MEDIEVAL HORSES FROM UTRECHT (JAN MEIJENSTRAAT)

W. Prummel

CONTENTS

1. INTRODUCTION*

In 1979, 19 horse skeletons were found together in a pit measuring 2 x 4 metres, at a depth of 2 m, during the excavation of Jan Meijenstraat in Utrecht, the Netherlands. These 19 complete or nearly complete horses provided an opportunity to examine the variations in size and shape that may be related to breed. Our knowledge of the history of the present European breeds of horse is rather poor (Nobis, 1955; anon., 1982; Prummel, 1979). As a rule, the fragmentariness of most archaeozoological horse materials limits the studies of them to univariate, sometimes bivariate analyses with many missing data. These horses from Utrecht are an exception to this rule.

The excavation (figs. 1 and 2) was carried out by the Archaeological Service of the Municipality of Utrecht. During this excavation a large number of square A.D. 15th/16th century pits was found. One of the excavators, H.L. de Groot, postulated in a preliminary report (1981: p. 50) that the pits had been dug to obtain sand and had afterwards been filled in with waste.

The faunal remains of most of these pits consist mainly of complete animal skeletons. There are dogs, pigs and, most frequently, horses. The pit called UTJMPK 2 (Utrecht, Jan Meijenstraat, ***Paardekuil*** (*i.e.* horse pit) 2), which contained the largest number of well-preserved horse skeletons, was used for this study. In the 15th century, the Jan Meijenstraat area was situated on riverine sand sediments, close within the northern boundary of the town. It was then sparsely inhabited (De Groot, 1981).

2. THE RECONSTRUCTION OF THE HORSES BY A. VAN BERKEL

Because of the lateness and the wetness of the season, the excavation had to be carried out very quickly. Mr. A. van Berkel of the Archaeological Service of Utrecht reconstructed the various skeletons from the drawings and photographs taken during the excavation. Without his painstaking work the multivariate analyses in this study would not have been possible.

Figures 3-7 show the situation of the skeletons of the horses A-Q. Only the bones with certainty ascribed to a horse are drawn. The letters A-Q are given in a sequence from bottom to top, whereas the figures 3-7 are in a sequence from top to bottom. The drawings are not regular field drawings, but reconstructions from the rough field drawings and photographs, and do not reflect the actual vertical position. In these drawings the skeletons are transposed to an economic number (5) of horizontal planes. Actually, the horses were situated more or less horizontally above and/or beneath the artificial plane in the drawing. The numbers on the bones in the drawings refer to the find numbers in the excavation administration. In the original drawings, the horses were differently coloured. For reasons of economy they are printed here in black, white and various greys.

There is no regularity in the position in the pit of the various parts of the body of the horses (figs. 3-7). This means that the bodies were dumped into the pit from various directions, probably to fill in the pit most economically. The skeletons are of complete not-butchered and not-emaciated animals, and they were dumped simultaneously or at short intervals (De Groot, 1981). Possibly they were buried inside the town during a siege. Utrecht was besieged A.D. 1483 (Van de Vlerk, 1983).

The completeness of the 19 skeletons A-S varied. From R and S, only vertebrae and ribs were preserved. Mr. van Berkel could not differentiate completely the intertwined skeletons of the horses M and N. Often, the phalanges of fore-feet and hind-feet of various horses were lying together. Therefore, he did not try to attribute them to a fore-foot or hind-foot of any particular horse.

I made a biological check on the reconstruction of the horses by the excavators on the basis of drawings and photographs, by counting the bones and comparing their sizes and their teeth eruption or replacement stage or their epiphyseal fusion stage. Only some attributions proved to be incorrect.

* Table 1 has been reproduced as microfiche (4) in an envelope attached to the rear cover of this volume.

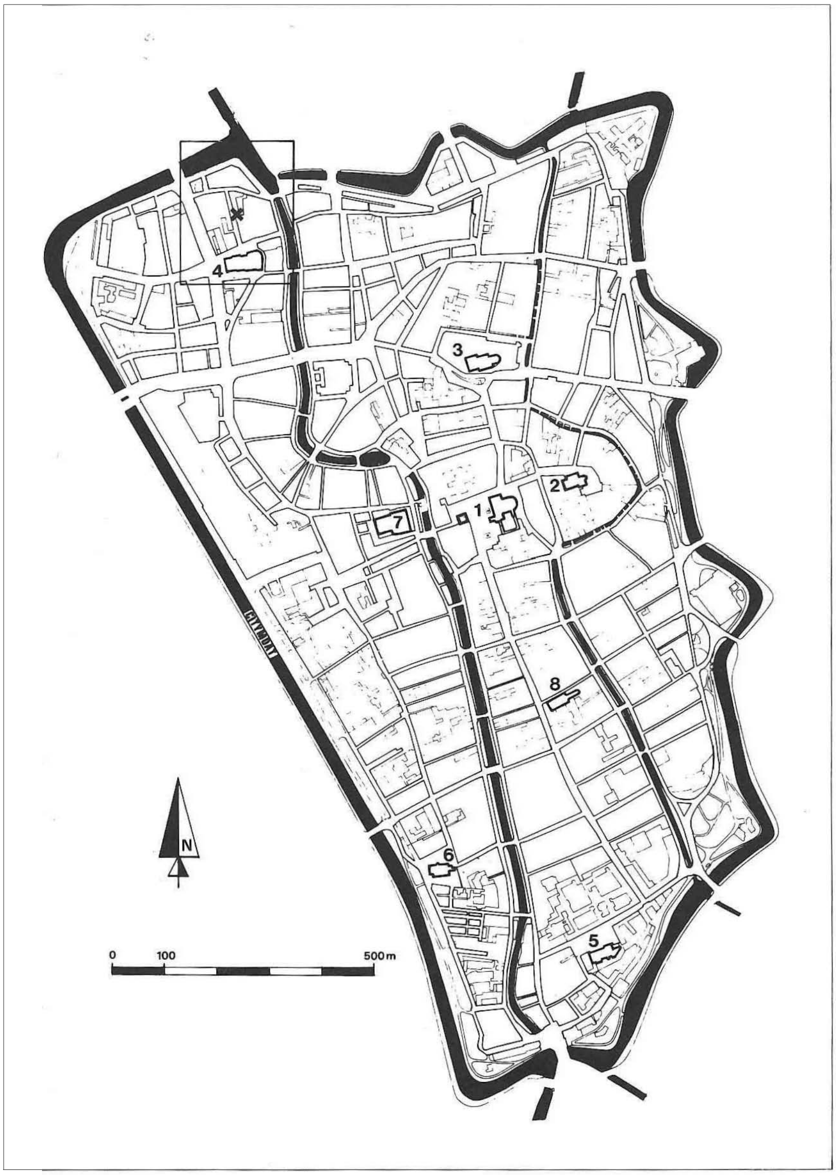

Fig. 1. Map of the city of Utrecht with: 1. Cathedral; 2. Pieters-church; 3. Jans-church; 4. Jacobi-church; 5. Nicolaas-church; 6. Geerte-church; 7. Buur-church and 8. Catharina-church; in black the city moat and the two canals; the framed area is shown enlarged in figure 2.

3. SEX, AGE AT DEATH AND WITHERS HEIGHT

All the canines of the maxillae present (15) were strongly developed, meaning that at least 15 of the 19 horses were male horses: stallions or castrated males. The horses of unknown sex are: F, I, M and N. Of these at least two were male, because two male skulls were found which could not be ascribed to a particular horse. This induces me to conjecture that all the horses were male. Regrettably, this sex allotment could not be checked by studying the pelvises, because the suture between both halves of all horses was still open. This prevented the observation of the size and the shape of the aperture between them.

