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ANTHROPOLOGIA HUNGARICA

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On early prehominization

By

T. TÓTH

(Received January 7, 1988)

Abstract. The fossil primate finds, especially the Rudabánya specimen No. 77 (RUD-77), represent a very significant group on account of the early steps in human evolution.

Having in mind the brief account of this subject, first of all, one has to pay attention to the investigations done in the last three decades (KRETZOI 1969, 1974, 1975, 1976, 1984; MORBECK 1983; KORDOS 1982, 1985; WOLPOFF 1980). The excavation of a rich fossil primate material enables us to outline in a well-established way the earliest (hominoid) period of the hominization. The starting and final steps in the broad chronological amplitude of the Miocene-Pliocene period are indicated by the taxa Proconsul-Ramapithecus, which existed in the intervall from 18 till 8 myrs. The osteological finds necessary for the analyses of the problems connected with early prehominization were presented by systematic excavations on the territory of three continents of the Old World. Earlier the excavations were concentrated on certain geographical zones of East Africa and South Asia. But the Hominoidea-remains found at Rudabánya in northeastern Hungary since 1967 extended territorially the ecological niche of the fossil Primates (KORDOS 1982, 1985, 1987a, b). Until 1988 eighty primate finds have been excavated at Rudabánya from strata of about 10 myrs (Lower Pannonian= Late Miocene, Early Vallesian). The phylogenetically most significant skull-find (RUD-77) belonging to this group indicates the re-evaluation of the theoretical variations. It should be noted that the chronology of the Hominoids from Rudabánya may be interpreted in a broader sense too: according to MORBECK (1983) above-mentioned finds "... are several million years younger than the Fort Ternan Ramapithecus wickeri and older than Ramapithecus, Sivapithecus, and Gigantopithecus from Potwar Plateau, Pakistan" (op. cit. p. 371).

After a press-conference, which was held in the Hungarian Geological Institute on 11 December 1986, L. KORDOS delivered a lecture during a scientific session on the presented Rudapithecus skull (RUD-77) reconstructed by him. From the 101 bone-fragments 24 were suitable for osteoanatomical piecing together in the vault and orbital regions. The bone-fragments of determinable position taken by him into consideration are as follows: subnasal maxillary bone, zygomatic bone-fragment, sphenoidal bone-fragment near to foramen magnum, occipital bone-fragment with a protuberance (KORDOS 1987a, b). By the way, he succeeded in piecing together the left upper tooth row (P^3-M^3) as well as the right upper one (M^1-M^3) with a palatine bone-fragment. All of these finds were presented by him on 22 January 1987 in our Department where he was lecturing about the phylogenetical significance of them with the object to iniciate a discussion - as it was proposed by the author of the present paper to KORDOS. Disputed was the reality of the sex-determination of RUD-77, because the os coxae of this specimen has not yet been found. Further, the relatively high orientation of the position of foramen magnum in the occipital section of the median-sagittal contour was also disputed. KORDOS himself has given an overall evaluation according to the determinable osteoanatomical position of the given bones, not regarding his conclusions as final ones. This is well expressed in his papers about the Rudapithecus cranium (1987a, b). In these papers he draws the attention to the fact that not only the supraorbital tori are missing, but al-

so the sagittal crest of the skull. It may be pointed out on the whole, that the absence of this special longitudinal exostosis within the Rudapithecus group for the present cannot be interpreted as a characteristic trait but as a manifestation of individual morphological variability-being independent of sexual dimorphism. It will be sufficient to refer to the fact that also the second specimen from Pliopithecis vindobonensis (Ind. II, C 39) has not any sagittal crest on its vault (ZAPFE 1960).

MORBECK (1983) made reference to the variability of the morphological traits in her descriptive and comparative analysis of the postcranial skeleton from the Rudabánya hominoid finds. The skull of RUD-77 as well as the other remains from this group quite well reveal the osteological polymorphism of the Miocene hominoids in spite of the fact that the different taxa might have developed in the Central-European subcontinent in the process of the adaptive radiation not only according to any chronological sequence, but coexisting simultaneously, too.

In this connection a new synthesis of all the existing conceptions towards a more realistic theoretical approximation of Human evolution deserves attention. According to it the main tendencies of an unlimited progressive development have been ensured in anthropogenesis, and the general preconditions of hominization became effective (universalization, autonomization, tendency towards the taxonomic integration, evolution of the systems of information) (ZUBOV 1983, 1985).

It must be borne in mind that the genealogical position of the Ramapithecinae appears to be rather controversial (ANDREWS, PILBEAM, SIMONS after KORDOS 1987b, FRAYER 1978, GREENFIELD 1979, KHRISANFOVA 1987, KORDOS 1985, MORBECK 1983). Recently the problem of the irregularity of Hominoidea-evolution was discussed (KHRISANFOVA 1985). As it is known according to KRETZOI (1975, 1976) the Rudabánya finds reveal some Ramapithecus-affinity.

Nevertheless, the possibility of the fact cannot be denied that the evolutionary morphological potential resulted in different taxonomical levels in the Middle Miocene-Early Pliocene chronological amplitude and that according to the adaptive ontogenetical plasticity the trend of hominization might have begun from the ecosensitive group of sensu lato Dryopithecinae (i.e. oldest Ramapithecinae) as a common morphological stock. This alternative interpretation is indicated by the find-group of Rudapithecus hungaricus KRETZOI - accepting, at the same time, the necessity of further finds. It must be noted that KORDOS (1985) himself does not contest the common, generalized (dryopithecoid/ramamorph) phylogenetical preliminaries of the morphological traits of Rudapithecus and Ramapithecus.

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ANTHROPOLOGIA HUNGARICA

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Comparison of early primate skulls from Rudabánya (Hungary) and Lufeng (China)

By

L. KORDOS

(Received November 16, 1987)

Abstract. This paper contains a comparative morphological analysis of the 10 myrs old Rudapithecus hungaricus (Rudabánya) and on the 7 myrs old Sivapithecus lufengensis (Lufeng) skull finds. The skull finds registered as RUD-77 and P.A. 677 show considerable similarity in the cerebral regions while there are basic morphological differences in the characteristics of the facial parts of the skulls. These similarities and differences between the two skulls also reveal the relation between the taxa Rudapithecus hungaricus and Sivapithecus lufengensis. With 2 tables, 1 list and 7 figures.

The Rudapithecus skull from Rudabánya and that of Sivapithecus lufengensis found at Lufeng are distinguished finds even among the important bone and teeth remains representing the process of early prehominization. At Rudabánya (NE Hungary) the ape remains were found in 10 million years old (Lower Pannonian = Late Miocene, Early Vallesian MN 9 zone) lignite and clay layers which had deposited in a contemporary swamp (KORDOS, 1982, 1985).

The first finds were discovered in 1967. Until the autumn of 1987 eighty primate find-associations had been found (KRETZOI 1969, 1974, 1975, 1976a, b, 1984: KRETZOI al., 1976, MORBECK 1983; KORDOS 1987a, b), labelled as "RUD" and with serial numbers ranging from 1 to 80 (List 1). On the basis of our present knowledge the author's opinion is that the Rudabánya locality yielded two kinds of early primates, namely Pliopithecus hernyaki KRETZOI and Rudapithecus hungaricus KRETZOI (KORDOS 1987b).

The 7-8 million years old (Middle Baodian = Late Miocene, Middle Turolian, MN 12 Zone) layers at the site Lufeng in Southern China had deposited in a valley. Just as in Rudabánya, grey clay layers alternate in this locality with lignite stripes (QI GUOQIN 1985, CHENG WANYOUNG 1986). During the 9 excavation campaigns between 1975 and 1983, five skull fragments, 10 mandibles, 49 skull and mandible fragments, 28 toothrows, 650 isolated teeth, two knuckles, one scapula and one clavicle were found (WU RUKANG al. 1986). According to Chinese experts, certain Lufeng finds, earlier reffered to Sivapithecus yunnanensis belong to male apes while the other ones, earlier referred to Ramapithecus lufengensis, are the remains of female animals. Therefore recently the name Sivapithecus lufengensis has been used for both taxa (WU RUKANG & al. 1986). Because of the differences between the Lufeng finds and the genus Sivapithecus, the introduction of a new generic name has recently been suggested (WU RUKANG, pers. comm. October 1987).

The remains found at the localities Rudabánya and Lufeng have special importance in the study of the process of prehominization in Eurasia because so far they are the only sites to yield skulls (Fig. 1, for measurements see Table 1).

In the autumn of 1987 I had the opportunity to spend one month in China within the scope of a cooperation programme between the Ministry of Geology and Mineral Resources (Beijing) and the (Central Geological Institute, Budapest), when I studied the original Chinese finds, especially the skulls and mandibles of female apes. I visited the Institute of Vertebrate Paleontology and Palaeoanthropology of Academica Sinica and consulted with several

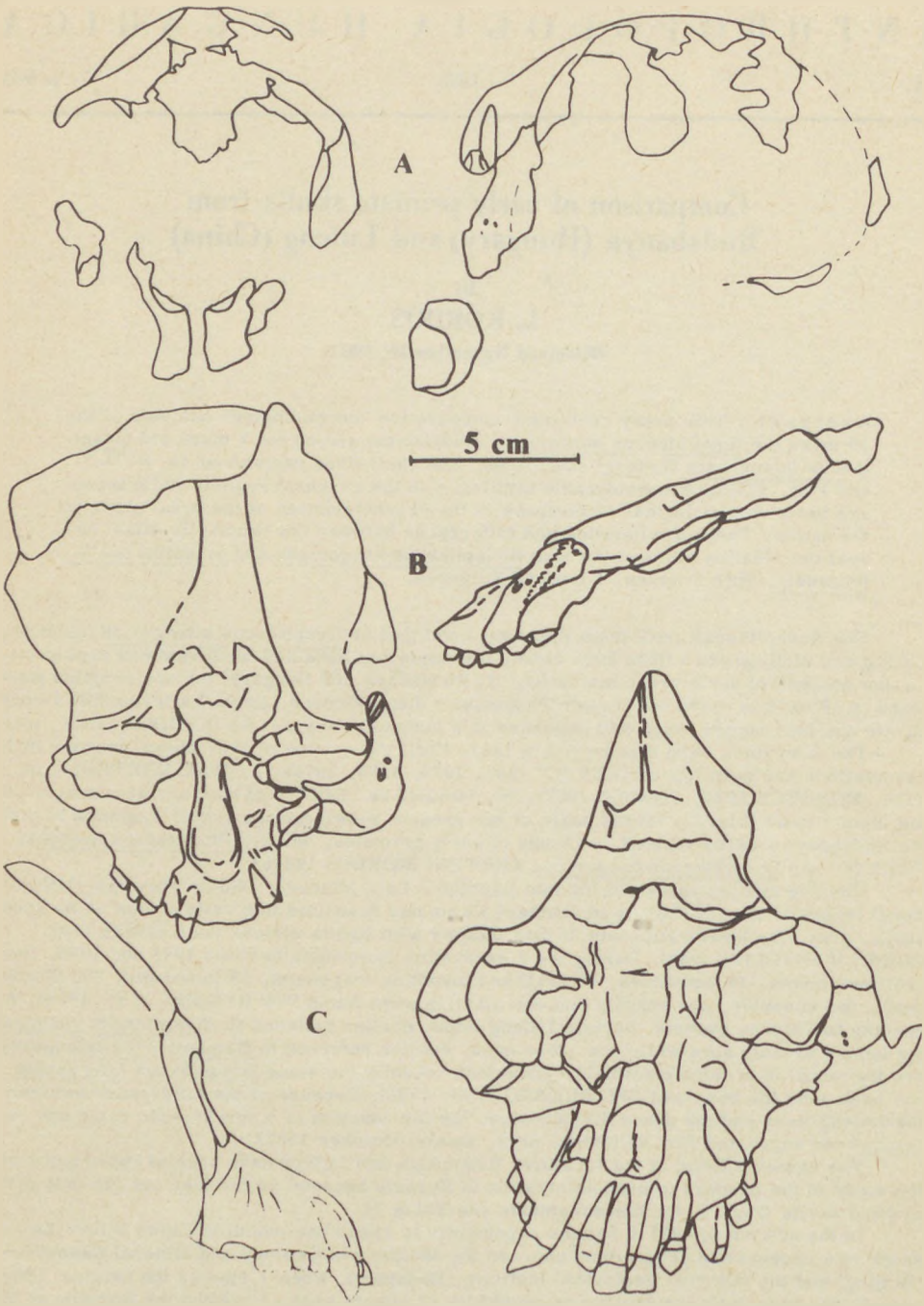

Fig. 1 Frontal and lateral views of the Rudapithecus hungaricus (A) and the Sivapithecus lufengensis skulls. B = P. A. 677., C = P. A. 644

Chinese experts on the comparison of Chinese and Hungarian finds. I wish to express my sincere thanks here to Professor WU RUKANG, LU QINGWU, HAN DEFEN, QI GOUGIN XU QINGHUA, QIU ZHUDANG, WU WENYU and LI CHUAN-KUEI for their assistance and readiness to cooperate.

Table 1 Measurements of Rudapithecus hungaricus (RUD-77) and Sivapithecus lufengensis (P.A. 677) (in mm)

Measurements	RUD-77	P.A. 677
Length of neurocranium	± 128	-
Half width of cranium at the eurion	40	42
Minimal distance of the frontale (ft-ft)	40	± 40
Mid-facial width at the zm	35	48
Width of the orbit (left)	± 28	33
Height of the orbit (left)	± 35	± 25
Interorbital distance	17	22 (reconstr.16)
P^3 length	6.4	6.2
P^3 width	10.0	9.1
P^4 length	6.6	7.2
P^4 width	10.2	10.6
M^1 length	8.8	10.6
M^1 width	± 9.4	10.6
M^2 length	9.4	11.4
M^2 width	11.1	11.3
M^3 length	9.1	10.6
M^3 width	10.6	11.0
M^1-M^3 length	27.7	-
P^3-M^3 width	40.4	-
Height of the palatine at the M^1	7.2	-
Lingual distance between M^3 and M^3	32.4	-

MATERIALS

The Rudapithecus skull find RUD-77 from Rudabánya consists of 101 bone fragments and 8 upper teeth. During its reconstruction in 1986, the frontal bone was completed by joining 24 fragments (direct bone-to-bone contacts). To the frontal bone the following parts are attached: the zygomatic bone, a fragment of the occipital bone (which, however, cannot be joint to it directly), a small piece of the basis, the subnasal maxillary bone (it possibly does not correspond to the facies anterior of both sides), the toothrows of both sides (left side P^3-M^3, right side M^1-M^3) with a fragment of the palatine (KORDOS 1987b).

According to WU RUKANG & al. (1981) the Sivapithecus lufengensis skull find P.A. 677 "is an almost complete skull, only the mandible was missing. The maxilla has in situ all teeth, except the two medial incisors, the left lateral incisor and the right canine. The

whole skull was compressed into a flat piece in the vertical or top-base direction during the process of fossilization, but with almost all parts intact".

TOP VIEW OF THE SKULL AND THE TEMPORAL LINES

The calvaria of the Rudapithecus skull practically belongs to the frontal bone. The sutures had been ossified to such a great degree that it is impossible to follow their track by the traditional methods. Consequently at present we are unable to make any anatomical distinctions among the other bones of the brain-case.

The distinction of sutures in the Lufeng find is not easy either. This skull is considerably compressed. Still, its right side can be studied well, thus giving an authentic picture of the find. With the aid of a sagittal mirror image of the right side, and with a slight correction a highly probable reconstruction of the top view of the calvaria results (Fig. 2). Projecting on each other in the same scale the main top view contour lines of the two reconstructed calvarias of the two skulls, we may prove that (1) the basic forms of the two calvaries are completely identically (2) the temporal lines cover each other completely in the supraorbital part of the frontal bone (frontotemporale) and near the lambda, (3) in the bregma region the distance between the temporal lines is narrower in the Rudabánya find than in the Lufeng one, (4) in the P.A. 677 find the opisthocranion is broken and missing, being therefore unsuitable for comparison, (5) there are no traces of sagittal crest on either skull, (6) the interorbital distance is wide on both specimens; (7) in frontal view the width of the orbits measured between the maxillofrontale and the sutura frontozygomatica is the same on the right side of both specimens but on the left it is narrower in the Rudabánya find, (8) the width of the skull (euryon distance) and its length (nasion-opisthocranion) are slightly (approximately by 8-10 % larger in the Lufeng find than in the one from Rudabánya.

Considering all these, it is highly probable that-in this comparison - this minimum dimensional and morphological difference between the two skulls is due to the damage of the Lufeng skull. That find had suffered compression from upwards and became flattened. The RUD-77 and P.A. 677 remains are completely identical as regards the basic morphology and dimensions of their calvariae.

THE QUESTION OF THE GLABELLA AND THE SUPRAORBITAL TORI

The glabella of the RUD-77 find is smooth, without any traces of supraorbital tori. This is of phylogenetic significance in the later phase of the evolution of primates, as well as in the process of hominization (KORDOS 1987a, b).

A clear recognition of these important marks is rather difficult on the Lufeng find P.A. 677. According to the formulation given by WU RUKANG & al. (1986): "The supraorbital ridges are slightly developed and uncontinuous with wide and concave glabella region". On the basis of the published photos, I found a difference between Rudapithecus and Sivapithecus lufengensis (KORDOS 1987b); namely, the supraorbital tori are more marked in the case of the Chinese skull than in the Rudabánya skull.

After the investigations made on the original Lufeng find P.A. 677 in China, I realized that the compression resulted in the collapse of the glabella region, therefore it is very difficult to reconstruct its straight or concave direction. Henceforward, it is hard to form an opinion on a possible presence or absence of supraorbital tori in the Chinese skull. It is certain that behind the more compact, thicker bony matter of the supraorbital bone, the thin frontal bone had been considerably pressed in and broken. That is why on the photos (WU RUKANG & al. 1981, 1986) the presence of supraorbital tori seems to be unquestionable. However, it is more probable that, although compared with the RUD-77 find the supraorbital tori are definitely observable in the Lufeng skull, they had developed only to a slight degree. This is corroborated by the fact that the bony matter of the torus can be well distinguished from the contact line of the frontal bone. Before a complete reconstruction of the skull, it is impossible to decide whether there was a depression between the two bones in the external surface. It is clear that reconstructions which attempt to demonstrate the presence of strong supraorbital tori in female Sivapithecus lufengensis are mistaken because they start from the present compressed condition of the find.

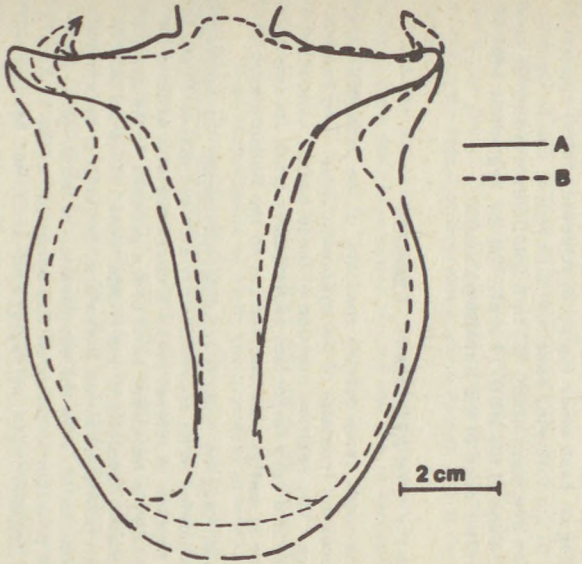

Fig. 2 Reconstructed top view of the Rudapithecus (B) and the Sivapithecus lufengensis (P.A. 677) skulls (A)

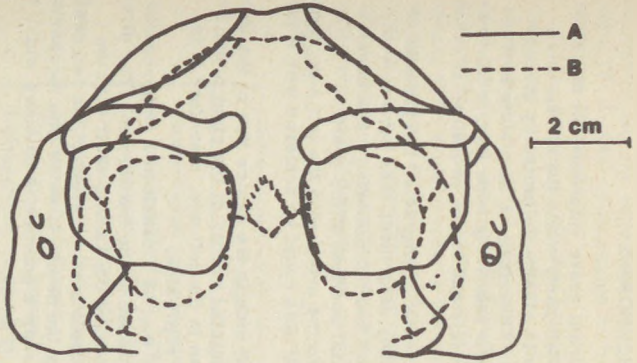

Fig. 3 Frontal view of the orbital region of the Sivapithecus lufengensis (P.A. 677) (A) and the Rudapithecus hungaricus (B). Reconstructions

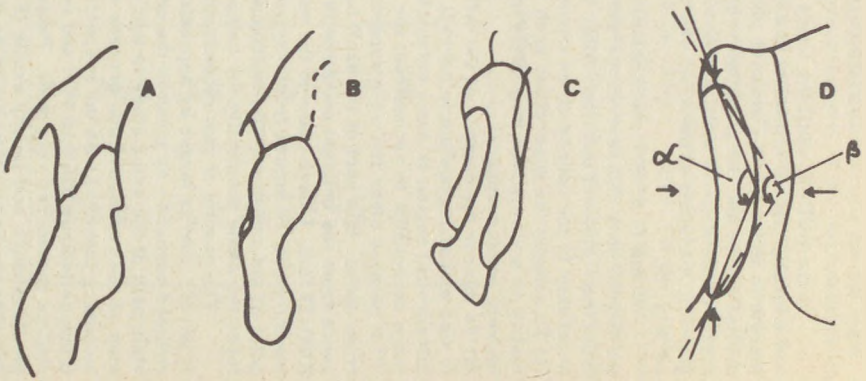

Fig. 4 Lateral view of the zygomatic region. A = Rudapithecus hungaricus, B = reconstructed P.A. 677 (S. lufengensis), C = S. lufengensis (P.A. 644), D = recent chimpanzee with the measuring points and arches

COMPARISON OF THE ORBITAL REGIONS

In the RUD-77 skull the bones bordering the orbits from above (supraorbital margins) and laterally (facies orbitalis) had remained intact in the left part, while the infraorbital margin is missing. The relative position of the two orbits is clearly delimited by the interorbital region and the glabellar region of the frontal bone. Therefore we may state that the orbits of the RUD-77 skull are connected to each other by a relatively wide interorbital region (1), the width of the orbit was smaller than its height (2), and it was probably "D" shaped (Fig. 3).

