de la Carrière Fournier à Chatillon-Saint-Jean (Drôme). III Artiodactyles, chevaux et oiseaux - *Bulletin de l'Association française pour l'étude du Quaternaire* 33: 271-305
- Musil, R., 1968 - Die Equiden aus dem Travertin von Ehringsdorf - *Paläontologische Abhandlungen* 23: 265-335
- Musil, R., 1991 - Pferde aus Bilzingsleben - in: Fischer, K., Guenther, E.W., Heinrich, W.D., Mania, D., Musil, R. & Nölzold, T. (eds.) - *Bilzingsleben IV. Homo erectus - seine Kultur und seine Umwelt*: 103-231-248. Veröffentlichungen Landesmuseums f. Vorgeschichte in Halle, Halle
- Nobis, G., 1971 - Vom Wildpferd zum Hauspferd - *Fundamenta B* (6): 1-96
- Prat, F., 1968 - Recherches sur les équidés pléistocènes en France - Unpublished Thesis (Thèse de Doctorat d'état ès Sciences Naturelles), Université Bourdeaux
- Reichenau, W.v., 1915 - Beiträge zur näheren Kenntnis fossiler Pferde aus deutschem Pleistozän - *Abhandlungen Geologischen Landesanstalt zu Darmstadt* 7: 1-155
- Samson, P., 1975 - Les équidés fossiles de Roumanie (Pliocène moyen-Pléistocène supérieure) - *Geologica Romana* 14: 165-352
- Schwarcz, H.P. & Latham, A.G. 1990 - Absolute age determination of travertines from Vertesszöllös. In: Kretzoi, M. & Dobosi, V.T. (eds.) - *Vertesszöllös: Man, Site and Culture* - pp. 549-552. Akademia Kiadó, Budapest
- Soergel, W., 1911 - Die Pferde aus der Schotterterrasse von Steinheim a.d. Murr - *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beil. Bnd.* 32: 740-761
- Stehlin, H.G. & Graziosi, P., 1935 - Recherche sugli asinidi fossili d'Europa - *Mémoires Société Paléontologique de Suisse* 56: 1-73
- Thies, O., 1926 - Beiträge zur Kenntnis der Heppenlochfauna und der Fauna der Frankenbacher Sande - *Jahrbuch der Preussischen Geologischen Landesanstalt zu Berlin* 46: 576-615
- Weiler, W., 1931 - Die diluvialen Terrassen der Pfrimm, mit einem Anhang über altdiluviale Säuger aus der Umgebung von Worms - *Notizblatt des Vereins f. Erdkunde und Hessischen Geologischen Landesanstalt zu Darmstadt* 1930, 5: 124-145
- Wernert, P., 1957 - Stratigraphie paléontologique et préhistorique des sédiments quaternaires d'Alsace Achenheim - *Mémoires du Service de la Carte Géologique d'Alsace et de Lorraine* 14: 1-262