All the horses died at rather early ages. No horse had heavily worn teeth. From all the horses of which the skull and/or the mandibles or a mandible were found (*i.e.* all except horses F, M, N, R and S) only A possessed a subadult set of teeth. The i3 was in the process of being replaced by the I3. This means that horse A nearly reached the age of three and a half years. The others had the complete permanent set

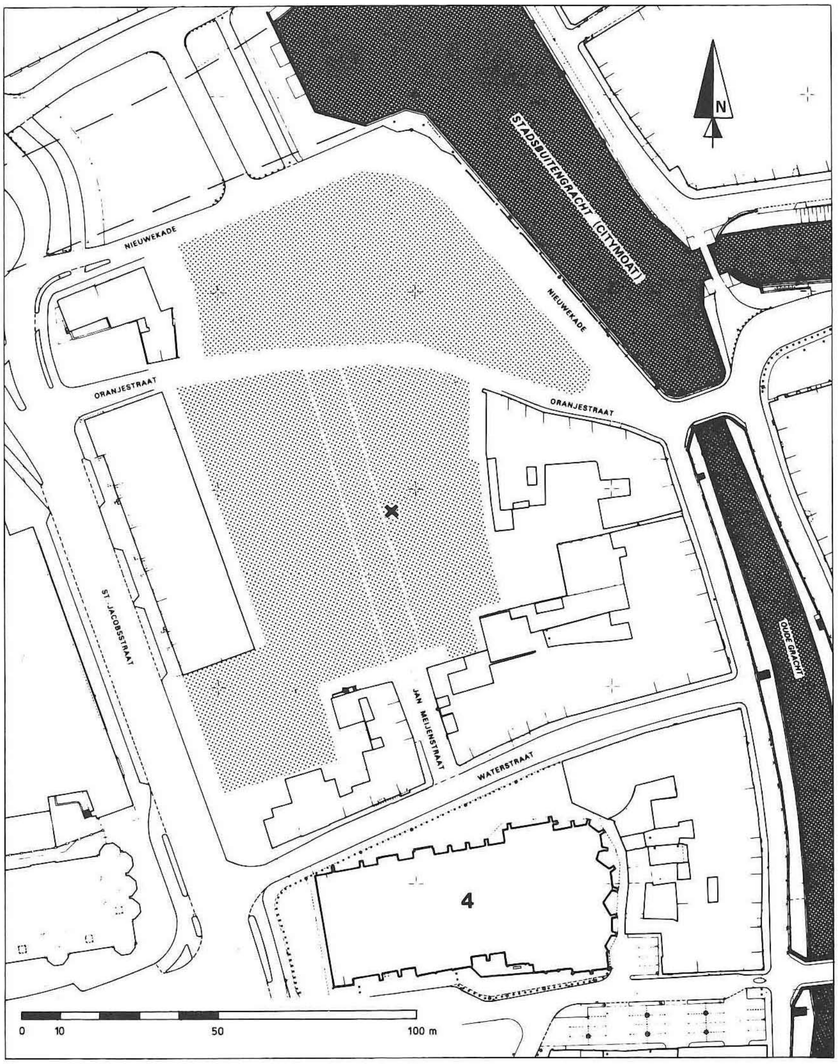

Fig. 2. The Jan Meijenstraat area with 4. Jacobi-church and x place of the excavation of the horse skeletons (UTJMPK 2).

of teeth: all erupted or replaced. These, the horses B-E, G-L and O-Q, had at least reached the age of four and a half years. Because of the moderate wear of the teeth, they probably did not survive long after reaching this age (Habermehl, 1975).

These conclusions on the age at death on the basis of the teeth are confirmed by the fusion stages of epiphyses and diaphyses of the long bones. Only horse A showed some epiphyses in the process of fusing: humerus and tibia proximal, which, according to Habermehl (1975), fuse at three and a half years. The long bones present of the other named horses only had fused epiphyses, from which can be concluded that they died after three and a half years.

The postcranial skeleton allows some conclusions on the age at death of the horses of which no teeth are present. Neither the epiphyses of femur nor the proximal epiphyses of tibia of horse M were fused with the diaphyses, indicating this horse died at about three and a half years of age. Of horses F and N only fused epiphyses were found, implying that these horses died after three and a half years.

The conclusion on the age of these 19 horses is that two horses (A and M) died before three and a half years, one of them (A) shortly before three and a half years. Horses F and N died at an unknown age after three and a half years. Horses B-E, G-L and N-S probably died not very long after four and a half years. In the

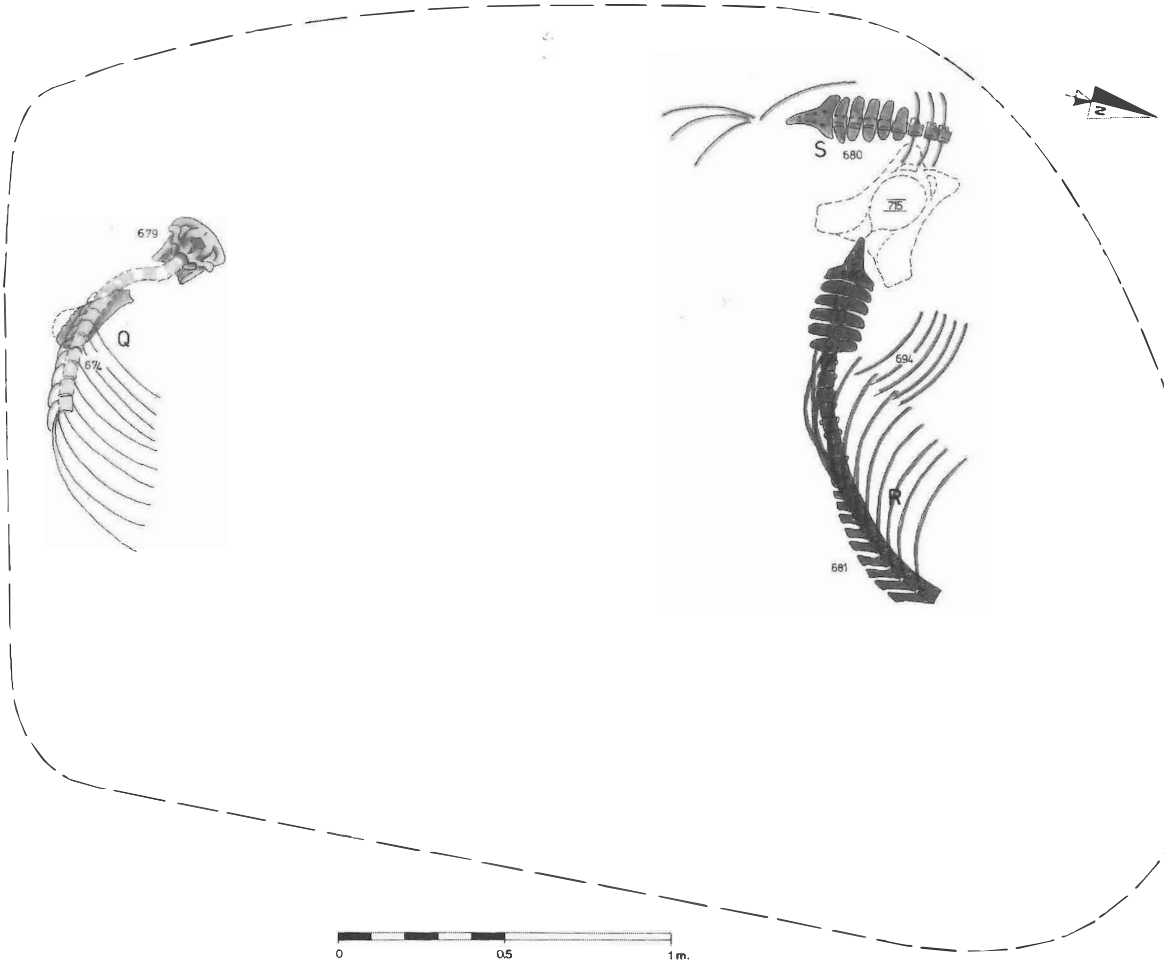

Fig. 3. The uppermost horses Q, R and S from UTJMPK 2. Reconstruction and drawing by A. van Berkel.

maxilla of the horses A, H and C the rudimentary first permanent premolar had erupted, whereas, almost certainly, eruption had not taken place in horses B-E, G, J, K, P and Q.