On the P.A. 677 skull belonging to a female Sivapithecus lufengensis, the glabella of the frontal bone and several margins of the orbit are already deformed; they have moved from their original position. After the study of the original find the following steps became necessary in the course of the reconstruction of the original position of the orbit:
(1) To connect the superciliar arch (which had pressed into the orbit) with the left side zygomatica in a view which may correspond to the frontal view (this could be achieved with a relatively great accuracy).
(2) To mirror the contour of the left-side orbit to the right side in the centre line of the face. It also makes it possible to correct the supraorbital and lateral arches of the right orbit. The infraorbital region is more complete in the right orbit than in the left one, therefore it is more reasonable to reconstruct the left side based on the right side.
(3) It became clear from the superior view of the calvaria that as a result of a compression from above, this part of the skull had become slightly flattened at the frontal bone. The divergence from the original condition is of 8-10%. After comparing the Lufeng skull with the RUD-77 find, I have come to the conclusion that it is probable that the width of the two skulls measured at the sutura fronto-zygomatica had been nearly the same. If we fit this measuring point of the undistorted Rudapithecus skull on the Lufeng skull a position is obtained which affords the same possibility for comparison for both skulls (Fig. 3).

The results of this reconstruction process is the following: The width of the orbit in the P.A. 677 find is larger by approximately 30% than its height. The orbit is rectangular, with rounded corners - as given in the original description (WU RUKANG et al. 1986). Another statement of the same study is that the interorbital region is very wide. After making the last step of the reconstruction process described above, this distance diminished considerably becoming identical with the respective distance in the RUD-77 skull. As compared to Sivapithecus indicus (GSP 15 000) and recent orang-outang this characteristic of the skull can still be considered very wide. Projecting on each other the reconstructed orbital regions of the Rudabánya and Lufeng skulls (Fig. 3) the following essential differences can be demonstrated: (1) the basic froms of the orbits are dissimilar, (2) in frontal view the frontal bone of the find P.A. 677 is higher than this bone in the RUD-77 skull, (3) the zygomatic bone of the Lufeng find is wider than the respective bone of the Rudabánya skull.

LATERAL VIEW OF THE ZYGOMATIC REGION

The bony frame which borders the orbit from outside consists of the processus zygomaticus of the frontal bone and the processus frontalis of the zygomatic bone. The two bones are joint by the sutura frontozygomatica. The relative position of these bones, connected with the development of the supraorbital tori is a very important evolutionary trait. Its importance has already been emphasized during the investigations carried ont on the Rudapithecus skull (KORDOS 1987a, b).

Generally speaking, these bones in Neogene finds (Proconsul africanus, Rudapithecus hungaricus, Sivapithecus indicus) are situated in an approximately straight plane. From the early Australopithecus finds to Homo sapiens in lateral views a characteristic arch of the orbit has developed. This arch is formed by a backward bend of the process of the zygomatic bone and by a forward bend of the processus frontalis of the frontal bone. Since no lateral perspective of the Lufeng finds has been published in the literature, in itself it does not afford any possibility to study this characteristic. Now the examination of the original finds P.A. 677 and P.A. 644 ones makes it possible to carry on this analysis. In the P.A. 677 (female) skull the processus frontalis, together with the superciliar arch, had been pressed into the orbit as results of pressure from aboved. At the same time they did not suffer any

distortion and the zygomatic bone remained intact in its original position. As for the male skull (P. A. 644), this region remained without any distortion in spite of the considerable co-pression of the skull.

In addition, a graphic superposition the main phases of the process was carried out simply by using certain angles for measurements (Fig. 4). (1) I defined the upper and lower inflexion points of the bony orbit as the two endpoints of a reference line, (2) another reference plane was obtained by drawing a perpendicular to the line between the above-mentioned two points, (3) the anterior point of contact of the bony orbit and this second plane forms the origin of an angle enclosing the upper and lower points of the orbit value, (4) the origin of the β angle is the point of intersection of this same second plane and the longitudinal central line of the processus frontalis, enclosing the two vertical extreme points of the orbit, (5) γ angle is the arithmetic mean of α and β . The results of this comparison made on some investigated skulls are given in Table 2.

Table 2

The angles of the zygomatic region

Taxa	α	β	γ
Sivapithecus indicus (GSP 15000)	167	152	160
S. lufengensis (P. A. 677)	164	118	141
S. lufengensis (P. A. 644)	146	132	139
Orang-utang (recent)	150	125	137
Rudapithecus hungaricus (RUD-77)	149	122	135
Proconsul africanus	136	125	130
"Zinjanthropus boisei"	135	115	125
Chimpanzee (recent)	131	117	124
Australopithecus africanus (Taung)	123	110	116
"Plesianthropus transvaalensis"	130	98	114
Petralona	130	87	108
Broken Hill	121	93	107
Steinheim	120	92	106
Gorilla (recent)	120	90	105
Jebel Irhoud	120	88	104
Homo sapiens (recent)	115	85	100

Even the scanty data make it possible to distinguish different evolutionary phases and trends, especially as regards the γ value. The Rudapithecus and the Chinese finds are in the same group. They are isolated from the Sivapithecus indicus-orang-cutang line, as well as from the trend of decrasing angle values which can be observed in a later phase of hominization.

After the comparison of the Rudabánya and Chinese primates finds we may say that in lateral view the bones which border the orbits laterally show considerable similarity in their development.

SAGITTAL SECTION OF THE SUBNASAL REGION

It is very simple to study the subnasal alveoral morphology of Rudapithecus hungaricus. The RUD-77 maxilla find was broken vertically along the median palatine suture, therefore the palatine process of the maxilla, the lateral margin of the nasal aperture, the anterior nasal spine, the naseoalveoral clivus, the prosthion, the infradentale and the oral and nasal incisive fossae (WARD & KIMBEL 1983) can be examined very well. If it is impossible to study directly the sagittal section in a find, usually X-ray and computerized tomography (CT) investigations are applied (WARD & KIMBEL 1983; DE BONIS & MELENTIS 1987; CONROY & VANNIER 1987). In the case of the Lufeng finds the subnasal alveoral morphology has been stuied so far. During this comparative investigation I made attempts to draw the mid-sagittal section of male Sivapithecus lufengensis (P. A. 644) with the aid of casts (Fig. 5).

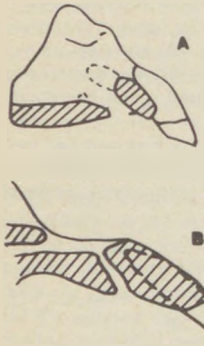

Fig. 5 Sagittal section of the subnasal region.
A = Rudapithecus hungaricus (RUD-12),
B = S. lufengensis (P.A. 644)

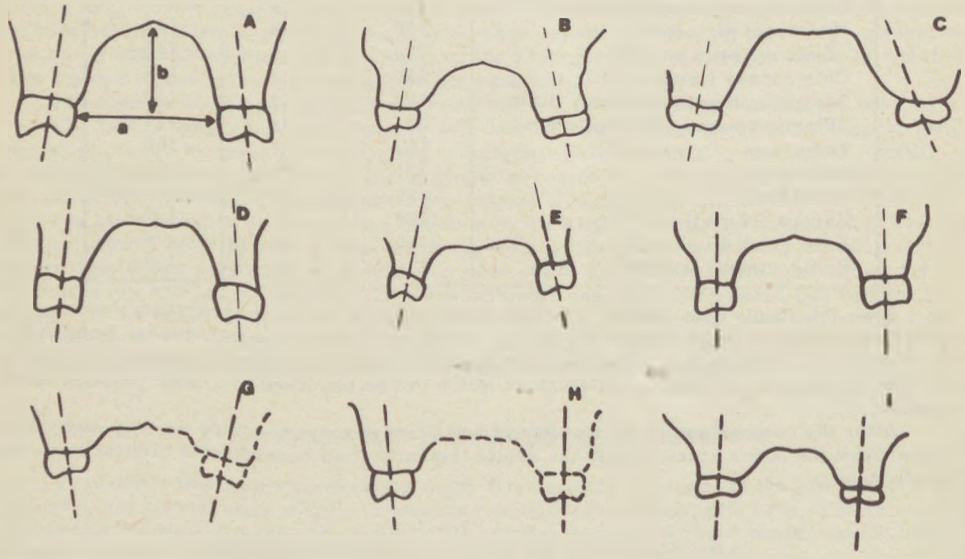

Fig. 6 Vertical section of the different hominoid-hominid remnants, with the measuring points of the depth of the palatine, and the trend of the molar axis. A = recent orangutan, B = Sivapithecus indicus (GSP 15000), C = S. lufengensis (P.A. 644), D = gorilla (recent), E = chimpanzee (recent), F = Homo sapiens (recent), G = Rudapithecus hungaricus, H = "Bodvapithecus", I = Australopithecus africanus (Taung)

As WARD & KIMBEL (1983) wrote in their classic paper this cluster of traits makes possible to distinguish two or three types among the Miocene hominids. The "Asian" form includes Ramapithecus, Sivapithecus indicus and recent Pongo, while Proconsul africanus from western Kenya, Australopithecus afarensis from the Hadar Formation of Ethiopia as well as recent African apes belong to the "African" type. According to the authors clearly "African" subnasal pattern occurs in a late Miocene hominoid specimen recovered at Rudabánya. A possible third group may cover some Australopithecus forms.

In the Lufeng find P.A. 644 the oral fossa incisiva is narrow and is situated in the line of P^4. The nasoalveolar clivus is long and has a curved surface between the prosthion and the anterior nasal spine. The nasal crest projects over the palatine process. Comparing it with the RUD-12 find, it can be seen that in the Rudabánya find the subnasal region is shorter than in the Lufeng one, the naseoalveolar clivus is ovoid and not elongated, the fossa incisiva is wide and is situated at the height of the canine, on the naseolaveolar clivus the anterior nasal spine emerges considerably over the plane of the palatine process.

Summing up the results of these preliminary investigations, it may be stated that as regards its subnasal alveolar morphology, the Sivapithecus lufengensis skull (P.A. 644) of Lufeng belongs to the "Asian" type rather than to the "African" one. RUD-12 belongs to the "African" type and in this group it is similar first of all to Rangwapithecus vancouveringi (KNM-SO 700) and Australopithecus afarensis (A.L. 199-1. and A.L. 200 1a).

VERTICAL SECTION OF THE MAXILLARY BONE

The dome-like rise of the palatine was regarded as an important morphological difference between the two pongohominid taxa (Rudapithecus hungaricus and Bodvapithecus altipalatus) of Rudabánya described by KRETZOI (1974, 1975). As I have emphasized before (KORDOS 1987b) it was a mistake to distinguish a Rudapithecus species with a palatine of "low" position and a Bodvapithecus species with a palatine of "high" position among the Rudabánya finds. The height of the palate measured at the respective teeth in practically the same in both taxa, it has a low position at M^2. This can be seen in both RUD-77 and RUD-12 and it can be reconstructed with great probability also in the type of "Bodvapithecus altipalatus" (RUD-7 find).

As for the Lufeng finds this section was observable only in the male specimen (P.A. 644) in which, compared to the Rudabánya finds, the dome-like rise of the palatine is considerably higher (Fig. 6). An index is used here to denote it in figures. This index is obtained by dividing the distance between the lingual sides of both M^2-s ("a" value) by the distance between this line and the palate, measured along a line perpendicular to the middle of the line ("b" value). The results are the following:

Specimen	"a" (mm)	"b" (mm)	index
Rudapithecus (RUD-12)	27	9	3.0
Rudapithecus (RUD-77)	+31	+12	2.6
S. lufengensis (P.A. 644)	43	22	2.0
S. indicus (GSP 15000)	30	15	2.0
Australopithecus africanus (Taung)	26	11	2.4
Pongo (recent)	34	23	1.5
Pan (recent)	27	11	2.5
Gorilla (recent)	32	14	2.3
Homo sapiens (recent)	30	13	2.3

After this brief outline we may state that Rudapithecus (including "Bodvapithecus"), chimpanzee and modern man belong to a group with "low" palate. Recent gorilla, with its rising palate, together with Australopithecus africanus, occupies an intermediate position between the previous group and those forms which have definitely high palate (Sivapithecus indicus, S. lufengensis and recent orang-utang). Thus from evolutionary viewpoint in this respect the Rudabánya finds are nearer to chimpanzee and modern man than to the Sivapithecus indicus and Chinese lufengensis which have several characteristics in common with each other.

With the aid of the vertical section of the maxilla it can also be demonstrated that in Rudapithecus the sagittal axes of the M^2 teeth converge toward the mandible while in all other extinct or recent apes investigated so far they diverge. At the same time they are more or less parallel in man and in the "Taung baby" (Fig. 6). The very strong lingual attrition on the M^1 and M^2 teeth of the RUD-77 skull is by all means due to this. It is highly probable that the converging type was the more archaic one. The "Asian" type had already abandoned this trait by 6-8 myrs. Probably the same development took place in the chimpanzee+gorilla line from 5-6 myrs onwards. However, strongly diverging axes did not develop during the process of hominization.

THE MAXILLARY DENTAL ARCH

The maxillary dental arch - in accordance with changes in the cerebral part of the skull - is a characteristically changing morphological trait, though it does not denote specific differences. A very probable reconstruction of the maxillary dental arch of Rudapithecus had already been carried out before by using RUD-12 and RUD-77 finds (KORDOS 1987b). The result is a regular "U-shaped" arch. The M^3-P^3 teeth are situated in a straight line and the two dental rows are parallel to each other. The curvature of the dental row begins at the canine.

The dental arch of the female Sivapithecus lufengensis (P.A. 677) had not been reconstructed so far, because as a result of compression the bones of the maxilla, together with the teeth, had moved from their original position. After a detailed study of this find one may try to reconstruct the original dental arch.

During this reconstruction the starting point was given by the horizontal part of the palatine with the M^2-M^3 teeth on both sides (Fig. 7), because they have remained in their original form. The fragment of the right-side bony palate with the M^1-P^3 teeth has slightly shifted over this part. Taking into consideration the contact surfaces of M^1 and M^2, this fragment could be joint to the earlier separated fragment of the palatine. The original find has been broken and removed in the line of the right canine and it is distorted at the incisive teeth. Taking into account other Lufeng finds during the reconstruction process, it became clear that the jointing of this part resulted a diasteme between the canine and the lateral incisives. I made several possible reconstructions for the dental arch but they differ from each other only in insignificant details. In all these versions the P^3-M^3 teeth are in the same axis and the two dental rows slightly diverge toward the M^3. They became considerably narrower at the frontal arch. Therefore the maxillary dental arch does not show the regular "U" form but it is a transitional form between "U" and "V" shapes.

It is only the frontal part of the maxillary bone of the Lufeng male skull (P.A. 644) (Fig. 7) which has remained without distortion. This part (together with the canines and incisive teeth) shows the same reduced form which appears in the female specimen. The P^3-M^2 toothrows diverge considerably. All these phenomena suggest the existence of a marked sexual dimorphism within the same taxa among Chinese finds.

Summarizing the present knowledge of the maxillary dental arch of Rudapithecus hungaricus and Sivapithecus lufengensis, one may state that the Rudapithecus find, which is 3-4 million years older than the Lufeng one, seems to be more "modernized". In addition there are fundamental morphological differences in the frontal arches of the two finds.

COMPARISON OF TEETH FROM RUDABÁNYA AND LUFENG

While the anatomical analysis of the Lufeng teeth has been already published (WU RUKANG et al. 1985, 1986), only part of the Rudabánya teeth have already been described (KRETZOI 1975, KORDOS 1987b). However, even this comparison, based on a relatively few finds, is enough to draw attention to some morphological peculiarities. The central incisor of Sivapithecus indicus is twice as large as the lateral incisor. At the same time this difference is not observable in Rudapithecus hungaricus, where the incisors are practically of the same measurements. The sagittal measurement of the alveole of RUD-12 is 7.7 mm for the central incisor and 7.0 mm for the lateral one. Consequently, the latter tooth is smaller only by 9-10% than the central incisor.

In the Chinese finds there is a diasteme between the canine and the lateral incisor. In the Rudabánya finds this hiatus is very small (RUD-12, -15).

In both groups of finds the canines of the females are small. In the Lufeng finds the premolars are wider than in the Rudabánya finds, especially in the talon region. The succession of the measurements of the molars is the same in both groups, namely, the crown of M^2 is the largest, followed by those of the M^3 and M^1 teeth.

The linguo-buccal cross-sections of the crown surfaces in premolars and molars show significant differences. In the Rudabánya find on both sides the enamel bends highly upwards, enciroling a deeply arched, concave region. In the Chinese specimens this arch is flatter, the crowns are more "flattened".

The M^3 of the RUD-77 find is not rectangular but rather of a trapezoid form which becomes narrower backwards. The respective tooth in P. A. 677 is rather quadratic. This basic form of M^3 in all the investigated Rudabánya specimens (RUD-18, RUD-45, RUD-77) is identical. In the Chinese finds, however, this shape varies (e.g. P.A. 658 in WU RUKANG & al. 1985). The following differences may be observed in the morphology of the occlusal surfaces of the upper teeth: the cusps and the ridges are sharp in the Rudabánya finds and in the adult specimens the fossae do not contain smaller plicas and tubercles. The opposite can be observed in the Lufeng upper teeth.

RESULTS

Comparison of the Lufeng and Rudabánya female skulls led me to conclude the following essential morphological similarities and differences:

- the basic forms of the calvarias are identical
- the developments of the temporal lines are identical
- there is no sagittal crest in either finds
- the interorbital distance is wide in both specimens
- the supraorbital tori are absent in RUD-77 but to a slight degree present in P. A. 677
- there are significant differences in the shape of the orbits. They are D-shaped in the Rudabánya find while in the one from Lufeng they are rectangular with rounded corners
- in Sivapithecus lufengensis the frontal bone is higher in frontal view than in Rudapithecus hungaricus. The zygomatic bone is wider in the Chinese find than in the one from Rudabánya
- the zygomatic regions are very similar to each other in lateral view
- the subnasal alveolar region belongs to the "Asian" type in the case of the Lufeng find and to the "African" type in the case of the Rudabánya skull
- on the basis of its palate height, Rudapithecus belongs to the "low palate" group while Sivapithecus lufengensis belongs to the "high palate" group
- in frontal view the axes of the upper teeth converge downward in the Rudapithecus find but they diverge in the Lufeng one
- the maxillary dental arch of the Rudabánya skull is "U-shaped", but it is slightly "V-shaped" in the Sivapithecus lufengensis skull
- there is a great difference in the measurements of the central and lateral incisors of Sivapithecus lufengensis, while their measurements are the same in Rudapithecus
- in the Chinese finds the diasteme between the canine and the incisor is large, while in the Rudabánya find it is smaller
- the molars differ from each other as regards their linguobuccal sections and the micromorphology of their occlusal surfaces.

Summarizing the investigated characteristics, I may state that in the cerebral regions there is a great similarity between RUD-77 and P. A. 677 skulls while as regards the morphology of the facial parts, fundamental differences can be observed. These similarities and differences between the two skulls represent also similarities and differences existing between the taxa Rudapithecus hungaricus and Sivapithecus lufengensis. The Rudabánya find, which is the older one - together with the European finds - and the younger Lufeng (SE-Asian) early apes have such evolutionary characteristics which are manifested in a deceleration of the development of the cerebral region of the skull and in an important morphological-phylogenetical development of the facial part.

On the basis of all these I conclude that Rudapithecus hungaricus is not identical with Sivapithecus lufengensis, neither could it be the direct ancestor of the Chinese form.