From the length measurements, taken according to Von den Driesch (1976) and Von den Driesch & Boessneck (1974) (table 1) withers heights were calculated, according to: a) Vitt, on the basis of basicranial length and maximum lengths of the long bones, and b) Kiesewalter on the basis of the lateral lengths of the long bones. The withers heights allowed a check on the attribution of the bones to the separate horses. The withers heights calculated from the long bones of all the horses fell into no more than two of Vitt's size categories. The withers heights of each separate horse according to Kiesewalter did not display much variation, either: proof of the correctness of the attributions.

On the basis of the withers heights according to Kiesewalter (table 2), the horses could provisionally be classified in two groups, with a considerable number of intermediates. The group with large withers heights (1.44-1.62 m) consisted of the horses A, D, F, I, J and K. That of the small withers heights (1.35-1.45 m) consisted of the horses E, N, O, P and R. In the group with the large withers heights, horse A greatly exceeded the other horses, which were much closer together (fig. 8).

Excluded from the discussion on the withers heights are those calculated from the lengths along the spina of scapula. These were always several 0.01 m, up to over 0.1 m higher, than the withers heights calculated from the other bones. I merely draw the attention to this

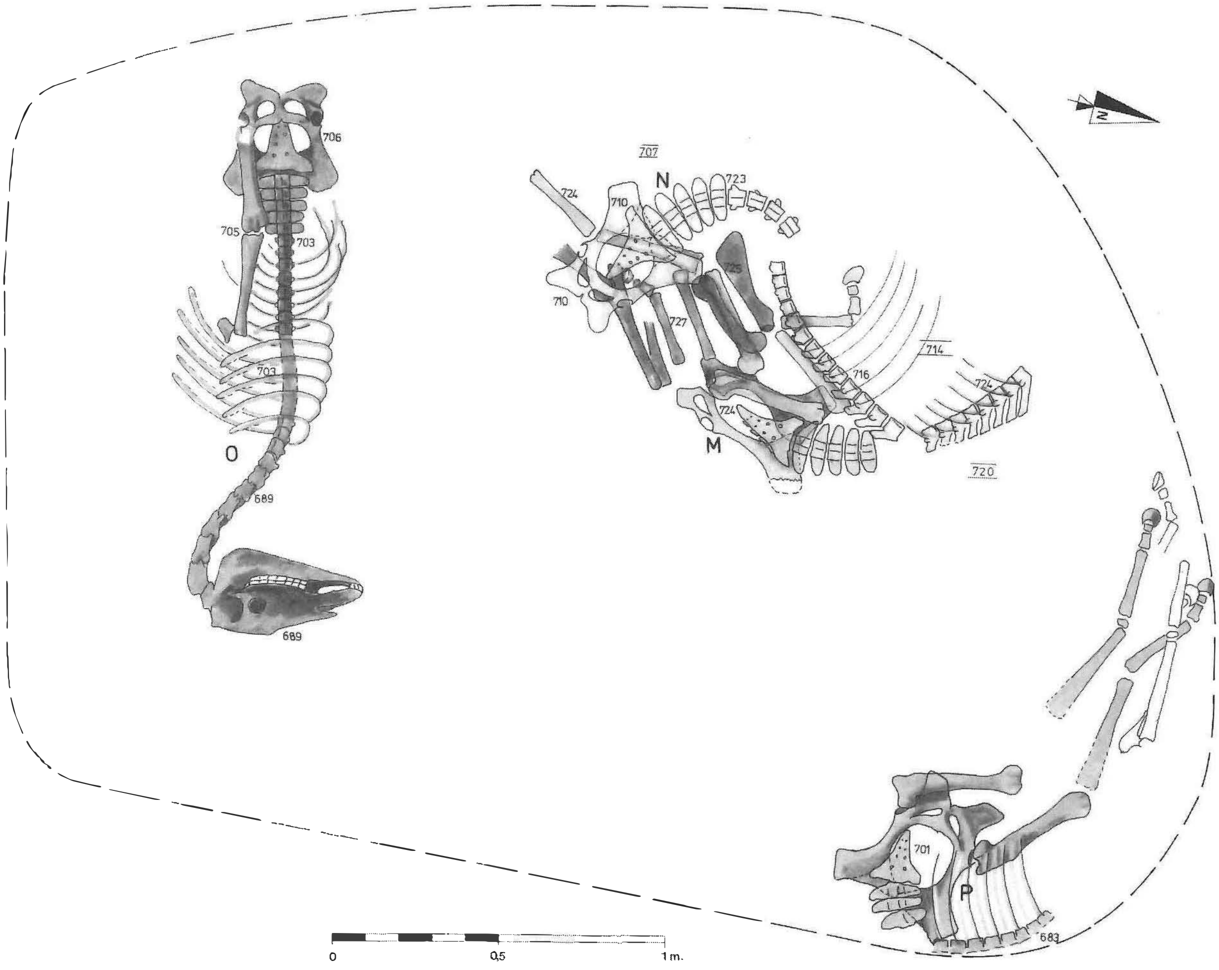

Fig. 4. Horses M, N, O and P from UTJMPK 2. Reconstruction and drawing by A. van Berkel.

difference, but give no opinion on which of these withers heights are the closest to the true ones.

An objection to a comparison of the horses on the basis of the withers heights is that these are multiplications of length measurements by factors obtained from a limited group of horses of an unknown breed or of different breeds. Regression equations would be better, but even then a 'grand total' withers height would be inaccurate, because of the possible inconstancy of the ratios between the lengths of the various bones. Moreover, the withers height by itself did not allow the horses to be grouped satisfactorily: not only did the groups of large and small horses overlap in their ranges, a group of five horses could not be fitted in at all.

4. SUBDIVIDING INTO GROUPS OF HORSES

4.1. The various principal component analyses

The univariate analysis showed that several measurements were significantly non-normally distributed (table 3). Although this rather high number of non-normally distributed measurements indicates a considerable amount of variation in size and shape of the horses, none of them sufficed to divide the

Table 2. Ranges of the withers heights in m calculated after Kiesewalter and withers heights after the maximum length of the scapula for horses A-S from UTJMPK 2; for length measurements, see table 1; for multiplication factors of Kiesewalter, see Von den Driesch & Boessneck, 1974: fig. 1)

Horse	Range of withers heights from humerus, radius, radius + ulna, metacarpus, femur, tibia and metatarsus	Withers heights from scapula
A	1.487 - 1.615	–
B	1.370 - 1.434	–
C	1.363 - 1.418	1.451
D	1.482 - 1.545	1.559
E	1.402 - 1.464	1.438
F	1.448 - 1.507	1.528; 1.567
G	1.358 - 1.397	1.446
H	1.350 - 1.406	–
I	1.440 - 1.516	1.495
J	1.447 - 1.510	1.532
K	1.464 - 1.544	–
L	1.369 - 1.425	–
M	1.381 - 1.448	–
N	1.453	–
O	1.449 - 1.504	–
P	1.429 - 1.464	–
Q	1.360 - 1.368	–
R	*c* 1.460	–
S	*c* 1.290 - 1.360	–

horses into distinct groups.

Analysis of more variables together can display variation in individuals on these variables more clearly, because they give a total of the separate variations. The method chosen here is the principal component analysis, which beneath the addition of the variations diminishes the number of variables to a smaller number of independent factors. These factors can be denominated, for instance, according to the variables that give the highest loading to them. To subdivide the individuals, factor scores can be calculated on these factors from the scores of these individuals on the variables. For applications of this method in the field of archaeozoology, see Clutton-Brock & Armitage (1976) and Prummel (1978). Warmerdam (1979) used a comparable method in systematic zoology.

By substituting horse for individual and measurement for variable, the above is a description of the application of the principal component analysis on these horses. R and S were excluded from the analysis, because of the many missing data. Five sets of factors were calculated from these horse measurements, according to the WESP-version (Van der Weele, 1977); only the last three of them gave practicable results:

a. All the measurements taken; the number of these was too large in relation to the number of individuals to obtain clear factors; moreover the number of missing data was too large;

b. The measurements of the skull and mandibles; this analysis did not give good results because of the high number of missing data;

c. The measurements of fore-leg and hind-leg, except scapula and pelvis (because of the many missing data); this analysis gave clear factors, but no factor scores for most of the horses were obtained, because of missing data; of many of the horses either the fore-legs or the hind-legs were present; in an analysis for both legs for these horses, no factor scores are obtained;

d. and e. The measurements of fore-leg and hind-leg separately; the factors obtained are about the same as those above, whereas the number of horses with missing data is cut down to a minimum.

4.2. Principal component analysis on fore-leg and hind-leg together, except scapula and pelvis

Forty-five measurements were used in this analysis. Seven independent factors sufficed to describe the variance (97.17 cumulative % of variance explained) present in these horses on these 45 measurements.

Rotation according to the varimax criterion method gave the loadings on these factors, in which a pattern can be discerned: the first factor was heavily loaded with the length measurements and more weakly with the proximal widths of humerus and femur. Two other proximal widths and several distal widths (4) gave heavy loading on the second factor, whereas several minimum widths of the diaphysis (3) gave heavy loading on the third factor.

Factors 4-7 are of less importance because of the small amount of variance they explain. For this reason I gave a description of only the first three factors:

factor 1 size, especially, height of the animal (explains 67.77 % of variance)

Table 3. Measurements of the post-cranial skeleton of the 19 horses from UTJMPK 2, with a distribution significantly deviating from normality. Included are the values of χ^2 that gave significance at the mentioned level α with the given degrees of freedom. For the other parameters of the measurements, see table 1.

Skeletal element	Measurement	χ^2	Degrees of freedom	Level of significance α
Scapula	Minimum length of the collum	7.45	1	0.01
Humerus	BT – width of the trochlea	12.04	1	0.001
	SD – minimum width of the diaphysis	14.78	1	0.001
	BP – proximal width	5.72	1	0.05
Metacarpus	BP – proximal width	8.75	1	0.01
	DP – proximal depth	6.08	1	0.05
	BD – distal width	4.23	1	0.05
	GL lat – maximum lateral length	4.37	1	0.05
	CD – minimum circumference of the shaft	6.06	1	0.05
Femur	BP – proximal width	5.15	1	0.05
	GLC – length from the caput	5.24	1	0.05
Tibia	SD – minimum width of the diaphysis	4.04	1	0.05
Metatarsus	DP – proximal depth	5.77	1	0.05
	DD – distal depth	7.12	1	0.01

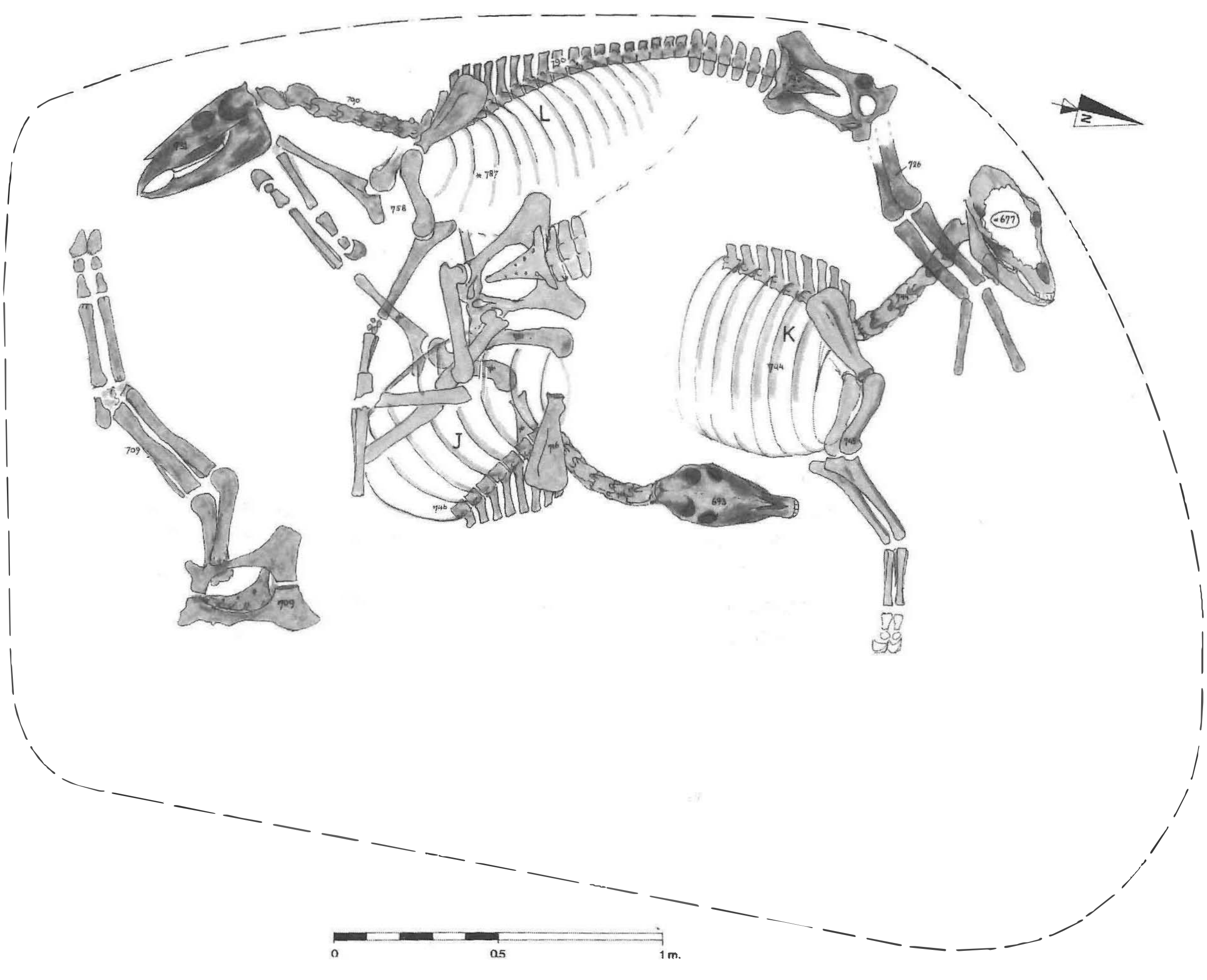

Fig. 5. Horses J, K and L from UTJMPK 2. Reconstruction and drawing by A. van Berkel.