List 1

List of the Primates from Rudabánya

RUD-1	Mandibular ramus sin. (with P_4-M_3) - Holotype of Rud. hung.
RUD-2	Demaged mandible (with C-M_2 dext. and sin.)
RUD-3	Molar (M_1 or M_3) dext.
RUD-4	C sup. sin. (male)
RUD-5	P^3 dext. (germ.)
RUD-6	M^1 sin.
RUD-6	Maxillary fragment with P^4-M^2 - Holotype of Bodv. altip.
RUD-8	C sup. sin. (female)
RUD-9	Fragments of mand. dext. and sin. (with C, D_4, P_4-M_2 dext. and M_1-M_3 sin.) - Holotype of Plio. hernyaki
RUD-10	P^3 sin.
RUD-11	M_2 dext. (germ.)
RUD-12	Left maxillary and palate (with I^1, C-M^1)
RUD-13	M^2 sin.
RUD-14	Mandibular fragments (with I_1-P_4, M_1-M_2 dext. and I_1-C, P_4-M_2 sin.)
RUD-15	Left maxillary (with I^1-M^2) and fragments of right one (with I^1-M^2)
RUD-16	M_3 dext.
RUD-17	Corpus of left mandible with C-M_3 and fragments of left mandible with I_2-M_3
RUD-18	M^3 sin.
RUD-19	M_3 sin.
RUD-20	C sup dext. (female)
RUD-21	Distal fragment of left humerus
RUD-22	Ulna prox. fragment
RUD-23	Caput of the left femur
RUD-24	Distal end of the left femur (it is not Primates)
RUD-25	Proximal end of the left tibia (it is not Primates)
RUD-26	Patella
RUD-27	Left astragalus, without head (talus in MORBECK 1983)
RUD-28	Phalanx
RUD-29	Distal end of metapodial
RUD-30	Phalanx
RUD-31	Distal two-thirds of phal. I.
RUD-32	Distal part of phal. I.
RUD-33	Medial fragment of phal. I.
RUD-34	Phalanx
RUD-35	Medial fragment of phal. I.
RUD-36	Distal part of phal. II.
RUD-37	Distal part of phal. II.
RUD-38	Phal. I., proximal end missing
RUD-39	Distal half of phal. I.
RUD-40	Medial fragments of phal. I.
RUD-41	Diaphysis of phal. I.
RUD-42	Medial fragment of phal. I.
RUD-43	Proximal end of phal. III.
RUD-44	Left maxilla with palatine, C, P^3-P^4 and M^2; and fragment of the frontal bone
RUD-45	Right M^1 and M^3
RUD-46	P_4 fragment
RUD-47	I^1
RUD-48	Lower M (? M_3)
RUD-49	Two lower molars
RUD-50	Associated teeth (9 specimens)
RUD-51	P^3
RUD-52	Two incisivi
RUD-53	Upper molar
RUD-54	Phalanx dist. fragment
RUD-55	Femur fragment
RUD-56	Phalanx

RUD-57 Metatarsal fragment
RUD-58 M^2
RUD-59 Distal end of phalanx
RUD-60 Proximal end of distal phalanx
RUD-61 Lower teeth from the same animal
RUD-62 It is not Primates (probably Suidae)
RUD-63 Distal end of phalanx
RUD-64 It is not Primates
RUD-65 C (germ.)
RUD-66 Radius ep. fragment
RUD-67 C
RUD-68 I, two lower molars
RUD-69 M_3 (?)
RUD-70 Premolar
RUD-71 Orbitofrontal region of the face fragment with C-M^3 - Holotype of Rangwapithecus (Ataxopithecus) serus
RUD-72 Talus
RUD-73 Premolar
RUD-74 Phalanx fragment
RUD-75 Phalanx fragment
RUD-76 M^2
RUD-77 Skull fragment with left P^3-M^3 and right M^1-M^3
RUD-78 Phalanx fragment
RUD-79 Premolar
RUD-80 Phalanx fragment

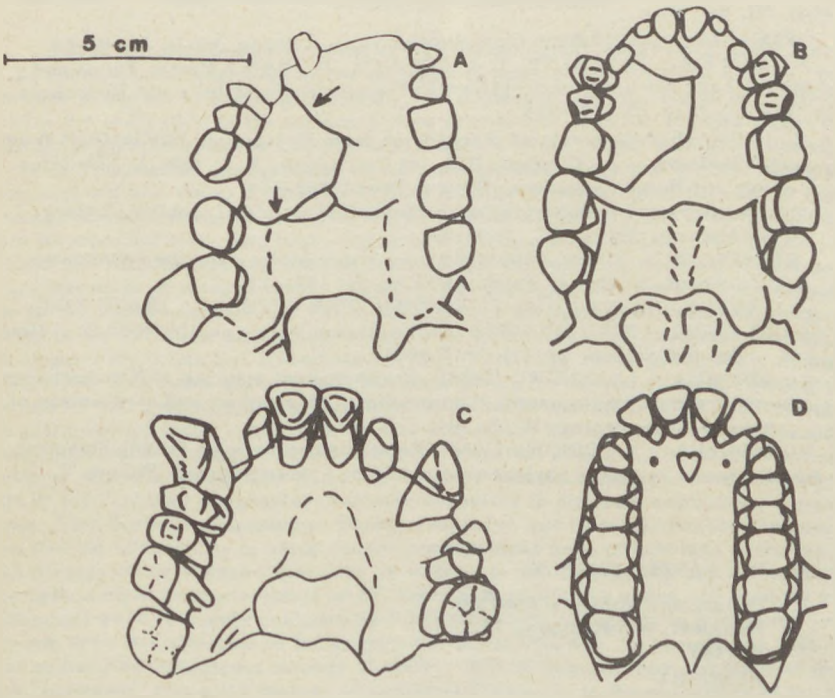

Fig. 7 The maxillary arch. A = original situation of the Sivapithecus lufengensis (P. A. 677) maxillary arch and after the reconstruction (B). C = Original arch of the male S. lufengensis (P. A. 644), D = Reconstructed maxillary dental arch of the Rudapithecus hungaricus

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On the flatness of the facial skeleton in Men

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Abstract. Having compared oecumenically the osteological remains from skeletalized populations the author outlines the problem of the development of facial flatness. With 4 tables.

MATERIAL AND METHOD

In the last decades an analysis of the morphological characters of the facial skeleton (e.g. flatness) was neglected by the majority of general craniological studies. This is true in the case of series originating from different millennia, too, excepting northern Eurasia (where the evaluation of the horizontal face profile has been for decades a part of the craniological programmes). The systematical analysis of the human cranium concerning particularly the morphological configuration of the maxillonasal region has started on the basis of two classical studies (WOO & MORANT 1934; ABINDER 1960) on more than seven thousand human crania excavated in the territory of North Eurasia (DEBETS 1951, 1961a, b). The flatness, as a taxonomical trait, has been diagnosed according to alternative conceptions. In contradiction to DEBETS (1951, 1961a, b) the flatness has not been considered by some authors as a manifestation of mongoloidism, because this character - in spite of its becoming a stable one on the Asian continent during the millennia of the geological Holocene - was clearly manifested in the values of the nasomalar angle of the European populations, too, which lived in the Upper Paleolithic and Mesolithic periods (YAKIMOV 1957, 1960, 1961; ALEKSEEV 1978, 1979, 1983; GOHMAN 1966, 1986). For expressing the mutual relation existing between the nasomalar and zygomaxillar angles YAKIMOV (1960) and TSUI CHEN YAO (1960) proposed the platyprosopy index - Zm: 77%. In this connection the analysis of recent craniological finds from South-African bushmen deserves a special attention. In the first craniological synthesis of World's people HOWELLS (1973) gives a summarized documentation by using the data of the bushman osteological remains deposited in different collections (Vienna, Cape Town, New York, Johannesburg, Paris, Edinburgh and Oxford). In July 1981 the present author had the opportunity to study recent craniological finds of bushman in the Institute of Human Biology of the Vienna University as well as in the Natural History Museum of Vienna. The osteometric characteristics of 101 adult individuals (48 males, 53 females from the Pöch-collection) were formerly analysed by PACHER (1961) according to traditional programme and she drew our attention to the possibility of a metisation. In accordance with this the present author has collected a number of metric data of flatness from the finds of the presumably "bushman" group (12 males, 16 females) (Table 1). In the evaluation of the lineal and angle values of the horizontal profile and nasal region the categories calculated by DEBETS have been used (ALEKSEEV & DEBETS 1964; Table 4 in the present paper). The curvature index (S:C) of os malare was determined on the crania of the bushman group with WOO's

method (WOO 1937; TÓTH 1968). The nasal spine angle was calculated on the basis of PACHER's data (1961). The platyprosopy index was also calculated by the present author. Finally, we have to mention a short summary concerning the facial flatness metric analysis carried out in 1880-1960 (TÓTH 1961).

INTERPRETATION OF RESULTS

Of the components of the facial flatness the nasomalar angle significantly differs from the Europoid mean in the male as well as in the female group (142.6° and 145.3°, respectively). The same is true for the group-values of the zygomaxillar angle (132.0° and 131.4°, respectively) (Table 1). On the basis of group-values of the dacrial and simotic height it can be concluded that both the male and female subpopulations had a very low nasal root (8.1 and 7.5 mm as well as 1.1 and 0.7 mm, respectively). The nasal spine angle has the value of 6.9° in the male, and 3.8° (!) in the female group. Both values are lower than the minimal category values known up to present (ALEKSEEV & DEBETS 1964). It is the amplitude (Min-Max) of these main morphometric components which deserves a special attention. The nasomalar angle of the horizontal profile is characterized by the values 133.7-153.2° in the male, and 135.8-150.9° in the female group (Table 1). The zygomaxillar angle is 126.2-138.7° and 119.3-138.3°, respectively. Dacrial subtense varies in the male group between 6.0 and 12.0, in the female one between 5.0 and 10.0. The simotic subtense of males is characterized by values from -0.7 to 3.0, that of females by values from -1.0 to 2.4. The variation of the nasal spine angle is in the male -6 to 20, and -5 to 20 in the female groups. On the basis of the values of the nasomalar and zygomaxillar angles the studied bushman population is characterized by a disharmonous configuration (heteroplatyprosopy) of the facial skeleton. This is well expressed by the values of the platyprosopy-index: 92.5 in the male, and 90.4 in the female group (Tables 2 and 3).

As it can be seen in the numerical tables the flatness of the facial skeleton characterizes the recent human populations from circumpolar and continental North Asia as well as from South Africa. Thus, it cannot be regarded as characteristic only for the Mongoloid groups, because the bushmen of South Africa, being subequatorial peoples, oecumenically are very far of them. It is well known that the living bushman groups have been studied according to a wide-ranging anthropological and genetical programme (TOBIAS 1966, 1970b, 1972). In connection with the bushmen's origin - among others - their similarity to the finds from Fish Hoek, dated for Holocene periods, was noted (TOBIAS 1971). This becomes evident from the flatness data, too (Table 2). Since the data of the nasomalar and zygomaxillar angles show a heteroplatyprosopy in the European Upper Paleolithic and Mesolithic human groups was also present (ALEKSEEV 1978, 1979, 1981; TÓTH 1984); the flatness expressing itself moderately in some prehistoric or living tribal populations can be regarded rather as a morphological trait than as a taxonomical one. In all certainty, the development of flatness has been affected by multifactorial effects. Recently the role of climate has repeatedly been stressed. An analysis of the evolution of human cranial measurements has been carried out by GUGLIELMINO-MATESSI & al. (1979) according to warm-dry, warm-humid, cold-humid and cold-dry climate. Facial flatness was observed in the case of recent populations living in warm-dry (bushman) and cold-dry zones (circumpolar northern Asiatic groups); it means that this morphological trait is well developed inspite of differences existing in climate. We have to pay attention to the fact that the pneumatization observable in the craniofacial massivum which was analysed on fossilic human finds does not show any group-characteristic, but rather a significant individual variability (TILLIER 1977a, b). Concerning the structural variation of the facial skeleton there are quite different opinions. According to STEEGMAN (1972 cit. FORSIUS 1973) in the comparative analysis of the Polynesians, Japanese and Europeans inhabiting the Hawai islands the effect of cold climate cannot be denied on the maxillo-malar region of the human cranium. Nevertheless, according to BUNAK (1960, 1972; FORSIUS 1973), the structure of the facial skeleton does not reveal a significant correlation with the climate. These osteomorphic variations are the results of differences in the growth intensity of the facial bones (BUNAK 1960). Further, from the factors of the development of the flatness of the facial skeleton the sensu lato environmental influences cannot also be left out of consideration (e.g. intrauterine osteopoesis). The role of the diet in the development of bone structure was also referred to (FEREMBACH 1973). Be-

yond the dietary uncertainties the effect of mineral intake and that of growth hormone as well as controlling genes has also been considered (TOBIAS 1970). Recently the distribution of microelements has been analysed in samples of osteological remains of some historical populations. The data show subcontinental differences concerning the intensity of the absorption of microelements in bone tissues (DOBROVOLSKAYA 1984, versus BUNAK 1960). This seems to be in agreement with the recent results belonging to the histogenesis of facial skeleton (OYEN & RUSSEL 1982). Thus, for an anthropological evaluation of the living and prehistoric populations of certain subcontinents we have to take into consideration the different combinations of a number of environmental factors having a definite role in the development of facial flatness. It can be supposed that the different complexes of the environmental factors have been realized in the deviating ecosensitivity of some tribal groups or individuals. The recent craniological remains from Kalahari bushmen significantly supplement further studies concerning the chosen subject.

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Table 1

Facial skeleton flatness in the Pöch's Bushmen-collection

Inv. N°	43 (1)	Subt. JOW	77	Zm'-Zm'	Zm'-SS-Zm'	Zm'	DC	DS	DS:DC	SC	SS	SS:SC	75(1)	S:C
S 1	97.0	17.5	140.2	94.0	21.5	130.5	25.0	6.5	26.0	9.0	-0.7	-7.7!	1.0!	25.5
S 3	92.5	16.5	140.5	97.0	22.5	130.0	24.0	8.0	33.3	7.3	0.4	5.5	0.0	19.0
S 10	100.5	16.3	144.0	100.0	23.4	129.5	22.0	9.0	40.9	9.5	1.8	18.9	19.0	17.0
S 22	95.0	14.5	146.0	90.0	17.5	137.0	24.5	9.5	38.7	7.0	0.7	10.0	2.0	19.5
S 24	98.0	17.0	141.6	93.5	18.0	137.6	23.0	8.0	34.8	8.0	3.0	37.5	20.0	25.3
S 42	100.0	17.0	142.4	102.0	19.0	138.7	26.0	12.0	46.1	11.0	2.5	22.7	12.0	21.5
S 59	98.5	21.0	133.7	91.5	23.0	126.3	25.0	7.5	30.0	10.0	1.3	13.0	6.0	18.3
S 60	98.0	16.0	143.8	88.0	21.5	127.5	25.0	8.0	32.0	8.0	1.7	21.2	10.0	17.2
S 68	98.5	18.5	138.7	101.5	25.5	126.2	24.5	10.0	40.8	10.0	1.5	15.0	9.0	20.2
S103	89.0	10.5	153.2	88.0	21.0	128.6	19.5	6.5	33.3	5.4	1.0	18.5	11.0	20.4
S119	91.0	16.5	140.0	81.0	17.0	134.5	18.0	6.0	33.3	2.0	0.0	0.0	-6.0	20.0
S120	92.0	13.5	147.2	83.0	16.0	137.4	17.0	6.0	35.3	2.8	0.5	17.8	-1.0	17.6
x (n) Males	95.8 (12)	16.2 (12)	142.6 (12)	83.9 (12)	20.4 (12)	132.0 (12)	22.8 (12)	8.1 (12)	35.4 (12)	7.5 (12)	1.1 (12)	14.3 (12)	6.9 (12)	20.1 (12)
S 2	94.0	15.5	143.4	85.5	21.0	127.4	23.0	9.3	40.4	6.0	1.8	30.0	10.0	19.1
S 25	98.0	15.5	144.7	82.5	20.0	127.7	23.5	7.5	31.9	8.0	1.0	12.5	3.0	22.7
S 26	92.0	17.0	139.3	96.5	28.0	119.3	23.0	9.5	41.3	11.0	2.4	21.8	11.0	16.6
S 28	97.0	16.5	142.2	99.0	22.0	131.9	24.0	8.8	36.6	5.5	0.6	10.9	20.0	18.2
S 30	89.0	18.0	135.8	87.5	23.0	124.2	25.0	6.0	24.0	9.5	0.5	5.2	-3.0!	15.8
S 38	96.0	14.0	147.3	87.5	16.5	138.2	21.0	5.0	23.8	3.0	-1.0!	-33.3	-3.0	23.8
S 40	95.5	15.5	144.0	94.0	19.0	135.7	22.0	7.5	34.1	8.5	1.0	11.7	4.0	22.0
S 44	92.0	13.0	148.3	93.0	17.5	138.3	19.0	5.5	28.9	4.0	0.0	0.0	3.0	20.7
S 45	93.5	12.0	150.9	89.5	19.5	132.5	23.0	10.0	43.5	5.5	1.0	18.2	3.0	25.0
S 46	91.0	13.0	148.0	90.0	18.0	136.3	24.5	7.7	31.4	9.0	1.4	15.5	5.0	25.0
S 99	89.0	11.5	150.6	88.0	20.0	130.6	21.0	7.0	33.3	5.0	1.5	30.0	-	17.8
S101	89.0	14.0	144.9	83.5	21.0	126.1	18.3	9.0	49.2	2.8	1.0	35.7	-5.0	19.0
S102	95.0	13.0	149.3	95.0	20.5	133.0	22.0	6.0	27.2	6.0	0.3	5.0	7.0	20.8
S105	91.0	16.0	141.0	96.0	20.0	134.4	22.0	7.5	34.1	7.5	-0.5	-6.6	-1.0	19.0
S142	94.0	13.0	148.9	91.5	18.0	136.8	21.0	7.0	33.3	9.0	0.6	6.6	4.0	19.3
C 25	92.0	14.0	146.1	93.0	21.0	131.2	20.0	6.0	30.0	6.0	0.0	0.0	-1.0	19.7
x (n) Females	93.0 (16)	14.4 (16)	145.3 (16)	90.7 (16)	20.3 (16)	131.4 (16)	22.0 (16)	7.4 (16)	33.9 (16)	6.6 (16)	0.7 (16)	10.2 (16)	3.8 (15)	20.3 (16)

Notes to the Table 1 MARTIN's numbers: 43(1)= Biorbital breadth, Subt. JOW-Height of nasion above biorbital breadth, 77= Nasomalar angle, Zm'-Zm'-Zygomaxillar breadth, Zm'-SS-Zm' = Height of subspinale above zygomaxillar breadth, Zm' = Zygomaxillar angle, DC= Dacrial breadth, DS= Dacrial subtense, DS:DC= Dacrial index, SC= Simotic breadth, SS= Simotic subtense, SS:SC= Simotic index, 75(1)= Nasalspine angle, S:C= Malar arc index.

Table 2

Numerical comparison of the facial skeleton flatness (males)

Characteristics / Series	77	Zm'	IP	DS	SS	75 (1)
Bushman (our data), South Africa, XIX-XXth c.	142.6 (12)	132.0 (12)	92.5 (12)	8.1 (12)	1.1 (12)	6.9 (12)
Fish Hoek (ALEKSEEV 1978) South Africa, Upper Paleolith	143.0 (1)	133.0 (1)	93.0 (1)	- -	- -	-3.0! (1)
Aleuts (DEBETS 1951), Far East Siberia	145.5 (30)	138.1 (28)	94.9 (28)	10.2 (35)	2.9 (35)	25.8 (24)
Eskimos (DEBETS 1951), Far East Siberia	146.5 (12)	135.8 (12)	92.7 (12)	10.2 (12)	3.0 (13)	25.3 (3)
Yukagirs (DEBETS 1951), East Siberia	148.7 (18)	137.0 (17)	92.1 (17)	7.4 (18)	2.5 (18)	17.2 (12)
Nivkhs' (DEBETS 1951), Far East Siberia	146.0 (13)	135.9 (13)	93.1 (13)	9.8 (13)	2.9 (13)	16.9 (8)
Ulchs (DEBETS 1951), Far East Siberia	146.2 (30)	137.5 (30)	94.0 (30)	8.7 (31)	2.2 (31)	17.0 (21)
Nanays (DEBETS 1951), Far East Siberia	147.7 (11)	137.3 (10)	92.9 (10)	8.7 (8)	2.4 (10)	15.1 (7)
Negidals (DEBETS 1951), Far East Siberia	148.6 (16)	142.3 (16)	95.7 (16)	8.3 (15)	2.3 (16)	15.3 (16)
Mongols (DEBETS 1951), Central Asia	146.4 (80)	138.4 (76)	94.5 (76)	9.3 (76)	2.8 (81)	22.4 (41)
Yakuts (DEBETS 1951), Central Siberia	146.2 (38)	137.2 (37)	93.8 (37)	9.2 (40)	2.7 (40)	19.1 (37)
Evenks (DEBETS 1951), Central Siberia	149.1 (28)	141.6 (28)	94.9 (28)	8.7 (28)	2.4 (26)	18.7 (22)
Nenets (DEBETS 1951), Western Siberia	146.4 (36)	135.8 (35)	92.7 (35)	9.4 (36)	2.7 (36)	23.3 (27)
Vlasac (ALEKSEEV 1979,1981), Mesolith, Lower Danube	142.2 (11)	135.0 (3)	94.9 (3)	- -	4.9 (3)	25.0 (2)
Lepenski Vir (ALEKSEEV 1979, 1981), Neolith, Lower Danube	138.4 (5)	129.0 (1)	93.2 (1)	13.0 (2)	4.9 (3)	40.0 (1)
European (ALEKSEEV 1978), Upper Paleolith	143.8 (13)	127.5 (11)	88.6 (11)	12.3 (6)	4.6 (10)	30.7 (11)

Notes to the Table 2 MARTIN's numbers: 77= Nasomalar angle, Zm' = Zygomaxillar angle, IP= Platiprosopy index, DS= Dacrial subtense, SS= Simotic subtense, 75(1)= Nasal-spine angle.
From Aleuts to Nenets, all series as recents (XVII-XIXth centuries). Platiprosopy index (IP) calculated by the author after group-values.

Table 3

Numerical comparison of the facial skeleton flatness
(females)

Series \ Characteristics	77	Zm'	IP	DS	SS	75(1)
Bushman (our data), South Africa, XIX-XXth c.	145.3 (16)	131.4 (16)	90.4 (16)	7.4 (16)	0.7 (16)	3.8 (15)
Aleuts (DEBETS 1951), Far East Siberia	146.1 (23)	136.0 (23)	93.1 (23)	9.5 (26)	2.3 (28)	21.1 (15)
Eskimos (DEBETS 1951), Far East Siberia	147.7 (25)	137.7 (22)	93.2 (22)	9 3 (25)	2.2 (26)	20.2 (9)
Yukagirs (DEBETS 1951), East Siberia	150.3 (10)	140.2 (9)	93.3 (9)	7.2 (11)	2.2 (11)	16.3 (6)
Nivkhs (DEBETS 1951), Far East Siberia	148.7 (12)	136.8 (12)	92.0 (12)	8.2 (12)	2.3 (12)	13.3 (6)
Ulchs (DEBETS 1951), Far East Siberia	147.7 (25)	138.4 (23)	93.7 (23)	7.7 (25)	1.7 (26)	14.0 (19)
Nanays (DEBETS 1951), Far East Siberia	146.3 (11)	137.6 (8)	94.0 (8)	7.9 (10)	2.2 (9)	13.2 (8)
Negidals (DEBETS 1951), Far East Siberia	146.7 (15)	140.0 (14)	95.4 (14)	6.8 (14)	1.5 (15)	13.8 (14)
Mongols (DEBETS 1951), Central Asia	145.6 (35)	138.2 (34)	94.9 (34)	8.7 (35)	2.8 (35)	16.2 (15)
Evenks (DEBETS 1951), Central Siberia	149.9 (27)	142.6 (27)	95.1 (27)	7.6 (27)	1.8 (28)	14.4 (21)
Nenets (DEBETS 1951), Western Siberia	147.4 (16)	135.6 (15)	92.0 (15)	8.9 (16)	2.6 (16)	18.2 (12)
Vlasac (ALEKSEEV 1979,1981), Mesolith, Lower Danube	146.3 (9)	126.3 (3)	86.3 (3)	9.9 (1)	4.6 (2)	- -
Lepenski Vir (ALEKSEEV,1979, 1981), Neolith, Lower Danube	143.4 (9)	124.8 (4)	87.0 (4)	12.5 (5)	4.5 (5)	33.5 (4)
European (ALEKSEEV 1978), Upper Paleolith	143.2 (5)	125.3 (3)	87.5 (3)	- -	4.7 (2)	29.1 (7)

Notes to the Table 3 - as in Table 2

Table 4

Distribution of the flatness metric categories (ALEKSEEV & DEBETS 1964)

Groups / Features	Males					Females				
	very small	small	medium	large	very large	very small	small	medium	large	very large
77	128-135	136-139	140-144	145-148	149-156	128-135	136-139	140-144	145-148	149-156
Zm'	116-124	125-130	131-136	137-142	143-151	116-124	125-130	131-136	137-142	143-151
75(1)	11-18	19-23	24-28	29-33	34-41	7-14	15-19	20-24	25-29	30-37
DC	14.6-18.5	18.6-20.5	20.6-23.0	23.1-25.0	25.1-29.0	13.8-17.5	17.6-19.4	19.5-21.8	21.9-23.7	23.8-27.5
DS	5.9-8.4	8.5-9.9	10.0-11.6	11.7-13.1	13.2-15.7	5.3-7.5	7.6-8.9	9.0-10.4	10.5-11.8	11.9-14.1
DS:DC	21.7-36.5	36.6-44.9	45.0-54.1	54.2-62.5	62.6-77.4	20.6-34.6	34.7-42.6	42.7-51.3	51.4-59.3	59.4-73.4
SC	2.6-5.7	5.8-7.5	7.6-9.5	9.6-11.3	11.4-14.5	2.6-5.7	5.8-7.5	7.6-9.5	9.6-11.3	11.4-14.5
SS	0.6-2.1	2.2-3.0	3.1-4.0	4.5-4.9	5.0-6.5	0.5-1.7	1.8-2.5	2.6-3.3	3.4-4.1	4.2-5.4
SS:SC	2.9-23.4	23.5-35.0	35.1-47.9	48.0-59.5	59.6-80.1	2.4-19.4	19.5-29.0	29.1-39.7	39.8-49.3	49.4-66.4

Notes to the Table 4 MARTIN's numbers: 77 = Nasomalar angle, Zm' = Zygomaxillar angle, 75(1) = Nasalspine angle, DC = Dacrial breadth, DS = Dacrial subtense, DS:DC = Dacrial index, SC = Simotic breadth, SS = Simotic subtense, SS:SC = Simotic index.

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The anthropological investigation of the Avar-age cemetery of Fészerlak

By

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Abstract: The author carried out anthropological research of 224 graves, the majority of which derives from the 8th century cemetery of Fészerlak. The most important anthropological measurements and those of averages are published along with the anatomic variations and anomalies. This series was compared to 22 other series from the Avar period by using PENROSE's method. With 11 tables, 2 figures and 2 plates.

INTRODUCTION

In 1969 some archeological and anthropological finds were discovered during agricultural work at Fészerlak-puszta (farmstead) located 6 km NW of Kaposvár. Excavations were carried out between 1970 and 1982 by Eugenia SZIMONOVA, staff-member of the Archeological Institute of the Hungarian Academy of Sciences (SZIMONOVA 1978, 1980).

224 graves were exposed. The archeologist believes that it is only one-third part of the cemetery. The north part of the cemetery is completely excavated (SZIMONOVA 1982). These graves concerning their archeological finds date from the 8th century, some graves (29, 70, 103, 126, 140) date back to the early 9th century. Some earlier graves were dug up at the southern part of the cemetery. Sets of belt ornament were found in the graves 168 and 183, which date these graves from the end of the 7th century. Grave 128 dates from the end of the 7th century and the beginning of the 8th century. This grave is very important from archeological point of view because it has both strap-end with inlayed decoration and yellow pottery vessel. The non-excavated part of the cemetery is located to the south, therefore the early, probably 7th century population cannot be taken into consideration. On the other hand, the northern part of the cemetery is completely excavated hence this series may be considered as the Avar population having lived at Fészerlak in the 8th century (SZIMONOVA's pers. comm.).

SZIMONOVA believes that the archeological grave-wears refer to typical common people of the Avar age. WENGER (1975) has examined the anthropological finds brought to light in 1970 and 1971 (Graves 1-65). The author has taken over his published craniological measurements of the first 65 graves with the exception of MARTIN 51 and 52. We have remeasured them, remeasured the angles and the long bones, we determined again the morphological characteristics and anatomical variations, anomalies as well on the material of the first item.

MATERIAL AND METHOD

The skeletal remains of the 218 individuals from 224 graves were saved. The anthropological remains are deposited in the Anthropological Department of the Hungarian Natural History Museum. The state of preservation of the material is good. Skulls and skeletal bones

derive from 171 graves, only crania from 26 graves, while merely postcranial material from 21 graves (Table 1).

There are 52 males, 88 females and 78 individuals of undeterminable sex (22 grown-ups and 56 children). 35 male and 36 female skulls were suitable for detailed metrical analysis (43.8% of the grown-ups).

Postcranial material of 35 males and 39 females were suitable for the calculation of stature. We could determine the weight in 31 cases (17 males, 14 females).

The taxonomic analysis could be made in 32 male and 16 female cases.

Table 1

Distribution of sex, age and preservation

Types of material	Age groups	Male	Female	Undet. sex	Total	
					N	%
Cranium and postcranium	Infans I	-	-	22	22	10.1
	Infans II	-	-	14	14	6.4
	Juvenis	3	5	3	11	5.1
	Adultus	25	48	3	76	34.9
	Maturus	19	21	-	40	18.4
	Senium	-	1	-	1	0.5
	Undeterminable	1	1	5	7	3.2
	Total	48	76	47	171	78.6
Cranium only	Infans I	-	-	9	9	4.1
	Infans II	-	-	5	5	2.3
	Juvenis	-	-	-	-	-
	Adultus	-	3	2	5	2.3
	Maturus	1	2	-	3	1.4
	Senium	-	-	-	-	-
	Undeterminable	-	-	4	4	1.8
	Total	1	5	20	26	11.9
Postcranial skeleton	Infans I	-	-	1	1	0.4
	Infans II	-	-	1	1	0.4
	Juvenis	-	-	1	1	0.4
	Adultus	1	3	-	4	1.8
	Maturus	-	1	-	1	0.4
	Senium	-	-	-	-	-
	Undeterminable	2	3	8	13	6.0
	Total	3	7	11	21	9.6
Total		52	88	78	218	
		23.8%	40.4%	35.8%	100%	

The distribution of the population according to age, sex and preservation is in Table 1.

In the case of grown-ups the age at the time of death was established by using the VALLOIS' grades of the suture ossification of the ectocranial surface, the degrees of abrasio (after KÖRBER) and by considering the surface changes of the facies symphyseos ossis pubis as well as the occification of the epiphyses of long bones. In the case of children the eruption of permanent and deciduous teeth was considered (FARKAS 1972).

We applied the MARTIN & SALLER (1957) age-group system. Sex was determined by the anatomical characters of the cranium and the skeletal bones. In taking of absolute measurements we applied the MARTIN-technique (1928). Measurements and indices were classified according to DEBETS's categories (ALEKSEEV & DEBETS 1964). Stature was deter-

Table 2 Parameters of male and female series

MARTIN No.	Males				Females			
	N	V	M	s	N	V	M	s
1	33	171-198	184.5	6.56	27	165-190	178.1	6.70
1c	32	169-198	184.0	7.21	27	168-191	179.1	6.90
5	32	95-110	102.8	4.11	22	90-105	97.2	4.22
8	35	124-148	138.4	5.21	29	118-145	133.1	6.56
9	35	87-106	97.4	4.63	33	85-104	93.9	4.14
10	32	106-137	119.0	6.53	29	103-127	114.6	6.11
11	31	109-133	122.6	6.09	27	102-135	116.5	6.12
12	26	102-124	109.9	4.85	22	92-120	105.6	5.71
17	32	125-145	136.8	4.98	22	118-136	129.6	4.66
20	28	105-121	115.0	3.63	23	101-117	111.1	3.60
32	26	76- 91	82.1	3.50	21	75- 91	85.4	3.59
32-	26	68- 84	75.8	3.55	21	70- 87	80.3	4.08
40	31	88-108	97.4	4.41	18	87- 99	93.4	4.13
43	32	97-112	104.9	3.28	28	93-105	99.6	2.98
45	26	123-145	133.9	5.06	13	115-130	121.8	4.26
46	32	87-106	95.5	5.30	23	83- 97	90.9	3.59
47	18	102-130	115.4	6.77	17	97-120	107.8	4.40
48	32	59- 77	69.0	4.12	30	56- 72	64.2	3.87
51	34	39- 45	42.0	1.64	30	37- 43	39.7	1.56
52	34	27- 36	32.1	2.59	30	28- 38	31.9	2.21
54	34	22- 30	24.7	1.75	27	18- 28	24.3	2.33
55	34	47- 59	51.4	2.84	31	43- 56	48.6	3.19
62	34	38- 52	46.1	3.13	22	39- 50	43.8	2.65
63	24	31- 46	38.9	3.88	23	26- 43	34.5	4.60
65	18	104-136	120.2	7.13	13	105-122	110.5	4.63
66	22	90-116	104.3	6.04	14	80- 99	89.8	5.61
69	29	23- 36	31.3	3.30	23	25- 35	29.3	2.90
70	27	55- 73	63.1	4.21	19	49- 61	56.8	3.52
71a	29	24- 39	31.3	3.44	23	26- 37	29.6	2.83
72	25	78- 89	83.5	2.69	19	75- 87	82.0	3.66
73	26	81- 89	84.4	2.29	20	76- 89	82.8	3.87
74	25	61- 93	80.5	7.08	19	63- 89	78.5	7.05
75	16	42- 64	54.5	7.34	15	46- 67	56.4	5.26
75/1	15	20- 38	29.5	6.64	14	18- 34	25.4	4.60
8:1	33	70.0-82.7	75.2	3.41	25	66.1-82.5	74.2	3.88
17:1	32	68.6-81.3	74.2	3.32	21	66.7-78.1	72.9	3.20
17:8	32	91.2-112.	98.7	4.84	20	87.3-105.8	97.4	4.58
9:8	35	63.6-78.5	70.5	3.65	29	65.0-76.7	70.8	3.26
47:45	17	76.1-95.9	86.1	4.79	9	83.6-100.0	89.4	6.42
48:45	26	40.8-60.6	51.4	4.39	13	49.0-56.5	52.4	2.56
52:51	34	61.5-93.0	78.1	7.21	32	74.4-95.0	82.6	6.14
54:55	34	38.6-63.8	48.2	4.60	27	41.9-89.7	51.2	9.05
63:62	24	64.6-116.4	83.9	11.44	18	61.7-103.6	81.6	11.33
38	30	1188-1586	1445.0	110.00	18	1107-1491	1293.0	115.11

Table 3

Distribution of measurements and indices according to ALEKSEEV & DEBETS

MARTIN No.	Classification	N M	N F
	very short	1	-
	short	5	4
1	medium	10	5
	long	11	9
	very long	6	9
	very short	2	1
	short	3	6
5	medium	16	5
	long	5	7
	very long	6	2
	very narrow	6	7
	narrow	9	9
8	medium	16	8
	wide	4	4
	very wide	-	1
	very narrow	1	1
	narrow	7	7
9	medium	12	15
	wide	10	7
	very wide	5	3
	very narrow	3	3
	narrow	5	5
10	medium	10	7
	wide	11	7
	very wide	3	7
	very narrow	-	1
	narrow	6	5
12	medium	12	9
	wide	5	5
	very wide	3	2
	very low	1	1
	low	2	3
17	medium	12	7
	high	7	10
	very high	8	1
	very small	1	1
	small	6	3
20	medium	12	6
	large	7	12
	very large	2	1
	very small	3	1
	small	8	1
32	medium	11	11
	large	3	7
	very large	1	1
	very small	1	-
	small	5	5
38	medium	6	4
	large	17	6
	very large	1	3

MARTIN No.	Classification	N M	N F
	very short	3	1
	short	10	7
40	medium	13	6
	long	4	4
	very long	1	-
	very narrow	2	2
	narrow	5	10
43	medium	15	10
	wide	9	6
	very wide	1	-
	very narrow	-	2
	narrow	7	4
45	medium	11	6
	wide	6	1
	very wide	2	-
	very narrow	5	2
	narrow	8	5
46	medium	13	12
	wide	4	4
	very wide	2	-
	very low	1	1
	low	7	6
47	medium	8	6
	high	1	4
	very high	1	-
	very low	4	2
	low	10	11
48	medium	14	15
	high	4	2
	very high	-	-
	very narrow	2	3
	narrow	4	10
51	medium	15	15
	wide	11	-
	very wide	2	2
	very low	13	16
	low	10	3
52	medium	8	10
	high	3	-
	very high	-	1
	very narrow	2	2
	narrow	15	6
54	medium	12	11
	wide	3	5
	very wide	2	3
	very low	3	1
	low	9	13
55	medium	16	7
	high	3	9
	very high	3	1

Table 3 (cont. 1)

MARTIN No.	Classification	N M	N F
	very short	1	1
	short	9	6
62	medium	14	8
	long	7	6
	very long	3	1
	very narrow	4	7
	narrow	5	10
63	medium	8	2
	wide	5	2
	very wide	1	2
	very narrow	1	-
	narrow	4	5
65	medium	8	6
	wide	3	1
	very wide	2	1
	very narrow	1	4
	narrow	1	4
66	medium	7	5
	wide	9	1
	very wide	3	-
	very low	4	3
	low	8	8
69	medium	14	5
	high	3	4
	very high	-	3
	very low	-	5
	low	-	7
70	medium	2	7
	high	9	-
	very high	16	-
	very small	-	2
	small	3	5
72	medium	8	5
	large	11	7
	very large	3	1
	very small	1	5
	small	8	6
73	medium	12	5
	large	5	4
	very large	-	-
	very small	1	-
	small	1	2
74	medium	4	4
	large	8	6
	very large	11	7
	very small	-	-
	small	6	1
75/1	medium	±	4
	large	4	6
	very large	5	3

MARTIN No.	Classification	N M	N F
	very long	13	13
	long	10	8
8:1	medium	6	2
	short	-	2
	very short	4	-
	very low	2	3
	low	8	6
17:1	medium	11	9
	high	7	3
	very high	4	-
	very low	-	-
	low	1	3
17:8	medium	9	6
	high	14	6
	very high	8	5
	very narrow	-	-
	narrow	5	3
9:8	medium	10	9
	wide	11	9
	very wide	9	10
	very wide	1	-
	wide	8	4
47:45	medium	6	3
	narrow	2	-
	very narrow	-	2
	very wide	5	-
	wide	10	5
48:45	medium	6	6
	narrow	2	2
	very narrow	3	-
	very low	10	4
	low	7	8
52:51	medium	11	2
	high	4	1
	very high	2	1
	very narrow	2	2
	narrow	13	8
54:55	medium	13	5
	wide	4	10
	very wide	2	2
	very narrow	5	6
	narrow	6	5
63:62	medium	9	3
	wide	1	1
	very wide	2	3

Table 4

Distribution of morphological characters

Characters		Male	Female	Total
Norma verticalis	ovoid	14	20	34
	pentagonoid	6	5	11
	ellipsoid	9	6	15
	sphenoid	-	-	-
	spheroid	-	-	-
	romboid	2	-	2
Glabella	Broca 1	-	22	22
	Broca 2	10	19	29
	Broca 3	13	1	14
	Broca 4	7	-	7
	Broca 5	2	-	2
	Broca 6	-	-	-
Arcus superciliaris	flat	1	29	30
	discernible	20	10	30
	strong	10	2	12
Protuberantia occ. ext.	Broca 0	-	5	5
	Broca 1	8	18	26
	Broca 2	16	2	18
	Broca 3	4	1	5
	Broca 4	-	-	-
	Broca 5	-	-	-
Processus mastoideus	small	9	28	37
	medium	12	5	17
	strong	11	-	11
Orbita	rounded	8	19	27
	subrectangular	23	15	38
	rectangular	-	-	-
Nasal aperture	infantile	-	1	1
	sulcus praenas.	6	2	8
	fossa praenas.	4	2	6
	anthropine	22	28	50
Spina nasalis anterior	Broca 1	4	4	8
	Broca 2	7	5	12
	Broca 3	7	6	13
	Broca 4	7	5	12
	Broca 5	1	4	5
Fossa canina	very small	5	3	8
	small	6	15	21
	medium	16	10	26
	large	4	3	7
	very large	2	2	4
Alveolar prognathy	vertical	19	15	34
	moderate	10	8	18
	expressed	3	7	10

mined by the method of PEARSON (in FARKAS 1972) and that of DEBETS & DURNOVO (1971). In calculating the weight we proceeded according to DEBETS & DURNOVO (1971), while the quadratic weight-stature index according to DEBETS's method. LIPTÁK's method was applied in the taxonomical analysis (1954, 1965, 1969). Comparative analysis was proceeded by using PENROSE's method (1954).

PALEODEMOGRAPHICAL ANALYSIS

It can be stated that few individuals died at the age of infans I. It is 32, which is 14.7% of the whole series. Twenty individuals died at the age of infans II (9.2%), 12 persons at a juvenis age (5.5%). Hence the number of children is 52 (23.8%). Most of the individuals (85) died at the adultus age (39%), 44 at the maturus age (20.2%) and 1 person at the senilis age. Among the grown-ups there are 52 males and 88 females.

The distribution of males by age can be given as follows: 3 individuals are juvenis (5.8%), 26 are adultus (50.0%) and 20 are maturus (38.5%). The age of 3 males could not be determined owing to the bad state of preservation.

The distribution of females: 5 persons are juvenis (5.6%), 54 are adultus (61.3%), 24 are maturus (27.2%) and 1 person is at the age of senilis (1.1%). The age of 4 females is undeterminable.

In comparing the age at the time of death of the males and that of the females, certain differences are readily observable. Fifty percent of the males and 61.3% of the females died in the adultus age. 38.5% of the males lived to maturus age while same is only 27.2 in the case of females. The cause of this difference may be explained by maternal mortality (ACSÁDI 1965).

There are several double-graves. Adultus women and infans I children were in Graves 20, 133 and 188. Adultus woman and juvenis child were in Graves 119 (Plate 1). Graves 120 is very interesting. It has adultus man and woman having been buried hand in hand (Plate 2). It is worth mentioning that there are also 2 horse skeletons (Graves 140, 194).

ANTHROPOLOGICAL ANALYSIS

Males: Brain-case according to the mean-values is long - medium long, medium wide, medium high. According to the calculated indices it is dolichocranic (but the ratio of hyperdolichocranic is the most frequent), chamaecranic (but the orthocranic value is the most frequent), acrocranic, eurymetopic.

The circumference of most of the skulls is ovoid in norma verticalis. Glabella is medially developed, generally of degrees 2 and 3. Arcus superciliaris is discernible (65%), strong (32%). Protuberantia occipitalis externa is of degree 2 in general, processus mastoideus is moderately or strongly developed.