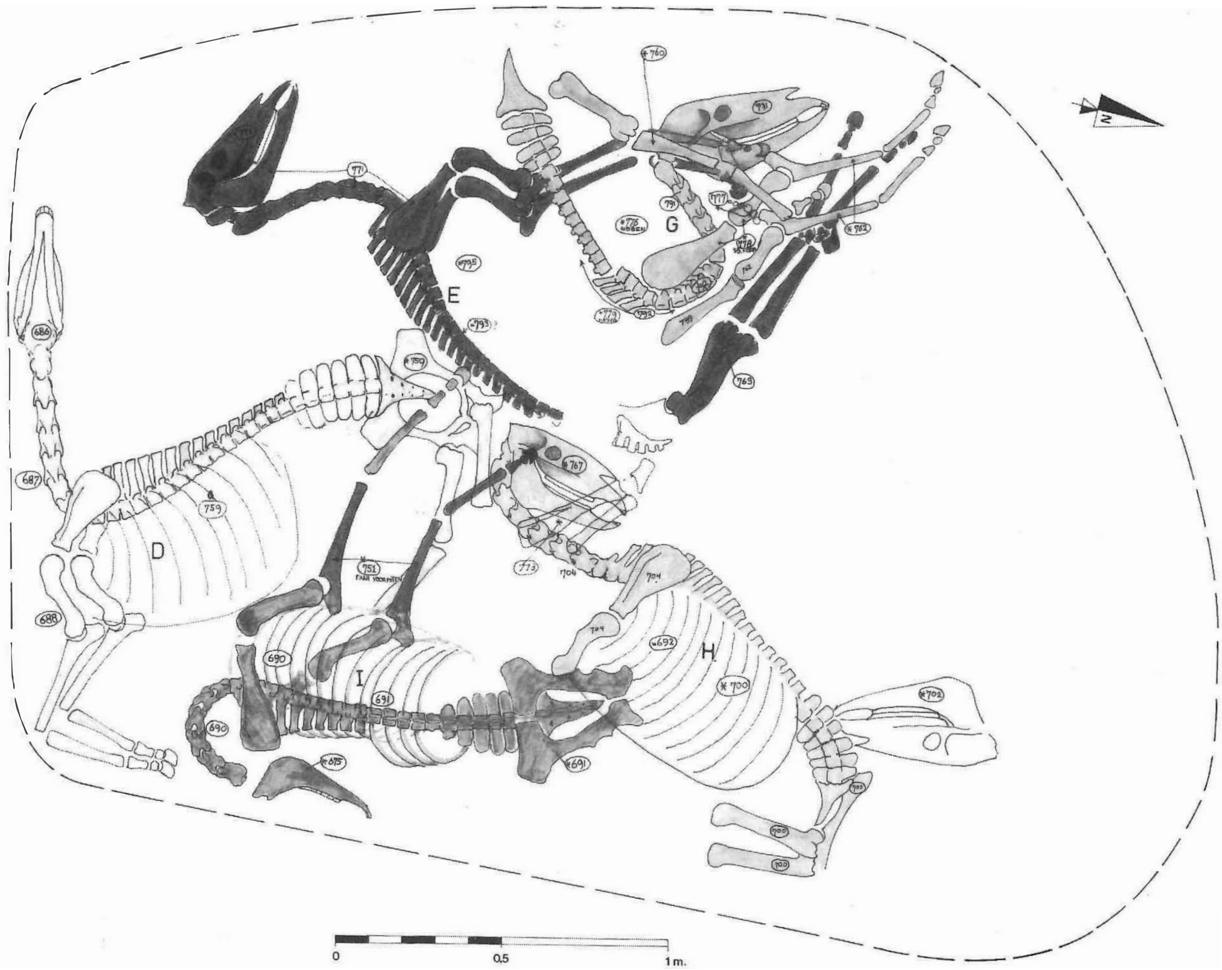

Fig. 6. Horses D, E, G, H and I from UTJMPK 2. Reconstruction and drawing by A. van Berkel.

factor 2 width, independent of size (explains 8.93 % of variance)
factor 3 constriction of the bones (explains 6.19 % of variance)

For only 10 horses, *i.e.* those without any missing data on these 45 measurements, factor scores were calculated. This prevents the subdivision of the horses into groups.

4.3. Principal component analysis on measurements from the fore-leg

Twenty-five measurements from humerus, radius and metacarpus (table 4) were used for this analysis. The first four factors had eigenvalues larger than 1 and together accounted for 90.5 % of the variance (table 5).

The maximum loadings of the 25 measurements on any of the four rotated factors (table 6) show a pattern comparable with that of fore-leg and hind-leg together: proximal or distal widths, lengths and minimum widths of the diaphysis are related to separate factors, although with a permutation in the sequence: that of the width is the factor here that accounts for the highest amount of variance.

I gave descriptions of the first three, most important, factors of the principal component analysis of the fore-leg:

factor 1 width
factor 2 length, independent of width
factor 3 constriction of the bones (N.B. the direction of the description of this factor is opposite to the direction of the factor; figures 9 and 10.

Table 4. Measurements used in principal component analysis of the fore-leg

Skeletal element	Abbreviation after Von den Driesch-Karpf (1976)	Description of measurements
Humerus	BD	Distal width
	BT	Width of the trochlea
	SD	Minimum width of the diaphysis
	BP	Proximal width
	DP	Proximal depth
	GLC	Maximum length from the caput
	GL	Maximum length
	GL lat	Maximum lateral length
Radius	BP	Proximal width
	SD	Minimum width of the diaphysis
	BD	Distal width
	GL	Maximum length
	GL lat	Maximum lateral length
	BF p	Width of proximal articular surface
	BF d	Width of distal articular surface
Radius + ulna	GL	Maximum length
	GL lat	Maximum lateral length
Metacarpus	BP	Proximal width
	DP	Proximal depth
	SD	Minimum width of the diaphysis
	BD	Distal width
	DD	Distal depth
	GL	Maximum length
	GL lat	Maximum lateral length
	CD	Minimum circumference of the diaphysis

Table 5. Eigenvalues, percentages explained variance (for each factor and cumulative) of the first four factors drawn from 25 measurements of fore-leg (table 4) by principal component analysis

Factor	Eigenvalue	% of explained variance	Cumulative % of explained variance
1	18.2174	72.87	72.87
2	1.7744	7.10	79.97
3	1.5052	6.02	85.99
4	1.1282	4.51	90.50

Table 6. Maximum loadings of the 25 fore-leg measurements on any of the four rotated factors from the principal component analysis on 25 fore-leg measurements (see table 4 for abbreviations and table 5 for eigenvalues)

Skeletal element	Factor 1	Factor 2	Factor 3	Factor 4
Humerus	BD: 782	DP: 707		SD: 498
	BT: 876	GLC: 671		
	BP: 597			
	GL: 678			
	GL lat: 718			
Radius	BP: 865	GL: 730	SD: 620	
	BD: 624	GL lat: 735		
	BFp: 870			
	BFd: 676			
Radius + ulna		GL: 770		
		GL lat: 739		
Metacarpus	BD: 543	GL: 862	SD: 924	BP: 793
		GL lat: 894	DD: 653	DP: 877
			CD: 830	

Table 7. Measurements used in principal component analysis of the hind-leg

Skeletal element	Abbreviation after Von den Driesch-Karpf (1976)	Description of measurement
Femur	BP	Proximal width
	DC	Diameter of the caput
	SD	Minimum width of the diaphysis
	BD	Distal width
	GL lat	Maximum lateral length
	GL	Maximum length
Tibia	BP	Proximal width
	SD	Minimum width of the diaphysis
	BD	Distal width
	DD	Distal depth
	GL	Maximum length
	GL lat	Maximum lateral length
Metatarsus	BP	Proximal width
	DP	Proximal depth
	SD	Minimum width of the diaphysis
	BD	Distal width
	DD	Distal depth
	GL lat	Maximum lateral length
	GL	Maximum length
	CD	Minimum circumference of the diaphysis