Characteristics of the facial skeleton are: medium wide zygomatic arc with medium bizygomatic breadth. Both face and upper face are medium high. Both orbita and nose are medium wide and medium high.

According to the indices the facial skeleton is mesoprosopic (but the ratio of the euryprosopic category is high too), mesen. Orbita is most frequently mesoconch but the chamaeconch category is frequent enough. Nose is both mesorrhine and leptorrhine in equal proportion. Palate is mesostaphyline. Orbita is usually subrectangular, lower edge of nasal aperture is anthropine. Spina nasalis anterior is generally of degrees 1, 2 or 3 of an equal proportion. Fossa canina is medium deep. Alveolar regio in the most proportion is vertical (59%), but moderate alveolar prognathy is observed too (31%). Stature is 166.3 cm by the PEARSON-method and 167.1 cm by the DEBETS's method. It is medium-great medium (Tables 2-4).

Females: Brain-case according to the mean-values is long, medium high, medium wide. According to the calculated indices it is dolichocranic (although hyperdolichocranic is the most frequent among the individuals: 44%), orthocranic, acrocranic (metriocranic category is also frequent), eurymetopic (medium, wide and very wide forehead are frequent).

The circumference of most of the skulls is ovoid in norma verticalis. Glabella is weakly developed, generally of degrees 1 or 2. Processus mastoideus is small.

Facial skeleton's characteristics are: medium wide zygomatic arc, medium bizygo-

matic breadth. Face is low and medium of an equal proportion. Upper face is mostly medium. Orbita is medium wide and medium high. Nose is medium wide and medium high on an average but there are low (42%), medium (22%) and high (29%) forms. Palate is medium long and narrow.

According to the indices the facial skeleton is mesoprosopic, mesen. Orbita is mesoconch (but chamaeconch category is the most frequent among the individuals). Nose is medium on the average but narrow and wide variations are also frequent. Palate is mesostaphyline. The shape of orbita is rounded or subrectangular (in almost equal proportions), lower edge of nasal aperture is anthropine. Every variation of spina nasalis anterior is observed in similar proportion. Fossa canina is medium deep or shallow. Alveolar regio is mostly vertical (Tables 2-4).

ANATOMICAL VARIATIONS AND ABNORMALITIES

The occurrence of 14 characteristics was recorded. The fragmentary material was also studied. The percentage of each characteristic was calculated on the basis of the cemetery's total number of individuals (218).

Sutura metopica occurs on 6 skulls (2.6%). This rate is lower than the one calculated by WENGER (1974a) for the Avar period series of Hungary (5.7%). Os apicis is present on

Table 5

Anatomical variations and abnormalities

Variations, abnormalities	Inf. I.	Inf. II.	Juv.	Male	Female	Total
Sutura metopica	1	1	1	2	1	6
Os apicis	1	1	1	2	2	7
Os apicis bipartium	-	-	-	1	2	3
Os bregmaticum	-	-	-	1	-	1
Os incae	1	-	-	2	-	3
Ossa wormiana lambdoidea	3	9	-	22	12	46
Ossa wormiana coronalis	-	2	-	4	2	8
Ossa wormiana sagittalis	-	2	-	-	2	4
Os epipterícum						
right side	-	-	-	2	2	4
left side	-	-	-	3	1	4
Crista frontale	-	-	-	1	-	1
Bathrocephalia	-	-	-	2	2	4
Plagiocephalia	-	-	-	1	1	2
Perforatio fossae olecrani humeri	-	-	-	3	3	6
Sacrum bifidum						
cranial	-	-	-	2	1	3
caudal	-	-	-	2	1	3
total	-	-	-	2	-	2
Sacralization	-	-	-	2	1	3
Spondylosis	-	-	-	3	1	5

10 individuals (4.4). Three of them are os apicis bipartium. It is more frequent than the one recorded by WENGER (1.4%). Ossa wormiana, their presence was classed by sutures. All cases are 58. This is a much higher number than the 14.3% recorded by WENGER. Ossa wormiana can be observed most often in the sutura lambdoidea (in 46 cases). It appears in

8 cases in the sutura coronalis and on 4 individuals in the sutura sagittalis. Os epiptericum can be found on 8 crania, 4 on the right, 4 on the left side. Os bregmaticum occurs on 1 male skull. Os incae could be found on the crania of an infans individual and 2 males. One of those has a bipartite os incae. Bathrocephalia appears on the skulls of 2 males and 2 females. Crista frontale can be seen on 1 male cranium. Plagiocephalia is perceptible on 1 male and 1 female cranium.

Perforatio fossae olecrani humeri appears in 6 cases (3 males and 3 females). Sacralizatio developed on 2 males' vertebral column. Spina bifida was found on 1 male's vertebra. Sacrum bifidum the lack of crista sacralis media could be seen in 8 cases. Six of them were partial ones (caudal or cranial) and 2 males had completely open sacrums. Spondylosis was recorded on the vertebrae of 4 males and 1 female.

In summing up it can be stated that in the series of Fészerlak the anatomical variations and abnormalities appeared on a large scale. They occurred more frequently on the males' crania and skeletons than on those of females (Table 5).

ANALYSIS OF LONG BONES

Long bones of 32 males and 33 females were suitable for investigation. Left and right side have been separately treated in each case (Tables 8-10).

Humerus. The mean value of the maximum length is 327 mm on the left, and 331.5 mm on the right side in the case of males. Those of females are 290.9 mm and 290.2 mm, respectively. Thus, there is a notable sexual dimorphism. Bilateral difference was observed only in the case of males. The mean-value of the minimum circumference of the diaphysis is 61.5 mm on the left, and 63.1 mm on the right side in the case of males. The same for females are 54.2 mm and 55.3 mm. Both males and females are gracile as for robusticity index (males: 18.6 and 18.9, females: 18.5 and 18.5).

Radius. Males have no difference between the two sides as for maximum length of radii. The right female radii are longer than the left ones according to the averages, the same holds true for the ulna.

In comparing the length of radius and that of humerus we can state that both sexes are characteristic of dolichoker (relatively long) forearm.

Femur. The mean-values of the maximum length are 449.4 mm on the left, and 447.8 mm on the right side in the case of males. The same for females are 410.8 mm and 410.0 mm. The minimum circumference of diaphysis: 89.0 mm and 89.3 mm as well as 80.0 mm and 78.4 mm.

Regarding the robusticity index, the female femur is gracile while the male one is medium robust. The right male femora are more robust than the left ones. In the case of females the left femora are more robust than the right ones in general.

Tibia. The mean-values of maximum length are 368.8 mm and 368.0 mm for males, 333.5 mm and 335.7 mm for females. There is a considerable sexual dimorphism. The minimum circumferences are 73.3 mm and 73.2 mm for males and 65.5 mm and 66.7 mm for females. There is no bilateral difference in either sexes regarding the tibia.

In drawing a parallel between males and females as regards robusticity index it can be seen that there is a little difference concerning the upper extremity and a considerable inequality concerning lower extremity (especially femur) for the males. The largest robusticity difference between the sexes was found in the case of right femur.

Bilateral difference was perceptible from all aspects analysed for the right side in the case of males, being most distinct on the humerus. We believe that there must have been a notable difference between the usage of the left and the right hand. Bilateral difference was not found on the humerus in the case of females. Women probably used both hands in an equal proportion while doing their work. It is interesting that the left lower extremity was recorded to be more robust than right one.

Stature of males is 166.3 cm by Pearson's method and 167.1 cm by Debets's method. Those of females are 153.1 cm and 154.9 cm. Then the two methods produced similar results. The distribution of individual statures is as follows:

	Male	Female
Short	2	6
Medium short	8	11
Medium	9	14
Medium tall	13	5
Tall	3	3

Body weight of males is 62.3 kg, that of females is 52.2 kg according to the averages. The quadratic weight-stature index (Q) of both males and females is 2.21. We may establish that the relation between weight and stature of males is the same as for females in this series. Nevertheless, it can be seen in Fig. 1 that the increase of body weight dependent on the increase of stature is less for the males than for the females (as angle of inclination of line fitted by least-square method is also less). The female series has only one individual different from the average. Female No. 58 has a rather strong physique. Her stature is 152.2 cm, weight is 60.8 kg, Q= 2.63. Two males have particularly slim physiques. Male No. 68 is 169.8 cm, weight is 54.0 kg, Q= 1.87. No. 121 is 164.0 cm, weight is 49.5 kg, Q= 1.84. On the other hand, two men have rather strong physiques: No. 17 is 164 cm, weight is 70.7 kg, Q= 2.63, while No. 140 is 169.9 cm, weight is 72.7 kg, Q= 2.52.

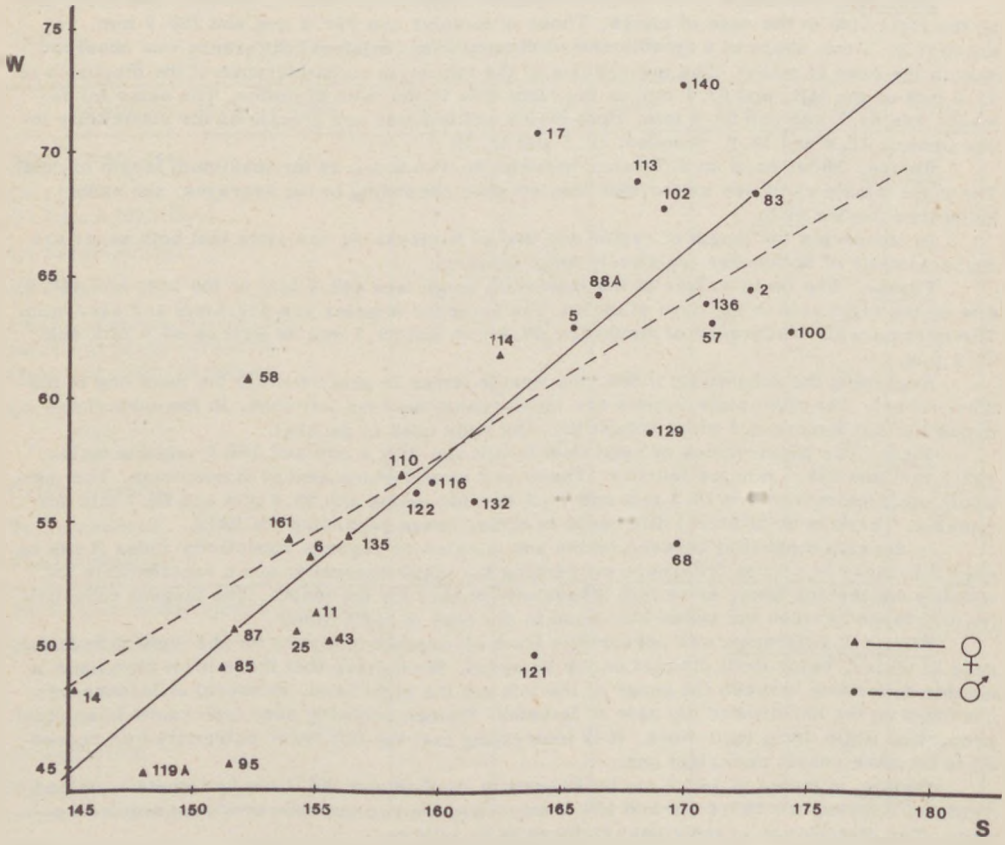

Fig. 1 Relation between body weight and stature

TAXONOMICAL ANALYSIS

The analysis of the primary taxonomical characteristics of Fészerlak has been published in a former paper of mine (FÓTHI in print). This paper presents the analysis of the secondary taxonomical characters of our series. It has been carried out on the basis of LIPTÁK's works (1954, 1965, 1969). It was possible to analyse 48 skulls (32 males and 16 females). We took into consideration the stature calculated according to the PEARSON's method.

The following groups were found in the series:

1. Mediterranean group: this type is characteristic for the whole cemetery, especially the females. Mediterranean characters are ascertained more or less on 14 female skulls. They can be clearly seen on the female skulls of Nos. 11, 14, 43, 48, 50, 59, 71, 74, 87. These characters are mixed with the Cromagnoid ones (Nos. 98, 114 females) and some unidentified elements (Nos. 124, 172). Among the males 8 individuals belong to the Mediterranean group (Nos. 37, 49, 68, 70, 100, 120A, 126, 129). This type occurs mixed with the Nordoid type in 7 cases (Nos. 8, 17, 108, 122, 132, 149, 154) and some unidentified elements in one case (No. 156).

2. Cromagnoid group: this type is clearly represented only in men. Man No. 57 is Cromagnoid-A, No. 136 is Cromagnoid-B. Mostly Cromagnoid-like with other elements are No. 97: Cromagnoid-Mediterranean, Nos. 102, 113 and 121: Cromagnoid-Nordoid, No. 205: Cromagnoid-Mongoloid.

3. Nordoid group: typical Nordoid characters were represented by 3 males (Nos. 2, 9, 44). The skulls of males Nos. 15 and 45 are also Nordoid mixed with other taxa (N-x). On the skull of the male No. 142 moderate Mongoloid influence (N-Mo) can be observed.

4. Brachycranial group: two male (Nos. 88A, 116) and two female (Nos. 110, 161) skulls belong to this type.

In summarizing the results of taxonomical analysis it can be stated that the part of the cemetery of Fészerlak uncovered so far was the graveyard of an 8th century Europoid population. The series comprised mostly dolichocranial elements, first of all, the Mediterranean type. The percentual distribution is as follows:

Mediterranean group:		62.5%
Cromagnoid	"	16.6%
Nordoid	"	12.5%
Brachycranial	"	8.3%

Mongoloid elements faintly occurred in the case of males Nos. 142 and 205. It is worth noting that there is a definite sexual dimorphism as for taxonomical type. Only 2 of the 16 examinable females did not exhibit Mediterranean features. While on the males not only the Mediterranean but some other types were also found. We believe that this interesting problem will be solved only after the whole of the cemetery will have been excavated.

In comparing the results of the two taxonomical analyses we may conclude that the Mongoloid influence was perceptible in more cases when applying the primary taxonomical analysis than the secondary one. It is evident that the facial flatness analysis is a suitable way to analyse the face region. We can detect with it fine variances of microevolution expending on a small area of the face.

On the other hand, there were several graves which contained face skeletons suitable for detailed examination and fragmentary brain-cases and long bones. In these cases only the primary taxonomical analysis could be applied.

COMPARATIVE ANALYSIS

Comparison was carried out on the basis of the PENROSE-method (1954) by taking 12 measurements (MARTIN 1, 5, 8, 9, 17, 40, 45, 48, 51, 52, 54, 55). The mean-values calculated from the measurements of adults were utilized. The standardization of mean-values was carried out by the DEBETS' mean-sigma values. We have drawn into comparison 22 other series from the Avar-period (males and females were treated separately (Fig. 2).

According to the generalized PENROSE-distance (D^2_p) the males of Toponár bear the closest resemblance to the males of Fészerlak. The series of Solymár, Vác-Kavicsbánya and Keszthely are similar to our series, too. Besides the male series of Csákberény, Szebény and Környe stand close to that of Fészerlak.

The female series of Solymár and Toponár are highly similar to that of Fészerlak. The series of Keszthely, Vác-Kavicsbánya, Kékesd and Környe are also quite close.

It can be concluded for both sexes that the series of Madaras, Üllő I and II, Tiszavasvári, Kecel, Szentes-Kaján, Alattyán-Tulát are the most distant ones. In summarizing the result of the comparative analysis we can state that the series of Fészerlak presents biological proximity to those series which are close geographically as well, namely, those of Transdanubia, among them first of all Toponár, Solymár, Vác-Kavicsbánya, Keszthely and Környe. The series of the Great Hungarian Plain show the least similarity to that of Fészerlak.

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Table 6 Individual cranial measurements and indices - Males

MARTIN No.	2 ad	5 ad	8 mat	9 mat	15 mat	17 mat	37 mat	44 ad	45 mat	49 ad	57 ad	68 ad	70 mat	88A mat	97 ad	100 ad	102 ad	108 mat
1	193	-	186	187	185	181	185	193	195	182	195	171	189	182	181	184	188	180
1c	195	-	188	185	188	183	181	194	198	180	194	169	189	182	180	180	189	178
5	101	-	100	108	110	109	107	102	103	99	110	105	102	102	101	105	100	101
8	141	134	145	136	140	139	133	142	140	139	135	124	143	144	131	138	136	148
9	101	98	104	102	105	100	103	96	98	99	106	92	96	92	94	96	99	97
10	124	122	123	116	130	123	118	112	125	125	126	108	121	137	110	115	120	-
11	126	-	128	125	130	126	121	118	120	126	121	110	-	125	114	117	126	126
12	111	-	110	107	114	107	108	104	112	107	106	108	106	117	102	-	110	114
17	139	-	136	144	143	144	132	137	143	129	143	139	133	140	132	145	136	137
20	120	-	116	121	116	117	114	115	120	113	116	112	-	117	111	117	112	119
32	85	-	-	80	88	83	78	82	84	81	84	76	-	77	83	77	80	86
32-	78	-	-	75	83	78	73	77	78	73	78	70	-	71	79	71	75	77
38	1586	-	1560	1491	1547	1500	1313	1566	-	1331	1557	1188	1491	1531	1294	1481	1452	1512
40	100	95	94	104	98	96	100	96	94	99	104	95	97	91	103	96	100	101
43	107	105	104	107	109	104	107	102	103	105	112	98	106	104	102	105	106	106
45	137	-	133	135	137	134	133	127	135	135	134	-	-	138	130	129	136	135
46	96	101	90	98	100	99	97	87	93	87	106	89	-	106	98	93	97	91
47	116	-	110	120	-	-	111	121	-	115	108	118	-	-	114	-	130	103
48	69	66	R 66	71	68	73	70	77	69	68	64	66	66	69	63	77	75	62
51	40	41	R 40	42	41	42	45	41	39	39	42	44	41	43	41	43	45	43
52	31	27	R 30	32	32	34	36	35	32	28	29	35	32	35	27	36	31	32
54	24	26	23	24	29	24	26	22	26	24	30	23	24	25	27	25	25	24
55	52	51	50	50	54	54	55	57	52	48	47	50	47	53	48	58	53	47
62	45	46	45	49	45	45	47	46	52	47	50	43	45	44	50	49	38	44
63	38	38	38	40	37	32	39	31	31	39	39	36	-	-	42	40	44	-
65	123	-	-	122	-	115	-	-	-	116	121	104	-	126	118	-	122	121
66	104	-	104	105	-	104	102	98	-	97	108	-	-	102	102	-	112	90
69	31	-	31	32	34	30	24	34	-	32	34	33	-	32	33	R 36	34	29
70	60	-	55	66	-	62	59	70	-	59	61	60	-	61	61	R 66	73	65
71a	35	-	31	33	33	30	37	30	-	28	33	28	-	29	35	24	30	33
72	83	-	-	83	-	85	84	82	85	82	81	80	-	88	81	84	78	81
73	84	-	-	85	87	85	85	83	86	83	81	83	-	87	81	85	82	82
74	81	-	-	75	-	83	79	75	79	80	85	61	-	93	77	82	69	79
75	-	-	-	52	56	54	51	60	63	44	-	42	-	51	46	60	-	-
75/1	-	-	-	31	-	31	33	22	22	38	-	38	-	37	34	23	-	-
8:1	73.1	-	78.0	72.7	75.7	76.8	71.9	73.6	71.8	76.4	69.9	72.5	75.9	79.1	72.4	75.4	72.4	82.5
17:1	72.0	-	73.1	77.0	77.3	79.6	71.9	71.0	73.3	70.9	74.1	81.3	70.4	76.9	73.0	79.0	72.5	76.2
17:8	98.6	-	93.8	105.9	107.1	103.6	99.2	96.5	102.1	92.8	105.8	112.1	92.7	97.2	100.9	104.8	100.2	92.4
9:8	71.6	73.2	71.7	75.0	75.0	71.9	77.4	67.6	70.0	71.2	78.5	74.6	66.9	64.2	71.8	69.1	72.8	65.7
47:45	84.7	-	82.7	88.9	-	-	83.5	95.3	-	85.2	80.6	-	-	-	87.5	-	95.9	76.1
48:45	50.4	-	49.6	52.6	49.6	54.5	52.6	60.6	51.1	50.4	47.8	-	-	50.0	48.6	59.9	55.1	46.3
52:51	85.4	70.5	R 83.3	75.0	89.9	93.0	83.0	88.6	87.8	81.0	69.8	79.6	77.8	81.2	66.3	83.8	69.3	75.7
54:55	46.2	51.0	46.0	48.0	54.7	44.4	47.3	38.6	50.0	50.0	63.8	45.0	51.1	46.2	55.8	42.8	46.1	52.0
63:62	84.4	82.6	84.4	81.6	82.2	71.1	83.0	67.4	64.6	83.0	78.0	83.7	-	-	83.9	80.7	116.4	-

Table 6 (cont. 1)

MARTIN No.	113 mat	116 mat	120A ad	121 ad	122 ad	126 mat	129 mat	132 ad	136 ad	140 ad	142 ad	149 ad	154 mat	156 mat	183/1 mat	196 mat	205 ad
1	181	190	176	187	186	179	173	176	177	191	184	182	175	190	198	-	187
1c	178	191	175	189	186	179	173	173	176	188	185	177	-	191	191	-	184
5	102	107	101	95	97	-	100	106	99	108	95	102	101	100	109	-	103
8	146	141	129	141	138	129	136	145	137	142	133	140	143	137	139	141	140
9	100	100	87	96	102	91	92	92	95	104	93	102	94	101	96	95	92
10	-	119	-	121	122	106	118	119	111	124	116	120	120	121	112	116	111
11	128	133	109	116	126	-	116	125	117	133	123	122	124	126	-	116	129
12	-	-	-	110	-	-	106	110	111	124	102	112	111	112	117	-	-
17	135	138	135	138	127	-	136	142	125	142	133	134	133	135	137	-	136
20	113	116	113	119	113	-	115	116	105	121	112	112	111	-	-	-	-
32	76	82	-	91	82	-	85	83	80	85	83	80	-	-	-	-	81
32-	68	77	-	84	75	-	79	74	75	78	75	73	-	-	-	-	74
38	1467	1547	1249	1518	1369	-	1352	1485	1249	1557	1359	1369	-	1481	1509	-	1444
40	94	100	98	88	102	-	94	97	95	108	88	96	-	98	-	-	98
43	108	105	-	102	108	97	99	102	108	110	104	107	-	107	-	103	105
45	138	142	-	123	137	-	124	139	130	145	134	-	-	135	-	-	128
46	95	92	-	97	99	88	98	98	99	104	87	95	90	94	-	92	100
47	123	-	-	-	119	-	109	118	108	123	-	-	-	-	-	-	112
48	76	68	71	73	70	69	67	69	66	72	69	71	-	72	-	-	59
51	44	43	R_{42}	40	44	41	41	44	43	44	42	42	R_{44}	42	-	41	40
52	35	35	R_{31}	32	33	35	29	33	29	31	33	33	R_{36}	34	-	30	30
54	25	25	23	27	26	23	23	23	24	27	23	25	23	26	-	25	24
55	59	50	52	51	54	50	50	52	52	52	51	52	52	52	-	49	49
62	44	46	50	42	52	46	47	43	47	52	43	48	44	48	-	42	46
63	-	-	36	-	39	41	-	43	42	44	40	38	-	-	-	-	46
65	114	134	-	-	-	-	118	122	114	136	-	-	-	123	-	-	117
66	-	105	-	107	-	110	103	109	109	116	-	101	-	95	-	-	-
69	35	29	32	32	33	24	29	31	23	33	-	36	33	33	-	-	29
70	69	55	R_{62}	-	R_{62}	59	64	67	65	66	-	R_{65}	66	R_{64}	-	-	R_{61}
71a	34	30	R_{27}	29	R_{33}	27	29	32	36	39	-	R_{29}	34	R_{28}	-	-	R_{34}
72	86	86	-	89	79	-	85	85	84	82	87	84	-	-	-	-	84
73	85	85	-	89	81	-	87	84	84	81	88	84	-	-	-	-	86
74	86	84	-	90	75	-	83	91	86	80	83	85	-	-	-	-	71
75	64	-	-	-	-	-	50	-	-	-	64	51	-	-	-	-	64
75/1	22	-	-	-	-	-	35	-	-	-	23	33	-	-	-	-	20
8:1	80.4	74.5	73.2	75.6	74.2	72.4	78.9	82.7	77.4	74.4	72.3	76.9	81.8	72.1	70.2	-	74.9
17:1	74.4	72.6	76.6	73.8	68.6	-	78.6	80.7	70.6	74.4	72.3	73.9	76.1	71.3	69.2	-	72.7
17:8	92.6	97.5	104.7	97.7	92.4	-	99.6	97.6	91.2	100.0	100.0	96.1	93.0	98.9	98.6	-	97.1
9:8	68.7	70.7	67.4	67.9	73.9	70.2	67.0	63.6	69.3	73.2	70.3	72.9	65.5	74.1	69.1	67.4	65.7
47:45	88.7	-	-	-	86.7	-	87.9	84.9	83.1	84.8	-	-	-	-	-	-	87.5
48:45	55.1	47.6	-	58.9	50.7	-	54.0	40.8	50.8	49.2	51.7	-	-	53.3	-	-	46.1
52:51	78.4	81.3	$R_{73.8}$	81.1	75.5	85.0	70.2	61.5	68.1	70.8	79.6	78.7	$R_{80.7}$	81.0	-	73.2	75.0
54:55	41.7	49.8	44.4	52.8	47.7	46.0	46.6	44.2	47.0	51.5	45.1	47.9	44.2	49.5	-	51.0	49.0
63:62	-	-	70.9	-	75.4	89.0	-	104.5	89.8	85.4	92.8	78.7	-	-	-	-	100.0

Table 7 Individual cranial measurements and indices - Females

MARTIN No.	6 ad	10 ad	11 ad	14 ad	18 mat	19 ad	20A ad	23 ad	25 ad	33 ad	43 ad	48 mat	50 mat	58 mat	59 mat	SZ ad	71 sen	74 mat
1	185	190	169	188	187	176	-	-	186	-	183	-	168	180	185	-	-	-
1c	186	191	171	190	185	180	-	-	190	-	185	-	170	181	185	-	-	-
5	-	101	91	101	-	100	-	-	99	-	95	95	90	105	-	-	-	-
8	133	141	134	133	127	124	138	-	140	-	139	135	125	132	136	-	145	-
9	98	104	92	98	95	93	100	-	100	-	93	96	89	97	95	94	98	95
10	113	120	118	115	114	114	122	-	120	-	118	127	107	117	120	117	125	118
11	120	121	116	119	-	109	-	-	135	-	118	117	114	118	121	-	121	-
12	109	120	103	107	-	107	-	-	107	-	106	-	100	110	104	-	-	-
17	-	134	130	126	-	124	-	-	134	-	133	134	127	135	-	-	-	-
20	111	-	112	113	-	107	-	-	112	-	112	117	107	113	115	-	114	-
32	75	-	86	85	-	85	-	-	86	-	86	89	85	83	87	-	87	-
32-	70	-	80	82	-	79	-	-	80	-	83	87	82	76	80	-	83	-
38	-	1491	1257	1340	-	1155	-	-	1481	-	1416	-	1107	1331	-	-	-	-
40	-	90	96	-	97	97	-	-	98	-	89	98	90	99	-	-	-	-
43	105	98	103	100	96	96	101	98	102	103	98	100	98	100	102	102	103	99
45	-	121	123	-	115	115	-	-	-	-	125	130	122	-	122	-	-	-
46	-	84	91	90	-	-	91	-	-	89	87	90	92	97	95	95	89	93
47	102	103	-	109	115	115	106	107	-	112	-	116	102	120	110	-	-	-
48	66	61	61	68	65	65	68	64	-	66	68	71	62	72	66	68	-	68
51	-	-	37	40	R_{38}	R_{38}	37	R_{37}	40	R_{40}	39	41	39	R_{41}	40	38	41	41
52	-	-	29	34	R_{30}	R_{32}	31	R_{30}	34	R_{34}	33	31	28	R_{31}	30	30	35	33
54	-	24	28	24	-	-	24	25	-	-	24	28	23	26	26	27	25	22
55	53	45	51	52	45	45	51	45	-	48	53	52	47	53	49	51	56	52
62	-	43	47	50	-	-	46	43	-	44	42	47	41	-	-	44	-	40
63	-	36	29	35	25	26	33	34	-	36	29	35	34	34	30	35	-	-
65	-	107	110	-	105	105	110	-	118	110	-	-	108	-	113	-	-	-
66	-	99	91	-	84	84	84	-	87	90	-	93	90	89	92	-	-	-
69	27	29	28	29	32	32	27	27	-	30	-	35	25	32	34	-	-	-
70	-	58	61	-	52	52	56	-	53	59	-	-	58	-	59	-	-	-
71a	31	28	37	30	30	30	30	-	26	27	-	26	30	33	34	-	-	-
72	75	-	79	85	-	78	-	-	-	-	81	81	81	83	87	-	-	-
73	77	-	82	87	-	76	-	-	-	-	81	82	83	82	89	-	86	-
74	63	-	66	73	-	82	-	-	-	-	82	74	76	89	81	-	-	-
75	55	-	54	67	-	53	-	-	-	-	54	51	60	58	60	-	64	-
75/1	20	-	25	18	-	25	-	-	-	-	27	30	21	25	27	-	-	-
8:1	71.9	74.2	79.3	70.2	67.0	70.5	-	-	75.3	-	75.1	-	74.4	73.3	73.5	-	-	-
17:1	-	70.5	76.9	67.0	-	70.5	-	-	72.0	-	72.7	-	75.6	75.0	-	-	-	-
17:8	-	95.0	97.0	94.7	-	100.0	-	-	95.7	-	95.7	99.3	101.6	102.3	-	-	-	-
9:8	73.7	73.8	68.7	73.7	74.7	75.0	72.5	-	71.4	-	66.9	71.1	71.2	73.5	69.9	-	67.6	-
47:45	-	85.1	-	-	100.0	100.0	-	-	-	-	-	89.2	83.6	-	90.2	-	-	-
48:45	-	50.4	49.6	-	56.5	56.5	-	-	-	-	54.4	54.6	50.8	-	54.1	-	-	-
52:51	92.7	76.9	90.2	85.0	$R_{90.0}$	$R_{89.7}$	89.7	$R_{79.5}$	82.9	$R_{90.5}$	90.7	81.0	78.6	$R_{78.6}$	78.1	84.6	85.4	79.3
'54:55	-	53.3	54.9	46.1	-	-	47.1	55.6	-	-	45.3	53.9	48.9	49.1	53.1	52.9	43.8	42.3
63:62	-	83.7	61.7	70.0	-	-	71.7	79.1	-	81.8	69.1	74.5	82.9	-	-	79.6	-	-

Table 7 (cont. 1)

MARTIN No.	T5 mat	87 mat	98 mat	110 mat	114 ad	119A ad	120B ad	124 ad	145 ad	161 ad	169 mat	170 ad	172 ad	187 mat	188/1 ad	195 ad	202 ad	222 mat
1	169	180	186	172	176	174	180	165	-	175	176	176	173	183	-	177	174	177
1c	168	182	186	174	179	175	184	168	-	173	174	178	173	183	-	173	175	179
5	98	94	103	93	96	93	97	93	-	102	103	-	-	93	-	99	-	99
8	128	132	134	142	139	-	131	118	-	144	135	129	126	121	133	134	133	-
9	90	94	90	97	90	-	92	89	93	95	94	95	85	93	99	88	91	88
10	107	120	116	-	115	-	109	103	-	115	-	108	105	-	116	110	111	105
11	116	112	117	123	115	109	116	102	-	122	120	115	-	106	-	116	116	115
12	102	108	102	109	100	-	100	92	-	107	114	104	-	-	-	110	-	104
17	132	125	133	129	133	128	128	122	-	131	132	-	-	128	-	118	-	136
20	-	110	112	110	113	110	113	104	-	115	111	111	101	-	-	-	-	113
32	-	83	84	86	90	87	91	90	-	83	-	-	79	-	-	-	-	87
32	-	80	79	83	84	81	87	84	-	75	-	-	74	-	-	-	-	79
38	1155	1249	1378	1335	1350	-	1285	-	-	1370	1267	-	-	1188	-	1131	-	-
40	-	89	-	89	97	88	94	92	-	98	-	-	-	87	-	-	-	93
43	-	98	100	98	98	-	-	94	99	103	-	-	97	-	104	-	-	93
45	-	121	-	127	124	-	119	-	-	-	-	-	-	-	-	-	-	120
46	-	92	95	94	92	-	94	83	93	-	-	-	91	-	87	-	-	87
47	-	-	-	-	109	-	100	97	-	-	-	-	-	109	-	-	-	102
48	-	63	65	66	61	61	61	60	63	67	-	-	68	58	56	-	60	60
51	-	41	41	41	40	40	39	39	39	43	-	-	40	R38	43	-	R39	40
52	-	31	33	34	31	30	31	30	32	35	-	-	31	R34	32	-	R29	38
54	-	25	22	24	20	25	23	18	22	24	-	-	23	28	26	-	26	25
55	-	46	50	48	46	45	47	43	47	50	-	-	49	47	47	-	49	46
62	-	45	45	-	44	41	43	45	41	-	-	-	46	42	46	-	-	39
63	-	-	38	-	43	40	41	32	43	-	-	-	38	34	-	-	-	35
65	122	112	-	-	-	-	108	-	-	-	-	-	-	-	-	-	-	110
66	-	97	-	-	97	-	-	80	-	-	-	-	-	-	-	-	-	-
69	32	30	-	28	30	25	-	26	-	-	-	-	27	28	34	-	-	28
70	R56	58	-	58	58	52	R59	50	-	-	-	-	R61	-	60	-	-	61
71a	R31	27	-	27	31	27	R33	26	-	-	-	-	R28	-	30	-	-	31
72	-	86	85	80	80	86	86	82	-	85	-	-	75	-	-	-	-	84
73	-	88	86	79	78	87	83	84	-	85	-	-	77	-	-	-	-	84
74	-	75	80	83	88	81	88	79	-	77	-	-	71	-	-	-	-	83
75	-	55	56	46	-	-	-	60	-	-	-	-	53	-	-	-	-	-
75/1	-	31	29	34	-	-	-	21	-	-	-	-	22	-	-	-	-	-
8:1	75.8	73.3	71.7	82.5	78.7	-	72.7	71.5	-	82.3	76.7	72.8	72.8	66.1	-	75.7	76.4	-
17:1	78.1	69.4	71.4	75.1	75.6	73.7	71.1	73.6	-	75.1	75.0	-	-	70.0	-	66.7	-	76.8
17:8	103.1	94.7	99.6	91.0	96.0	-	97.9	103.0	-	91.3	97.8	-	-	105.8	-	87.3	-	-
9:8	70.7	71.2	67.2	68.6	65.0	-	70.0	75.4	-	66.0	69.6	73.6	67.5	76.9	74.4	65.7	68.4	-
47:45	-	-	-	-	87.5	-	94.0	-	-	-	-	-	-	-	-	-	-	85.0
48:45	-	52.1	-	52.0	49.0	-	51.6	-	-	-	-	-	-	-	-	-	-	50.0
52:51	-	74.4	80.5	84.4	76.6	74.6	79.0	76.7	80.8	80.2	-	-	77.5	R89.5	74.4	-	R74.4	95.0
54:55	-	54.9	44.2	48.3	43.9	55.4	48.5	41.9	47.0	48.0	-	-	46.9	59.6	55.3	-	53.1	89.7
63:62	-	-	85.3	-	97.7	98.3	95.1	71.5	103.7	-	-	-	82.6	81.0	-	-	-	89.7

Table 8

Parameters of male and female series -- Post-cranium

MARTIN No.		Males				Females			
		N	V	M	s	N	V	M	s
Humerus	1 L	19	311-349	327.0	9.58	19	251-321	290.9	14.89
	R	21	320-347	331.5	7.82	11	258-320	290.2	18.38
	2 L	19	305-340	322.6	9.38	16	250-325	289.1	18.21
	R	20	311-340	326.1	8.28	11	257-312	287.3	16.30
	7 L	27	54- 68	61.5	3.92	29	42- 64	54.2	4.68
	R	28	56- 74	63.1	4.21	29	48- 64	55.3	4.05
	7:1 L	19	16.4-20.5	18.6	1.14	19	17.0-20.7	18.5	1.03
	R	21	16.8-20.9	18.9	1.14	12	17.3-19.4	18.5	0.66
Radius	1 L	19	232-263	248.1	8.09	10	203-234	221.5	10.58
	R	19	224-266	247.8	11.00	10	211-237	225.5	8.58
	1b L	19	229-260	245.0	8.19	9	200-242	221.2	13.74
	R	19	222-265	245.5	11.40	12	209-235	224.5	8.63
Ulna	L	11	255-283	265.5	10.23	5	226-254	244.0	11.71
	R	16	243-280	267.3	10.25	5	236-255	247.7	8.61
Femur	1 L	30	424-477	449.4	16.15	24	380-446	410.8	16.37
	R	27	423-475	447.8	17.05	23	379-452	410.0	17.75
	2 L	29	418-475	447.2	17.34	22	376-444	408.9	15.84
	R	25	418-472	445.9	16.77	21	375-443	410.1	14.20
	8 L	29	77-102	89.0	6.21	20	72- 89	80.0	4.31
	R	25	79- 99	89.3	5.84	25	71- 87	78.5	3.86
	8:2 L	28	16.8-21.9	20.0	1.22	17	18.3-21.7	19.5	0.83
	R	22	17.5-22.4	20.0	1.26	21	18.2-21.0	19.2	0.82
Tibia	1 L	25	326-398	368.8	17.36	22	282-364	333.5	20.41
	R	20	331-399	368.0	17.38	19	309-362	335.7	14.04
	1b L	28	323-402	365.8	17.59	23	274-356	331.6	20.74
	R	23	326-396	365.9	16.71	21	303-357	333.4	14.35
	10b L	32	68- 82	73.3	4.15	32	53- 72	65.5	5.28
	R	30	62- 81	73.2	4.54	33	59- 74	65.7	4.63
	10b:1b L	25	17.8-22.9	20.0	1.20	22	17.6-21.7	19.5	0.92
	R	23	17.2-23.2	20.0	1.29	19	17.7-21.7	19.7	1.00
Stature acc. to Pearson		35	158.8-171.4	166.3	2.98	39	140.8-160.3	153.1	4.23
Stature acc. to Debets		24	159.2-174.4	167.1	4.48	20	145.1-165.9	154.9	4.83
Weight acc. to Debets		17	49.5-72.7	62.3	6.40	14	44.7-61.8	52.2	5.14
Q		17	1.84-2.63	2.21	0.20	14	1.97-2.63	2.21	0.16

Table 9

Measurements of long bones - Males

MARTIN No. / Age	2 ad	5 ad	8 mat	9 mat	15 mat	17 mat	37 mat	44 ad	49 ad	57 ad	SZ5 -	68 ad	70 mat	83 ad	88A mat	97 ad	100 ad	102 ad
Humerus 1 L	349	-	-	320	-	327	-	-	317	325	-	312	-	-	323	320	337	330
R	338	331	-	323	-	335	-	-	321	328	-	323	-	340	325	324	347	-
2 L	340	-	-	316	-	323	-	-	-	322	-	308	-	-	319	314	332	325
R	331	329	-	319	-	331	-	-	313	324	-	315	-	335	320	320	339	-
7 L	61	-	-	63	65	67	65	-	59	60	-	54	64	66	60	59	60	66
R	62	64	61	64	-	69	67	60	59	62	-	58	-	66	61	60	62	66
7:1 L	17.5	-	-	19.7	-	20.5	-	-	18.6	18.6	-	17.3	-	-	18.6	18.6	17.8	20.0
R	18.3	19.3	-	19.8	-	20.6	-	-	18.4	18.9	-	18.0	-	19.4	18.9	18.5	17.9	-
Radius 1 L	252	241	-	243	-	247	-	-	237	263	254	250	-	-	250	-	257	253
R	252	-	227	245	-	249	256	-	235	261	-	-	-	266	-	-	254	252
1b L	249	238	-	240	-	243	-	-	233	260	252	246	-	-	246	-	254	250
R	250	-	224	243	-	245	255	-	232	260	-	-	-	265	-	-	252	249
Ulna L	274	-	-	-	-	267	-	-	255	-	-	-	-	283	-	-	279	270
R	271	-	243	269	-	270	-	274	-	-	-	268	-	-	-	-	279	-
Femur 1 L	470	443	427	437	-	445	458	462	424	467	-	459	472	464	447	-	477	458
R	467	446	-	429	-	441	457	464	424	465	-	456	467	469	447	436	475	459
2 L	469	442	418	431	-	445	466	457	419	464	-	458	470	461	444	-	478	456
R	466	442	-	426	-	440	457	-	422	463	-	453	465	467	447	434	472	453
8 L	90	91	84	90	-	95	102	90	83	84	-	77	99	90	93	-	88	96
R	91	88	-	87	93	97	87	82	87	87	-	79	99	93	93	84	87	92
8:2 L	19.2	20.6	20.1	21.0	-	21.5	21.9	19.7	19.8	18.1	-	16.8	21.1	19.6	20.9	-	18.5	20.9
R	19.6	19.9	-	20.5	-	22.2	21.3	-	19.4	18.8	-	17.5	21.3	19.9	20.8	19.2	18.5	20.3
Tibia 1 L	372	367	326	-	372	376	382	382	-	385	-	360	398	-	363	-	388	382
R	368	376	331	-	372	373	-	382	-	384	-	357	399	-	363	-	385	385
1b L	376	366	323	-	368	371	386	380	-	380	-	356	402	-	366	-	386	379
R	368	372	326	-	370	367	375	380	-	380	-	356	396	375	361	-	382	371
10b L	70	75	74	73	76	78	75	75	73	75	-	66	76	73	73	69	72	78
R	70	76	75	71	77	78	75	75	74	76	-	67	78	74	73	69	72	78
10b: 1b L	18.6	20.6	22.9	-	20.7	21.0	19.6	19.7	-	19.7	-	18.5	18.9	-	19.9	-	18.7	20.5
R	19.0	20.4	23.2	-	20.8	21.3	20.0	19.7	-	20.0	-	18.8	19.7	19.7	20.2	-	18.9	21.1
Stature acc. to PEARSON	168.3	166.4	158.8	164.0	167.0	166.5	168.7	169.0	162.6	168.5	169.0	165.4	171.4	169.7	165.1	163.8	170.7	167.9
Stature acc. to DEBETS	172.7	165.5	162.0	-	-	164.0	168.7	171.0	-	171.2	-	169.8	170.9	172.9	166.5	-	174.4	169.2
Weight acc. to DEBETS	64.4	62.8	-	-	-	70.8	-	-	-	63.0	-	54.0	-	68.3	64.2	-	62.7	67.6
Q	2.16	2.29	-	-	-	2.64	-	-	-	2.15	-	1.87	-	2.28	2.32	-	2.06	2.36