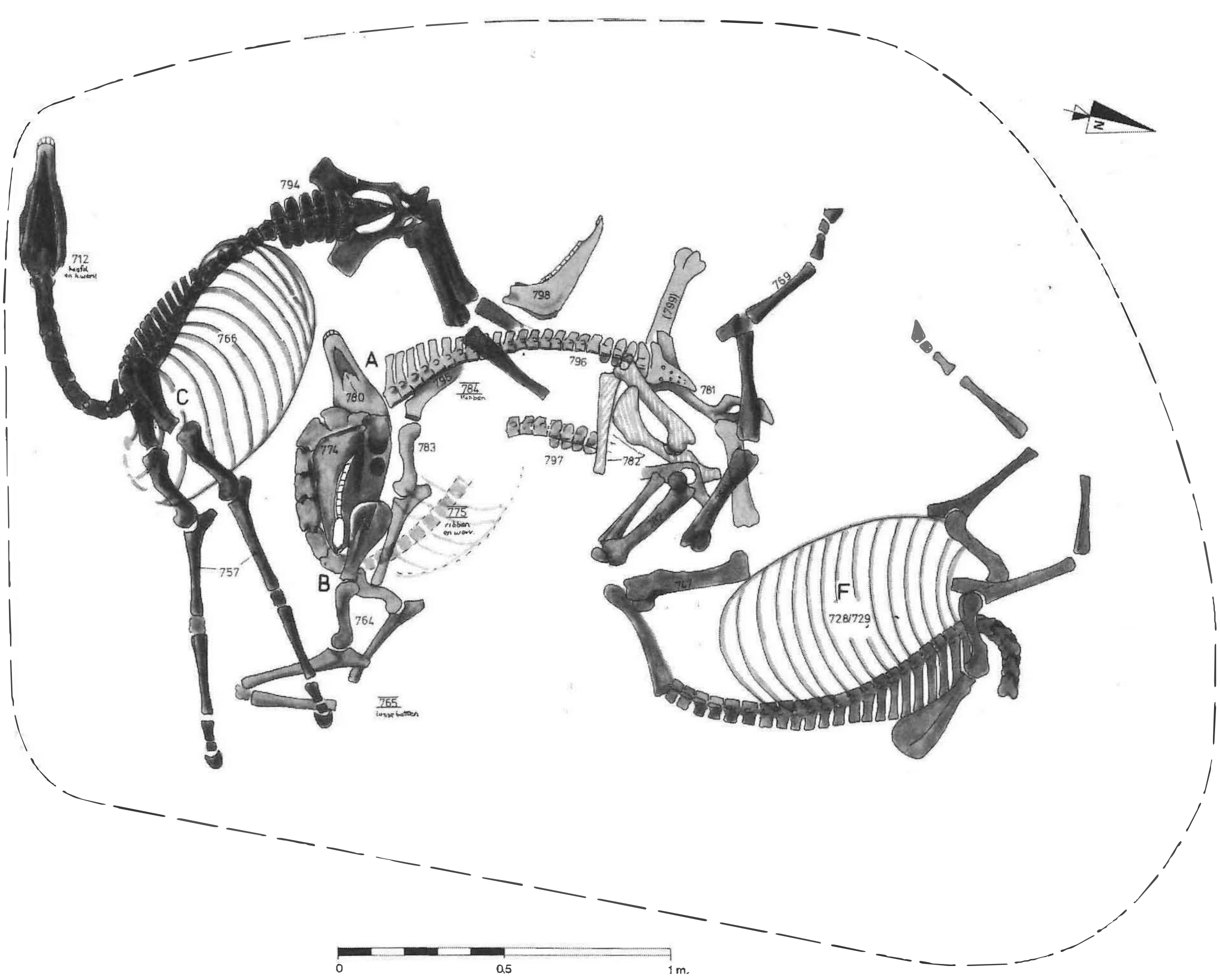

Fig. 7. Horses A, B, C and F from UTJMPK 2. Reconstruction and drawing by A. van Berkel.

Factor scores on these four fore-leg factors were calculated from their 25 measurements for the horses A up to and including L. For horse Q, from which only humerus measurements were available, factor scores were calculated by filling in for the radius, radius and ulna and metacarpus measurements, the averages of those from horses A-L. This resulted in fore-leg factor scores for 13 horses (figs. 9 and 10). The factor scores are discussed together with those of the hind-leg.

4.4. Principal component analysis on measurements from the hind-leg

In this analysis, 20 measurements were used (table 7). The first four factors had eigenvalues larger than 1. Together they accounted for 85.53 % of the total variance (table 8), and were rotated according to the varimax criterion method (table 9).

The maximum loadings of the 20 hind-leg measurements on any of these rotated factors (table 9) show a pattern comparable with that of the fore-leg: all length measurements on one and the same factor (with some proximal and distal widths): in this case the first factor; most other widths at the ends on the second factor, and the minimum width of the diaphysis on the third factor (and another proximal width on the fourth factor).

The first three factors are worth describing (the percentages variance explained are in table 8):

factor 1 length
factor 2 width, independent of length

Table 8. Eigenvalues, percentages variance explained (for each factor and cumulative) of the first four factors drawn from 20 measurements of hind-leg (table 7) by principal component analysis

Factor	Eigenvalue	% variance explained	Cumulative % variance explained
1	11.8956	59.48	59.48
2	2.7201	13.60	73.08
3	1.4144	7.07	80.15
4	1.0755	5.38	85.53

factor 3 constriction of the bones (N.B. the direction of the description of the factor is opposite to the direction of this factor; figures 11 and 12).

The factor scores for the 12 horses without missing data on these 20 hind-leg measurements (A, C-G, I-M and P) are shown in figures 11 and 12. In these figures are also included those factor scores obtained by filling in for the missing data the averages of the measurements of the other horses.

4.5. Discussion of the factor scores of the horses A-Q on the three factors of fore-leg and hind-leg

As mentioned above, the sequences of the factors width and length according to the percentage of variance accounted for fore-leg and hind-leg are opposite to each other. The explanation of this difference is possibly the larger number of length measurements taken from the fore-leg: whereas the length measurements of humerus, radius and metacarpus can be taken as parallel to those of femur, tibia and metatarsus, the two radius ulna maximum lengths (GL and GLlat) are extra (tables 4 and 7). The fact that the length of the radius was measured four times (twice directly and twice indirectly, together with the ulna), limited the total amount of variance in the length measurements, so that the largest variance was that in the width measurements of the ends. Moreover, more width measurements of the fore-leg than from the hind-leg had distributions different from normal (table 3).