Table 9 (cont. 1)

MARTIN No.		103 mat	104/2 -	108 mat	113 mat	116 mat	120A ad	121 ad	122 ad	126 mat	129 mat	132 ad	134 ad	136 ad	140 ad	142 ad	156 mat	198/1 ad	208 ad
Humerus	1 L	-	-	334	331	-	-	317	311	334	335	325	-	333	334	-	-	-	-
	R	-	-	337	339	331	-	321	-	337	334	330	-	343	335	320	-	-	-
	2 L	-	-	331	328	321	-	310	305	330	334	318	-	328	327	-	-	-	-
	R	-	-	332	334	323	-	311	-	332	330	324	-	336	329	315	-	-	-
	7 L	61	-	68	64	56	-	55	59	63	55	59	64	58	66	64	-	-	-
	R	-	-	69	67	58	-	59	61	64	56	62	63	58	70	64	-	-	-
	7:1 L	-	-	20.3	19.3	-	-	17.4	19.0	18.7	16.4	18.2	-	17.3	19.8	-	-	-	-
	R	-	-	20.5	19.8	17.7	-	18.2	-	19.0	16.8	18.8	-	16.9	20.9	20.0	-	-	-
Radius	1 L	-	-	-	253	-	-	232	234	-	252	244	-	254	254	245	-	-	-
	R	-	-	-	256	-	224	236	-	-	255	246	-	254	254	244	-	-	242
	1b L	-	-	-	251	-	-	229	232	-	250	243	-	251	252	242	-	-	-
	R	-	-	-	252	-	222	233	-	-	252	244	-	251	253	241	-	-	242
Ulna	L	-	-	-	277	-	-	256	255	-	-	262	-	275	-	-	-	-	-
	R	-	-	274	280	-	251	258	-	-	-	263	-	275	276	259	-	-	267
Femur	1 L	-	-	-	453	424	428	438	428	466	456	436	467	463	463	445	434	442	430
	R	-	-	449	440	423	428	423	424	466	457	430	-	461	461	-	-	-	430
	2 L	-	-	-	452	419	423	436	424	464	455	432	461	458	462	441	-	440	428
	R	-	-	444	441	-	426	421	418	465	456	427	-	457	460	-	-	-	429
	8 L	-	-	-	96	89	81	77	87	-	88	84	94	90	96	86	79	88	93
	R	-	-	-	99	87	81	-	84	-	86	83	-	87	97	-	-	-	93
	8:2 L	-	-	-	21.1	21.2	19.2	17.8	20.5	-	19.3	19.4	20.3	19.7	20.8	19.5	-	20.0	21.7
	R	-	-	-	22.4	-	18.9	-	20.0	-	18.9	19.4	-	19.0	21.0	-	-	-	21.7
Tibia	1 L	-	385	-	369	-	334	354	357	-	370	352	381	376	386	347	-	-	357
	R	-	-	-	-	-	335	357	354	-	374	353	-	-	385	-	-	372	356
	1b L	-	382	-	364	340	333	356	358	-	370	349	376	372	383	343	355	362	360
	R	386	-	-	-	-	333	350	352	-	370	350	-	-	382	-	-	358	356
	10b L	73	74	-	77	68	65	63	75	-	69	70	77	76	82	74	-	75	78
	R	72	-	-	77	68	65	62	74	-	68	68	-	76	79	73	-	75	81
	10b:1b L	-	19.2	-	21.2	-	19.5	17.8	21.0	-	18.5	19.9	20.2	20.2	21.2	21.2	-	-	21.9
	R	18.7	-	-	-	-	19.4	17.2	20.9	-	19.3	19.3	-	-	20.5	-	-	20.2	22.8
Stature acc. to PEARSON		-	170.1	166.9	166.8	161.6	159.9	162.6	161.3	168.6	167.7	164.0	169.4	168.0	168.6	163.7	162.9	165.7	162.5
Stature acc. to DEBETS		-	-	-	168.1	159.8	161.8	164.0	159.2	-	168.6	161.5	-	171.0	169.9	166.7	-	-	161.3
Weight		-	-	-	68.8	56.6	-	49.5	56.2	-	58.5	55.8	-	63.8	72.7	-	-	-	-
Q		-	-	-	2.43	2.22	-	1.84	2.22	-	2.04	2.14	-	2.18	2.52	-	-	-	-

Table 10

Parameters of long bones - Females

MAR-TIN No.		6 ad	10 ad	11 ad	14 ad	19 ad	20 ad	25 ad	26 ad	43 ad	48 mat	50 mat	58 mat	59 mat	60 -	61 -	71 sen	85 ad	87 mat	88B mat
Humerus	1 L	301	-	294	277	-	287	292	-	294	-	251	294	278	289	-	-	293	293	-
	R	301	-	302	281	-	-	-	-	-	-	258	-	-	-	-	-	299	297	-
	2 L	296	-	293	277	-	283	289	-	-	325	250	-	274	-	-	-	-	285	-
	R	296	-	301	280	-	-	-	-	-	-	257	-	-	-	-	-	294	291	-
	7 L	54	-	52	51	58	50	52	-	50	59	46	61	56	55	-	56	52	56	56
	R	56	55	54	52	57	52	53	-	50	61	48	64	56	57	-	57	54	57	57
	7:1 L	17.9	-	17.7	18.2	-	17.4	17.5	-	17.0	-	18.3	20.8	20.0	19.0	-	-	17.8	19.1	-
	R	18.6	-	17.9	18.5	-	-	-	-	-	-	18.6	-	-	-	-	-	17.9	19.0	-
Radius	1 L	-	-	232	206	-	-	-	-	223	-	-	-	-	-	-	-	-	218	226
	R	231	-	237	211	-	-	-	-	226	-	-	-	-	-	-	-	-	-	-
	1b L	-	-	229	203	-	-	-	-	222	-	-	-	-	-	-	-	-	216	242
	R	229	-	235	209	-	-	-	-	224	-	-	-	-	-	-	-	235	219	-
Ulna	L	248	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	R	-	-	255	-	-	-	-	-	-	-	-	-	-	-	-	-	-	241	-
Femur	1 L	412	436	417	380	404	-	412	420	416	-	-	408	-	-	-	415	411	403	418
	R	413	437	414	380	-	-	411	-	418	452	-	404	-	-	443	413	401	402	415
	2 L	412	434	413	376	401	-	410	416	-	-	-	408	-	-	-	410	405	401	414
	R	409	433	410	375	-	-	411	-	413	443	-	404	-	-	411	410	399	401	414
	8 L	83	82	78	76	-	-	75	-	79	-	-	89	-	-	-	83	-	75	80
	R	78	79	75	75	-	-	77	-	77	82	-	85	-	-	76	84	74	73	80
	8:2 L	20.2	18.9	18.9	20.1	-	-	18.3	-	-	-	-	21.7	-	-	-	20.3	-	18.7	19.3
	R	19.1	18.2	18.3	20.0	-	-	18.7	-	18.5	18.5	-	21.0	-	-	18.5	20.5	18.4	18.2	19.3
Tibia	1 L	335	343	339	311	341	-	333	339	336	356	282	-	-	-	-	-	333	322	344
	R	-	343	339	309	-	-	335	-	337	360	-	328	-	-	-	336	331	319	-
	1b L	337	342	341	304	336	-	-	340	337	356	284	322	-	-	-	337	336	323	338
	R	-	343	339	303	-	-	330	-	336	356	-	321	-	-	-	332	332	318	-
	10b L	67	65	68	63	66	66	62	65	59	74	54	70	-	-	-	69	64	66	63
	R	66	68	66	63	66	-	63	66	60	74	53	71	-	-	-	72	64	65	68
	10b: 1b L	20.0	19.0	19.9	20.1	19.4	-	18.6	19.2	17.6	20.8	19.0	-	-	-	-	-	19.2	20.5	18.3
	R	-	19.8	19.5	20.2	-	-	18.8	-	17.7	20.6	-	21.7	-	-	-	21.3	19.2	20.4	-
Stature acc. to PEARSON		154.5	156.8	155.1	148.1	153.1	150.5	152.8	154.6	153.6	160.3	140.8	151.8	148.0	151.0	153.2	153.4	152.0	151.1	155.3
Stature acc. to DEBETS		154.8	161.8	155.0	145.1	152.0	-	154.2	156.8	155.6	165.9	-	152.2	-	-	-	154.6	151.2	151.7	156.0
Weight		53.5	-	51.2	48.1	-	-	50.4	-	50.1	-	-	60.8	-	-	-	-	49.0	50.5	-
Q		2.24	-	2.13	2.29	-	-	2.12	-	2.07	-	-	2.63	-	-	-	-	2.14	2.20	-

Table 10 (cont. 1)

MARTIN No.		95 mat	96 mat	98 mat	104/1 ad	110 mat	114 ad	119A ad	120B ad	124 ad	135 ad	138 ad	143 ad	144 mat	153 ad	161 ad	169 mat	186 -	210 ad	220 mat
Humerus	1 L	-	-	298	-	296	313	276	-	-	301	321	-	-	-	281	-	-	-	-
	R	288	-	-	-	304	320	277	-	267	-	-	-	-	-	287	-	-	-	-
	2 L	-	-	291	-	292	309	273	-	-	296	317	-	-	-	277	-	-	-	-
	R	284	-	-	-	300	312	-	-	263	-	-	-	-	-	284	-	-	-	-
	7 L	51	-	59	55	58	58	47	-	42	55	59	-	64	-	55	-	-	-	-
	R	53	60	60	56	59	60	48	-	47	55	-	58	-	-	56	-	-	-	-
	7:1 L	-	-	19.6	-	19.6	18.5	17.0	-	-	18.6	18.4	-	-	-	19.4	-	-	-	-
	R	18.7	-	-	-	19.4	18.8	17.4	-	17.5	-	-	-	-	-	19.3	-	-	-	-
Radius	1 L	-	-	-	-	220	233	203	234	-	-	-	-	-	-	221	-	-	-	-
	R	216	-	220	-	-	237	-	226	-	231	-	-	-	-	222	-	-	-	-
	1b L	-	-	-	-	217	231	200	231	-	-	-	-	-	-	-	-	-	-	-
	R	214	-	219	-	-	235	-	225	-	231	-	-	-	-	220	-	-	-	-
Ulna	L	-	-	-	-	-	252	226	-	-	-	255	-	-	-	240	-	-	-	-
	R	236	-	-	-	-	254	-	252	-	-	-	-	-	-	-	-	-	-	-
Femur	1 L	394	-	392	-	419	446	392	-	-	-	-	-	439	380	405	404	-	-	419
	R	396	-	391	-	426	440	390	-	-	419	-	-	-	379	410	406	402	-	-
	2 L	390	-	391	-	418	444	387	-	-	-	-	-	434	-	402	400	-	-	415
	R	394	-	390	-	426	441	-	-	-	417	-	-	-	-	406	405	401	-	-
	8 L	-	-	-	-	81	88	72	-	-	-	-	-	85	78	80	80	-	-	78
	R	76	-	79	-	81	87	71	-	-	80	-	-	82	77	82	81	77	-	-
	8:2 L	-	-	-	-	19.4	19.8	18.5	-	-	-	-	-	19.6	-	19.9	20.0	-	-	18.8
	R	19.2	-	20.3	-	19.0	19.6	-	-	-	19.2	-	-	-	-	20.2	20.0	19.2	-	-
Tibia	1 L	323	364	-	337	342	348	-	-	282	347	-	354	-	-	327	-	-	-	-
	R	325	362	-	-	344	350	320	-	-	353	-	-	-	-	332	-	-	322	333
	1b L	-	359	-	335	342	346	-	-	274	349	-	349	-	-	322	-	-	-	-
	R	323	357	-	-	345	347	314	-	-	348	-	-	-	-	326	-	348	318	327
	10b L	62	79	67	66	66	69	59	-	53	68	-	69	72	63	65	-	-	-	-
	R	62	77	67	66	68	69	59	-	-	68	-	-	72	64	65	-	60	63	63
	10b:1b L	19.0	21.7	-	19.6	19.3	19.8	-	-	18.6	19.5	-	19.8	-	-	19.9	-	-	-	-
	R	18.9	21.1	-	-	19.8	19.7	18.4	-	-	19.3	-	-	-	-	19.6	-	-	19.6	18.9
Stature acc. to PEARSON		154.8	159.9	152.5	154.0	155.5	158.9	148.6	156.6	143.0	155.8	159.9	158.0	158.2	146.8	152.4	151.8	151.0	150.5	153.8
Stature acc. to DEBETS		151.5	-	-	-	158.5	162.5	148.0	-	-	156.4	-	-	-	-	153.9	-	-	-	-
Weight		45.1	-	-	-	56.9	61.8	44.7	-	-	54.4	-	-	-	-	54.3	-	-	-	-
Q		1.97	-	-	-	2.26	2.34	2.04	-	-	2.22	-	-	-	-	2.29	-	-	-	-

Table II

Generalized PENROSE-distance of different male and female series from Fészerlak

Series	Males D^2_p	Females D^2_p
1. Fészerlak, 8th c.		
2. Alattyán-Tulát, 7-8th c. (WENGER 1952)	8.78	10.43
3. Ártánd, 8-9th c. (ÉRY 1966)	4.43	7.72
4. Csákberény, 6-7th c. (TÓTH 1962)	3.94	6.84
5. Előszállás-Bajcsihegy, 6-7th c. (WENGER 1966)	9.86	6.64
6. Fehértó-A, 9th c. (LIPTÁK & VÁMOS 1969)	5.67	6.73
7. Homokmégy-Halom, 8-9th c. (LIPTÁK 1957)	6.04	6.66
8. Kecel I, 8th c. (LIPTÁK 1954)	8.56	7.24
9. Keszthely, 7-8th c. (WENGER 1977)	1.65	3.98
10. Kékesd, 8-9th c. (WENGER 1968)	5.69	5.41
11. Környe, 6-7th c. (TÓTH 1971)	3.74	5.18
12. Madaras-Téglavető, late Avars (LIPTÁK & MARCSIK 1976)	13.04	12.54
13. Solymár, 7-8th c. (FERENCZ 1983)	2.42	1.76
14. Szebény, 8th c. (TÓTH 1961)	3.96	10.45
15. Szeged-Kundomb, medium Avars (LIPTÁK et MARCSIK 1966)	6.28	6.71
16. Szekszárd-Palánk, early Avars (LIPTÁK 1974)	4.95	6.84
17. Szentes-Kaján, 7-8th c. (WENGER 1955)	7.25	11.97
18. Tiszavasvári, early Avars (WENGER 1972)	10.08	11.90
19. Toponár, 8th c. (WENGER 1974b)	2.24	3.56
20. Üllő I, 8th c. (LIPTÁK 1955)	8.45	9.82
21. Üllő II, 8th c. (LIPTÁK 1955)	7.87	5.68
22. Váchartyán, 7-8th c. (BÁTAI 1952)	7.62	9.21
23. Vác-Kavicsbánya, 7-8th c. (FERENCZ 1981)	1.77	2.64

Fig. 2 Geographical location of the series

Explanation of plates: Plate 1: Grave 119

Plate 2: Grave 120

Plate 1

Plate 2

ANTHROPOLOGIA HUNGARICA

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Anthropological studies on an early Avar period population at Bačko Petrovo Selo (Yugoslavia). Part 1: Individual metric data

By

K. ÉRY

(Received April 26, 1988)

Abstract: Present study gives the individual metric data of the bone remains of an Avar period population from the turn of the 6th/7th centuries. With 4 tables.

MATERIAL AND METHODS

The Archaeological Department of the University of Beograd has totally unearthed, under Prof. Jovan KOVAČEVIC's leadership, a cemetery from the early Avar period at Bačko Petrovo Selo (Péterréve, Vojvodina), on the banks of Csík-ér. From the 137 graves the bone remains of 100 individuals could be preserved. The archaeological and anthropological finds of the cemetery were deposited in the collection of the Municipal Museum and Gallery of Bečej.

The examination of the anthropological finds were carried out, upon the request of J. KOVAČEVIĆ in Bečej between 1971 and 1973, while a manuscript in English language was handed in Beograd, in the spring of 1975. According to the original plans the data of the cemetery would be published in an independent volume, where the archaeological part would be written by J. KOVAČEVIĆ, the anthropological part by K. ÉRY, the serological analysis of the human bone remains by I. LENGYEL, the zoological remains by S. BÖKÖNYI.

The Hungarian authors have handed in their studies in time, still the monograph has not been published, and we have no information even about its being prepared. The 13 years that have passed since that time, I think, provide enough justification to publish the anthropological results in the Anthropologia Hungarica.

Another justification for this publication is the fact that the early Avar period population of the Carpathian Basin is yet poorly known. The cemetery on the Lower Tisza at Bačko Petrovo Selo was started, according to J. KOVAČEVIĆ's archaeological dating, at around 568, and as attested by the laboratory analyses carried out by I. LENGYEL it was used for 80 ± 20 years.

The first part of the study contains the individual cranial and post-cranial bone measurements of the adults. The second part will give the evaluation of the data in the next volume of the Anthropologia Hungarica.

The bones were measured according to the manual of MARTIN & SALLER (1957). The cranial capacity was calculated by using the porion-bregma height. Stature was calculated according to PEARSON (1899) and that of BREITINGER (1938) and BACH (1965).

Acknowledgement. I wish to offer my sincere thanks to Prof. J. KOVAČEVIC for asking me to study this osteological material, as well as for the information received in the course of the study. My grateful thanks are also due to Mrs. L. BUKINAC, Director of the Municipal Museum and Gallery of Bečej and her staff members for the aid ensuring untroubled work. I express my hearty thanks to I. LENGYEL, M.D., for allowing me to utilize his laboratory test results and for his valuable advice.