For the fore-leg and the hind-leg three parallel sets of independent factors were described: width, length and degree of constriction of the bones. From the independence of these factors (standard in this type of analysis), it follows that the widths at the ends and the maximum lengths are partly independent of (or: do not completely correlate with) each other, and that the minimum widths of the diaphysis are partly independent of (or: do

Table 9. Maximum loadings on the 20 hind-leg measurements on any of the four rotated factors from the principal component analysis on 20 hind-leg measurements (see table 7 for abbreviations and table 8 for eigenvalues)

Skeletal element	Factor 1	Factor 2	Factor 3	Factor 4
Femur	BP: 643 GL lat: 736 GL: 780	DC: 879 BD: 675	SD: 620	
Tibia	GL: 791 GL lat: 766	BP: 748 BD: 637 DD: 655	SD: 666	
Metatarsus	BD: 592 GL lat: 929 GL: 943	DP: 650 DD: 841	SD: 913 CD: 809	BP: 903

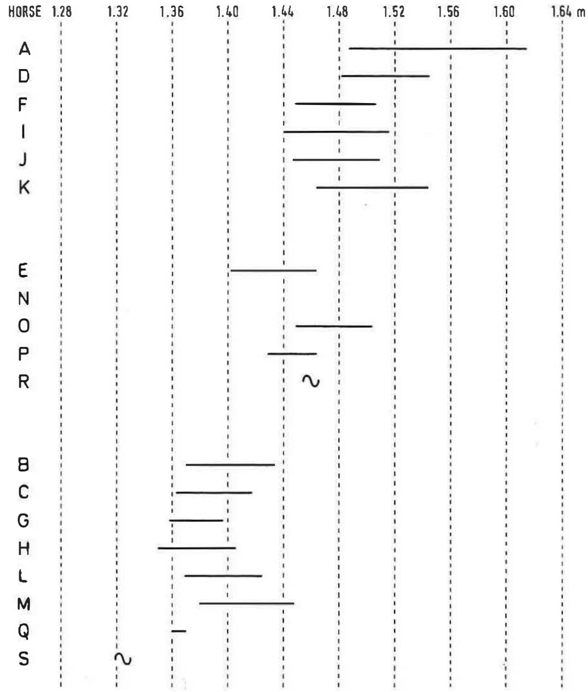

Fig. 8. Ranges of the withers heights in m of horses A-S from UTJMPK 2; for actual figures see table 2.

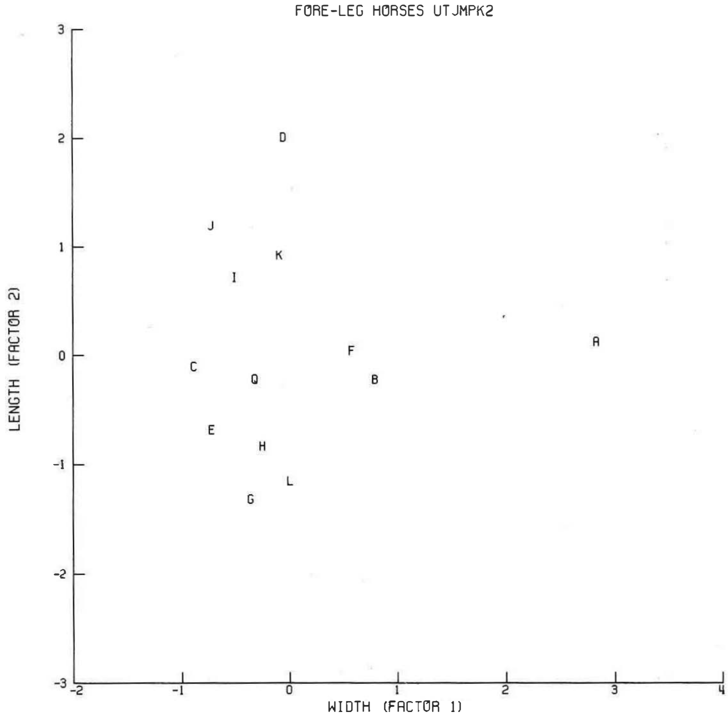

Fig. 9. Fore-leg of the horses of UTJMPK 2. Plot of the factor-scores on factor 2 (length) against those of factor 1 (width). The letters in the plot correspond with those of the horses (A, B *etc.*).

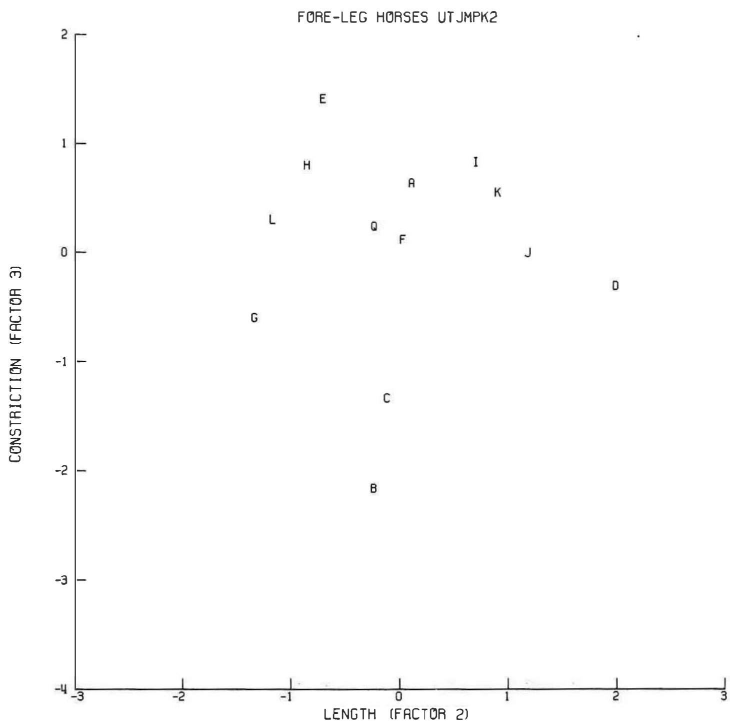

Fig. 10. Fore-leg of the horses of UTJMPK 2. Plot of the factor-scores on factor 3 (constriction of the bones) against those of factor 2 (length). The letters in the plot correspond with those of the horses (A, B *etc.*).

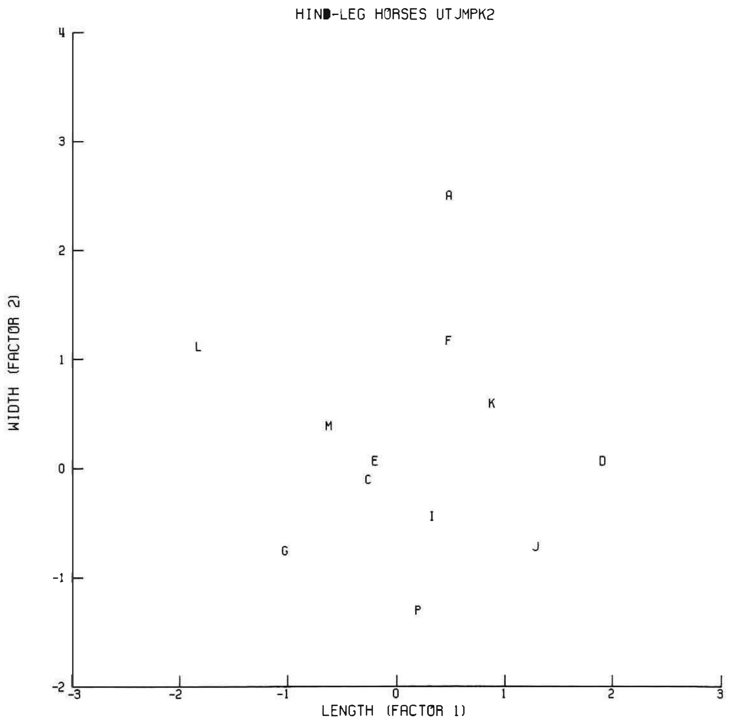

Fig. 11. Hind-leg of the horses of UTJMPK 2. Plot of the factor-scores on factor 2 (width) against those on factor 1 (length). The letters in the plot correspond with those of the horses (A, B *etc.*).

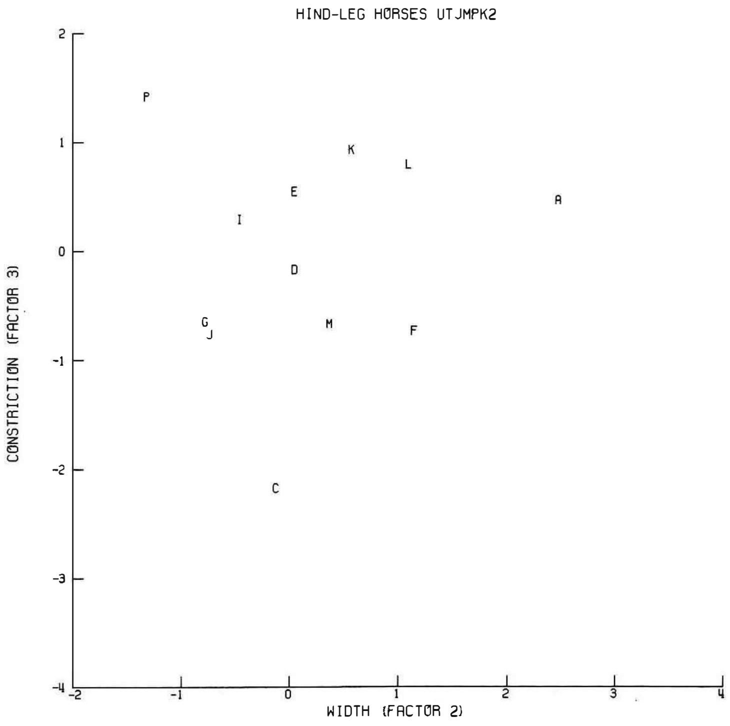

Fig. 12. Hind-leg of the horses of UTJMPK 2. Plot of the factor-scores on factor 3 (constriction of the bones) against those on factor 2 (width). The letters in the plot correspond with those of the horses (A, B *etc.*).

Table 10. Subdivision of horses A-Q on the basis of their factor scores on the factors width, length and constriction of the bones of fore-leg and hind-leg

1. broad ends of bones: horse A
   medium length
   fairly constricted
2. narrow ends of bones: horses B-Q
   2.1. tall bones
   fairly constricted: horses D, J and K
   2.2. bones of medium length
   2.2.1. little constricted: horses E, O and P
   2.2.2. fairly constricted: horses F, I, M and N
   2.2.3. strongly constricted: horses B and C
   2.3. short bones
   fairly constricted: horses G, H and C

not completely correlate with) the lengths and the widths.

Factor 1 of the fore-leg and factor 2 of the hind-leg allowed a subdivision of the horses into two categories: those with broad and with narrow ends of the bones, respectively (figs. 9 and 11). Factor 2 of the fore-leg and factor 1 of the hind-leg subdivide the horses into three categories: 'tall', 'medium length' and 'short' (figs. 9 and 11). Factor 3 also subdivides the horses into three categories: 'little contricted', 'fairly constricted' and 'strongly constricted' (figs. 10 and 12; N.B. the increase of the constriction is from top to bottom in these figures).

On the basis of these categories, a subdivision of the horses A-Q could be made as in table 10. It shows that the two or three categories of each factor do not form strict combinations. For instance, 'fairly constricted' combines with both categories of width and with all three categories of length. Both 'little constricted' and 'strongly constricted' only combine with 'medium length'.

Close examination of figures 9-12 will reveal that other distinctions of categories in the factors and other subdivisions of the horses (by placing the border-lines elsewhere), would have been possible. In all other subdivisions, horse A, with its broad bone ends, would be separated from horses B-Q. Because I assumed that all the skeletons were from male horses, I conclude that horse A belonged to a separate type (or breed) of horse, whereas the variation in height and in degree of constriction of the bones in the horses B-Q was too gradual to discern separate types (or breeds) in them.

However, an assessment of the gradualness of this variation as being possible within one breed is subjective, because of the absence of data on the variation of length, width and constriction of the bones within a single breed.

4.6. Further research

Other groups of complete horse skeletons known archaeologically which offer possibilities for research on the origin of European horse breeds are those from the early medieval burial-fields (for a list of those with horse burials: Müller-Wille, 1970/71; for measurements amongst others: Nobis, 1955; 1973; Figge, 1981). Nobis suggested the presence of various types of breeds in the burial-field of Rübenach on account of a bivariate analysis. I am unaware of medieval parallels to this disgraceful dumping of horse bodies together in a pit.

The horses used in this study suggested possibilities for an analysis of horses in this way. The variation of present primitive breeds of horses in the factors length, width and constriction of the bones should be analysed to interprete that of excavated horses from (pre)historical times as intra- or interbreed variation.

5. REFERENCES

Anon. *Le cheval dans l'agriculture* (= Ethnozootechnie 30). Paris, 1982.

Armitage, P.L. & J. Clutton-Brock, 1976. A system for classification and description of the horn cores of cattle from archaeological sites. *Journal of Archaeological Science* 3, pp. 329-348.

Driesch, A. von den, 1976. *A guide to the measurements of animal bones from archaeological sites* (= Peabody Museum Bulletins, Harvard University 1). Harvard.

Driesch, A. von den & J. Boessneck, 1974. Kritische Anmerkungen zur Widerristhöhenberechnung aus Längenmaßen vor- und frühgeschichtlicher Tierknochen. *Säugetierkundliche Mitteilungen* 22, pp. 325-348.

Figge, J., 1981. *Osteologische und osteometrische Studien an Knochenfunden von Pferden aus dem sächsischen Gräberfeld in Liebenau dem fränkischen Friedhof in Griesheim, dem Gräberfeld auf Esch (Groß-Gerau) und einer Opferstätte bei Goddelau.* Inaugural-Dissertation. Gießen.

Groot, H.L. de, 1981. Jan Meijenstraat e.o. In: T.J. Hoekstra, Archeologische kroniek van de gemeente Utrecht over 1980. *Maandblad Oud-Utrecht*, pp. 44-50.

Habermehl, K.-H., 1975. *Die Altersbestimmung bei Haus-*

und Labortieren. 2nd ed. Berlin/Hamburg.

Müller-Wille, M., 1970/71. Pferdegrab und Pferdeopfer im frühen Mittelalter; mit einem Beitrag von H. Vierck. *Berichten Rijksdienst voor het Oudheidkundig Bodemonderzoek* 20-21, pp. 119-248.

Nobis, G., 1955. Beiträge zur Abstammung und Domestikation des Hauspferdes. *Zeitschrift für Tierzüchtung und Züchtungsbiologie* 64, pp. 201-246.

Nobis, G., 1973. Die Pferde aus dem fränkischen Gräberfeld von Rübenach (= Germanische Denkmäler der Völkerwanderungszeit, Serie B, Die fränkischen Altertümer des Rheinlandes, 7). In: Chr. Neuffer-Müller & H. Ament, *Das fränkische Gräberfeld von Rübenach, Stadt Koblenz.* Berlin, pp. 275-281.

Prummel, W., 1978. Animal bones from tannery pits in 's-Hertogenbosch. *Berichten Rijksdienst voor het Oudheidkundig Bodemonderzoek* 28, pp. 399-422.

Prummel, W., 1979. The size of Dutch horses and Labouchère's theory on the origin of the Frisian horse. In: M. Kubasiewicz (ed.), *Archaeozoology* I. Szczecin, pp. 431-438.

Vlerk, L.C. van der, 1983. *Utrecht ommuurd.* Vianen.

Warmerdam, M., 1982. Numeriek-taxonomische studie van de twee vormen van de woelrat *Arvicola terrestris* (Linnaeus, 1758) in Nederland en België. *Lutra* 24, pp. 34-66.

Weele, L.Th. van der, 1977. *WESP, Waarlijk Eenvoudig Statistisch Pakket* (RC Publicatie 8). Groningen.

6. KEYWORDS

The Netherlands, Utrecht, A.D. 15th/16th century, horse skeletons, male, withers height, breed, principal component analysis, fore-leg, hind-leg, length, width, constriction of the bones.