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Table 1 Individual male cranial measurements (20-x years)

Grave No. / MARTIN No.	8	10	16	34	37	44	49	51	54	57	68/a	69
1	188	179	175	184	180	196	(174)	195	201	192	180	185
5	108	-	109	-	101	111	107	101	(107)	(111)	98	101
8	148	144	151	135	140	154	-	151	-	156	149	134
9	100	96	100	96	93	106	98	109	106	109	95	97
10	120	118	126	114	117	124	-	127	(118)	128	120	112
12	117	-	124	-	116	127	-	114	-	124	113	114
17	130	-	144	-	136	131	-	131	(131)	(133)	128	134
20	113	115	119	112	116	120	-	114	-	117	112	113
23	541	-	525	515	516	566	-	557	-	557	526	521
25	372	-	360	365	366	372	-	382	-	-	361	370
26	131	129	124	117	119	122	-	131	124	138	126	120
27	128	121	134	129	129	132	-	125	140	133	118	129
28	113	-	102	119	118	118	108	126	-	-	117	121
29	115	117	114	104	106	110	-	115	110	122	112	107
30	113	107	117	117	115	123	-	117	129	118	110	116
31	93	-	91	95	95	94	108	100	-	-	91	98
38	1507	1441	1507	1375	1426	1681	-	1585	-	1638	1456	1382
40	104	-	105	-	95	108	101	103	(106)	-	96	100
43	108	106	112	106	103	113	-	117	-	119	105	105
45	138	(131)	146	131	132	147	141	142	-	(151)	134	132
46	100	90	99	92	95	106	100	96	-	-	95	107
47	-	-	112	120	114	127	-	(121)	(117)	(115)	121	116
48	71	(60)	67	70	66	74	68	71	(67)	65	69	70
51	44	39	43	43	43	48	48	46	(45)	46	43	42
52	32	32	35	31	31	37	35	32	(31)	32	29	33
54	27	26	26	24	25	26	25	27	29	29	24	27
55	56	46	54	52	50	57	54	53	50	51	50	50
60	57	54	60	53	54	56	56	61	-	-	59	59
61	66	66	65	65	64	67	67	63	66	67	62	66
62	48	50	53	49	47	53	51	53	-	-	47	52
63	42	46	47	44	43	44	47	41	42	42	42	42
65	-	118	126	114	124	-	-	115	-	-	118	123
66	-	98	117	105?	101	-	-	96	-	-	102	100
68/1	-	109	112	109	101	120	-	107	115	(101)	111	106
69	33	29	32	34	29	32	-	32	33	-	31	30
72	88	(87)	80	84	85	92	-	81	-	-	84	82
75/1	30	(30)	33	31	40	23	-	31	-	-	30	30
79	119	124	117	128	115	126	-	116	126	124	125	120
8:1	78.1	80.5	86.3	73.4	77.8	78.6	-	77.4	-	81.3	82.8	72.4
17:1	70.7	-	82.3	-	75.6	66.8	-	66.5	-	(69.3)	71.1	72.4
17:8	87.8	-	95.4	-	97.1	85.1	-	86.8	-	(85.3)	85.9	100.0
20:1	60.1	64.3	68.0	60.8	64.4	61.2	-	58.5	-	60.9	62.2	61.1
20:8	76.4	79.9	78.8	83.0	82.9	77.9	-	75.5	-	75.0	75.2	84.3
9:8	67.6	66.7	66.2	71.1	66.4	68.8	-	71.7	-	69.9	63.8	72.4
47:45	-	-	76.7	91.6	86.4	86.4	-	85.2	-	(76.2)	90.3	87.9
48:45	51.4	(45.8)	45.9	53.4	50.0	50.3	48.2	50.0	-	(43.0)	51.5	53.0
52:51	72.7	82.1	81.4	72.1	72.1	77.1	72.9	69.6	(68.9)	69.6	67.4	78.6
54:55	48.2	56.5	48.2	46.2	50.0	45.6	46.3	50.9	58.0	56.9	48.0	54.0
61:60	115.8	122.2	108.3	122.6	118.5	119.6	119.6	103.3	-	-	105.1	111.9
63:62	87.5	92.0	88.7	89.8	91.5	83.0	92.2	77.4	-	-	89.4	80.8

Table 1 (cont.1)

MARTIN No. \ Grave No.	71	74	78	79	82	88	98	103	107	126	Juv. 84	Path. 115
1	194	-	191	182	192	(189)	(177)	190	-	189	189	176
5	102	-	97	98	107	-	-	(114)	-	-	105	103
8	141	-	144	138	135	-	(161)	143	-	136	135	149
9	99	100	97	101	91	96	107	100	-	98	97	98
10	123	-	123	121	120	119	130	123	-	118	116	121
12	118	-	109	107	107	-	-	-	-	109	115	113
17	140	-	135	122	132	-	-	(140)	-	-	135	130
20	118	-	113	110	113	-	-	109	-	112	-	115
23	543	-	539	517	530	-	(545)	544	-	(531)	528	520
25	398	-	388	360	378	-	(368)	-	-	-	364	354
26	133	-	136	121	129	127	122	138	-	121	119	124
27	141	-	133	122	122	120	135	130	-	139	130	126
28	124	-	119	117	127	-	(111)	-	-	-	115	104
29	114	-	119	106	111	111	108	119	-	106	107	107
30	127	-	120	110	113	110	117	118	-	122	119	109
31	104	-	99	93	99	-	(91)	-	-	-	92	91
38	1537	-	1494	1369	1428	-	-	1440	-	1410	-	1460
40	99	-	92	91	108	-	-	(108)	-	-	97	98
43	105	(112)	106	107	104	103	115	107	104	108	107	106
45	129	-	131	135	132	-	(143)	138	-	-	-	135
46	94	-	98	94	95	92	93	102	93	-	-	95
47	129	-	111	119	128	-	-	(122)	-	(108)	117	118
48	73	-	65	68	75	(66)	66	71	(64)	63	68	69
51	44	-	45	43	43	(41)	47	44	42R	43	43	44
52	35	-	35	35	33	(35)	36	33	31R	29	35	31
54	27	-	24	26	28	24	26	27	27	-	23	26
55	56	-	51	52	54	(48)	50	55	(52)	46	48	53
60	-	-	53	-	63	51	-	-	58	-	54	54
61	-	-	65	-	66	57	-	-	66	-	61	62
62	47	-	48	-	55	45	-	-	49	-	49	48
63	41	-	45	-	42	38	-	-	44	-	39	39
65	117	-	122	-	117	121	125	119	-	128	-	122
66	105	-	115	101	102	100	106	109	-	103	-	96
68/1	118	-	118	98	116	107	114	120	120	106	106	98
69	31	-	27	28	33	29	29	31	29	27	31	36
72	81	-	83	90	83	-	-	81	-	-	-	88
75/1	20	-	31	-	31	-	-	32	-	-	-	33
79	127	-	121	121	127	125	135	133	126	132	130	126
8:1	72.7	-	75.4	75.8	70.3	-	(90.9)	75.3	-	72.0	71.4	84.7
17:1	72.2	-	70.7	67.0	68.8	-	-	(73.7)	-	-	71.4	73.9
17:8	99.3	-	93.8	88.4	97.8	-	-	(97.9)	-	-	100.0	87.3
20:1	60.8	-	59.2	60.4	58.9	-	-	57.4	-	59.3	-	65.3
20:8	83.7	-	78.5	79.7	83.7	-	-	76.2	-	82.4	-	77.2
9:8	70.2	-	67.4	73.2	67.4	-	(66.5)	69.9	-	72.1	71.9	65.8
47:45	100.0	-	84.7	88.2	97.0	-	-	(88.4)	-	-	-	87.4
48:45	56.6	-	49.6	50.4	56.8	-	-	52.6	-	-	-	51.1
52:51	79.6	-	77.8	81.4	76.7	(85.4)	76.6	75.0	73.8R	67.4	81.4	70.5
54:55	48.2	-	47.1	50.0	51.9	(50.0)	52.0	49.1	(51.9)	-	47.9	49.1
61:60	-	-	122.6	-	104.8	111.8	-	-	113.8	-	113.0	114.8
63:62	87.2	-	93.8	-	77.8	84.4	-	-	89.8	-	79.6	81.3

Table 2 Individual female cranial measurements (20 - x years)

Grave No. / MARTIN No.	43	45	46/a	47	50	59	62	64	72	77	81	86	90	92	94	96	97
1	181	-	173	-	-	176	-	176	184	-	178	(159)	173	174	181	(169)	-
5	-	-	107	-	-	106	-	100	(102)	-	95	-	102	95	101	-	-
8	132	-	129	-	-	141	-	142	133	-	143	(149)	138	137	143	-	-
9	92	-	94	91	94	103	-	91	88	92	100	(91)	97	94	101	-	-
10	-	-	111	-	-	119	-	121	(111)	-	123	-	118	114	118	(131)	-
12	110	-	107	-	-	117	-	118	108	-	112	(111)	113	113	111	-	-
17	-	-	130	-	-	132	-	127	(123)	-	125	-	126	125	122	-	-
20	-	-	102	-	-	111	-	108	109	-	111	(112)	106	106	111	-	-
23	-	-	486	-	-	508	-	510	510	-	521	-	499	497	525	-	-
25	385	-	336	-	-	347	-	350	367	-	369	331	342	344	352	-	-
26	130	122	116	117	130	122	-	122	123	(122)	126	(118)	115	118	125	124	130
27	140	-	109	-	-	114	121	128	126	115	130	(108)	114	118	112	(132)	133
28	115	-	111	-	-	111	-	100	118	-	113	(105)	113	108	115	-	-
29	114	107	104	102	113	109	-	104	111	-	111	(103)	104	105	111	108	115
30	121	111	98	-	-	104	108	112	111	-	118	(97)	104	108	101	108	124
31	99	-	95	-	-	95	-	85	96	-	93	(89)	94	85	95	-	-
38	-	-	1150	-	-	1329	-	1309	1297	-	1356	(1291)	1245	1244	1374	-	-
40	-	-	103	-	-	-	-	(96)	(101)	-	96	-	99	92	-	-	-
43	99	96	101	98	99	107	-	100	99	105	110	101	108	99	110	-	-
45	-	-	120	-	-	(129)	-	135	(118)	-	129	(125)	130	118	-	-	-
46	-	81	91	88	-	-	-	93	87	94	101	91	95	90	91	-	-
47	-	-	106	107	(121)	(110)	-	99	108	-	107	117	106	110	(116)	-	-
48	-	63	61	65	70	-	-	55	63	-	64	67	64	65	(69)	-	-
51	-	43	42	40	41	43	-	43	(42)	-	44	41	44	40	46R	-	-
52	-	34	30	32	33	-	-	32	(32)	-	32	33	34	34	(36)R	-	-
54	(22)	19	25	26	26	-	-	25	27	-	27	25	24	25	-	-	-
55	-	44	46	46	48	52	-	42	50	-	49	51	48	50	(54)	-	-
60	56	50	58	47	-	-	-	47	-	51	56	48	56	51	54	-	-
61	60	57	59	57	-	(65)	-	61	-	59	-	59	64	63	55	-	-
62	48	42	51	-	-	-	-	44	-	-	49	43	49	45	45	-	-
63	37	39	38	35	-	(42)	-	39	-	39	-	40	41	41	31	-	-
65	-	-	110	-	-	123	-	118	108	116	115	-	123	-	118	128	-
66	-	-	89	-	-	94	-	105	88	87	94	-	97	-	82	105	-
68/1	-	-	105	-	96	105	-	100	99	96	103	(97)	100	104	99	101	-
69	-	-	27	29	33	28	26	23	28	27	24	30	26	28	30	-	23
72	-	-	82	-	-	-	-	85	86	-	84	(91)	83	82	-	-	-
75/1	-	-	24	-	-	-	-	26	27	-	27	(26)	29	26	-	-	-
79	-	-	127	135	132	125	-	125	126	113	121	(130)	121	130	121	140	-
8:1	72.9	-	74.6	-	-	80.1	-	80.7	72.3	-	80.3	(93.7)	79.8	77.0	79.0	-	-
17:1	-	-	75.1	-	-	75.0	-	71.8	(66.9)	-	70.2	-	72.8	71.8	67.4	-	-
17:8	-	-	100.8	-	-	93.6	-	89.4	(92.5)	-	87.4	-	91.3	91.2	85.3	-	-
20:1	-	-	59.0	-	-	63.1	-	61.0	59.2	-	62.4	(70.4)	61.3	60.9	61.3	-	-
20:8	-	-	79.1	-	-	78.7	-	76.1	82.0	-	77.6	(75.2)	76.8	77.4	77.6	-	-
9:8	69.7	-	72.9	-	-	73.1	-	64.1	65.4	-	69.9	(61.1)	70.3	68.6	70.6	-	-
47:45	-	-	88.3	-	-	(85.3)	-	73.3	(91.5)	-	83.0	(93.6)	81.5	93.2	-	-	-
48:45	-	-	50.8	-	-	-	-	40.7	(53.4)	-	49.6	(53.6)	49.2	55.1	-	-	-
52:51	-	79.1	71.4	80.0	80.5	-	-	74.4	(76.2)	-	72.7	80.5	77.3	85.0	(78.3)R	-	-
54:55	-	43.2	54.4	56.5	54.2	-	-	59.5	54.0	-	55.1	49.0	50.0	48.0	-	-	-
61:60	107.1	114.0	191.7	121.3	-	-	-	129.8	-	115.7	-	122.9	114.3	123.5	101.9	-	-
63:62	77.1	92.9	74.5	-	-	-	-	88.6	-	-	-	93.0	83.7	91.1	68.9	-	-

Table 2 (cont. 1)

Grave No. / MARTIN No.	99	100	108	112	118	119	121	129	133	134	Sporadic find	Juvenile		Senilis (atrophised)			Path.
												55	93	60	78	119	120
1	184	-	-	178	177	178	175	172	(160)	165	176	177	-	186	-	188	164
5	98	103	-	-	(94)	(96)	101	94	96	98	98	-	98	101	-	100	90
8	136	140	-	134	148	137	142	130	-	144	141	137	-	(129)	-	(134)	140
9	98	91	93	92	94	96	94	88	98	93	93	93	91	93	-	97	95
10	112	115	120	119	124	114	119	108	-	112	122	112	108	(114)	(112)	112	122
12	108	-	-	107	-	-	-	100	107	109	111	112	-	107	-	114	107
17	126	131	-	-	(127)	125	(130)	120	-	123	135	-	131	132	(143)	135	123
20	108	111	-	113	108	108	113	105	-	103	112	103	111	111	-	114	106
23	515	-	-	510	523	508	(509)	484	-	493	511	497	499	(513)	-	520	492
25	370	-	-	-	358	353	-	357	-	-	364	-	-	372	369	378	344
26	128	130	127	131	124	123	122	116	-	107	133	119	126	114	124	129	122
27	125	-	124	120	124	117	136	121	-	106	122	116	-	135	130	130	123
28	117	-	-	-	110	113	-	120	-	-	109	-	-	123	115	119	99
29	111	116	111	112	111	108	107	104	-	97	114	106	113	101	112	113	106
30	113	-	108	109	113	107	118	111	-	95	106	104	-	121	120	119	110
31	92	-	-	-	87	95	-	100	-	-	94	-	-	104	94	98	87
38	1310	-	-	1307	1357	1284	1349	1177	-	1214	1339	1233	-	(1295)	-	1373	1209
40	90	95	-	-	-	-	99	86	91	87	96	-	93	93	-	-	90
43	102	101	100	106	105	102	103	95	107	105	103	97	98	100	-	108	104
45	131	(131)	-	-	-	(126)	(124)	116	-	-	139	-	121	124	-	130	124
46	90	95	90	90	95	90	91	85	103	92	84	90	88	87	-	91	101
47	-	113	108	102	(116)	-	(107)	106	-	107	110	(99)	-	-	-	-	116
48	65	66	61	59	(69)	(59)	(60)	61	65	64	63	58	66	65	-	-	67
51	40	43	40	43	(41)	42	41	38	45	41	41	(41)	42	39	-	44	41
52	33	31	33	30	(34)	-	29	32	33	33	33	(31)	33	33	-	33	33
54	24	26	26	27	-	21	25	23	27	23	26	23	21	25	-	29	23
55	50	51	47	46	(50)	(48)	46	46	52	47	51	46	49	49	-	47	46
60	-	50	49	59	52	53	54	50	52	47	54	-	57	-	-	-	53
61	-	60	57	(63)	63	60	58	-	65	61	65	-	59	-	-	-	66
62	-	46	-	48	-	-	48	43	-	-	49	-	46	-	-	-	46
63	-	38	40	41	40	39	36	-	46	41	43	-	35	-	-	-	39
65	114	126	121	122	129	-	121	105	-	113	128	110	-	119	125	122	-
66	90	94	-	92	107	96	90	83	-	-	101	96	-	93	93	91	99
68/1	97	109	101	98	106	104	96	99	-	96	116	99	-	101	109	111	100
69	-	27	24	26	30	27	-	27	-	27	28	25	-	30	25	28	30
72	91	87	-	85	-	-	86	84	-	90	81	-	86	86	-	-	82
75/1	34	26	-	22	-	-	-	31	-	(27)	-	-	34	24	-	-	16
79	120	135	126	116	134	126	126	121	-	123	124	125	-	121	138	121	128
8:1	73.9	-	-	75.3	83.6	77.0	81.1	75.6	-	87.3	80.1	77.4	-	(69.4)	-	(71.3)	85.5
17:1	68.5	-	-	-	-	70.2	(74.3)	69.8	-	74.6	76.7	-	-	71.0	-	71.8	74.1
17:8	92.7	93.6	-	-	-	91.2	(91.6)	92.3	-	85.4	95.7	-	-	(102.3)	-	100.8)	86.6
20:1	58.7	-	-	63.5	60.3	60.7	64.6	61.1	-	62.4	63.6	58.2	-	59.7	-	60.6	63.9
20:8	79.4	79.3	-	84.3	73.0	-78.8	79.6	80.8	-	71.5	79.4	75.2	-	(86.1)	-	(85.1)	74.7
9:8	72.1	65.0	-	68.7	63.5	68.6	66.2	67.7	-	64.6	66.0	67.9	-	(72.1)	-	(72.4)	66.9
47:45	-	(86.3)	-	-	-	-	(86.3)	91.4	-	-	79.1	-	-	-	-	-	92.8
48:45	49.6	(50.8)	-	-	-	(46.8)	(48.4)	52.6	-	-	45.3	-	54.6	52.4	-	-	53.6
52:51	82.5	72.1	82.5	69.8	-	-	70.7	84.2	73.3	80.5	80.5	(75.6)	78.6	84.6	-	75.0	80.5
54:55	48.0	51.1	55.3	58.7	-	(43.8)	54.4	50.0	51.9	48.9	51.0	50.0	42.9	49.0	-	61.7	50.0
61:60	-	120.0	116.3	(106.8)	121.2	113.2	107.4	-	-	129.8	120.4	-	103.5	-	-	-	124.5
63:62	-	82.6	-	85.4	-	-	75.0	-	-	-	87.8	-	76.1	-	-	-	84.8

Table 3

Individual male post-cranial measurements (20 - x years)

MARTIN No.	Grave No.		37	44	49	51	54	57	68/a	69	71	74	78	79	82	88	98	103	107	115	123	126	128
Clavicula	1	R	148	158	-	145	-	-	155	146	140	152	144	145	152	150	150	150	156	154	-	-	-
		L	150	-	-	152	-	163	151	149	153	155	153	-	165	153	147	149	-	157	-	-	-
	6	R	37	42	-	39	40	48	41	40	37	45	38	37	38	37	42	44	40	39	-	37	37
		L	35	-	-	39	-	48	41	42	36	43	37	38	41	35	45	44	-	37	-	-	40
Humerus	1	R	301	-	-	309	323	-	338	309	343	309	319	-	332	355	331	353	352	300	-	317	-
		L	299	-	-	306	331	347	334	307	339	304	312	-	328	343	321	353	345	299	-	-	-
	2	R	300	-	344	304	323	-	331	308	343	309	313	317	324	346	325	342	344	294	-	313	-
		L	296	-	-	303	330	342	326	306	337	301	-	-	321	336	314	352	337	293	-	-	-
	4	R	60	-	-	64	65	69	61	65	69	70	-	62	73	71	69	67	69	59	-	-	-
		L	59	-	64	63	-	68	59	65	68	70	-	62	71	68	-	67	71	57	-	-	-
	7	R	73	-	68	74	77	72	72	70	67	78	71	68	66	71	70	69	72	63	-	67	-
		L	70	68	67	72	75	71	68	66	68	75	69	68	65	68	70	67	70	60	-	63	-
	10	R	48	-	48	50	50	-	48	50	52	55	-	47	51	53	49	53	53	46	-	48	-
		L	49	50	-	48	50	48	48	49	52	52	-	-	49	51	48	52	51	46	-	-	-
Radius	1	R	225	-	262	234	251	254	260	239	255	224	-	233	255	258	245	260	-	230	-	252	-
		L	225	252	-	234	249	255	261	-	252	223	(220)	-	253	254	247	261	-	227	-	250	-
Ulna	1	R	249	-	-	254	282	274	279	-	276	251	-	-	279	277	270	-	-	248	-	-	-
		L	245	-	-	261	-	276	282	253	274	253	-	250	-	275	-	285	-	-	-	271	-
Femur	1	R	399	442	-	431	460	474	466	423	472	431	436	447	462	471	450	-	-	407	-	-	466
		L	393	448	-	436	455	480	468	-	468	-	436	-	465	474	455	-	-	404	-	-	469
	2	R	396	438	-	428	457	469	463	418	460	429	432	444	460	468	445	-	-	403	-	-	463
		L	393	445	-	431	450	474	463	-	458	-	-	-	464	472	450	-	-	402	-	-	466
	6	R	28	29	28	30	36	31	30	30	32	32	32	29	36	34	31	32	33	25	-	26	28
		L	28	29	30	30	35	31	30	32	31	32	34	29	36	33	31	32	-	25	-	26	28
	7	R	31	30	32	28	32	31	30	29	30	31	30	30	29	31	27	29	33	25	-	30	28
		L	31	32	31	28	31	30	30	29	30	31	30	29	29	32	29	30	-	26	-	31	28
	9	R	34	37	36	33	37	34	34	35	35	36	33	32	34	36	31	33	38	31	-	-	35
		L	35	36	38	33	36	37	35	-	36	36	35	34	35	36	32	34	-	33	-	-	35
	10	R	27	29	26	26	32	29	28	26	27	29	29	30	29	30	29	29	28	22	-	-	26
		L	27	28	26	28	30	26	28	-	28	30	31	28	29	28	30	28	-	24	-	-	27
	19	R	46	50	-	48	-	51	50	48	52	54	48	47	52	53	47	55	52	44	-	-	50
		L	46	50	-	47	50	50	-	-	52	55	47	-	52	53	47	-	-	43	-	-	49
	21	R	79	81	84	85	80	83	82	81	88	82	81	-	85	87	89	-	-	78	-	-	82
		L	77	82	81	84	79	83	82	81	88	82	81	81	83	88	88	89	-	79	-	-	82

Table 3 (cont. 1)

MARTIN No. \ Grave No.			37	44	49	51	54	57	60/a	69	71	74	78	79	82	88	98	103	107	115	123	126	128
Tibia	1	R	325	-	-	343	370	369	386	345	381	343	353	364	372	378	355	388	-	333	361	-	374
		L	320	367	-	342	-	372	385	343	378	338	353	369	375	380	355	388	-	335	363	-	377
	1/b	R	321	-	-	341	366	368	382	336	380	340	354	365	372	377	358	390	-	332	358	-	373
		L	317	364	-	341	-	371	380	341	378	339	356	368	378	380	356	388	383	333	359	-	373
	3	R	77	-	78	78	79	79	77	77	81	79	74	76	79	84	79	-	-	73	82	-	79
		L	76	78	79	76	78	79	75	76	80	76	-	75	78	83	79	86	-	73	-	-	79
	8/a	R	34	-	37	33	38	37	36	33	37	36	34	34	35	35	33	36	34	30	34	37	32
		L	32	33	38	33	-	38	37	32	36	34	35	34	38	36	34	34	34	33	33	35	32
	9/a	R	26	-	26	28	27	23	28	26	28	26	28	30	25	27	30	29	32	23	28	25	26
		L	27	26	28	25	-	25	27	27	27	25	27	26	24	32	30	29	33	26	29	27	30
Fibula	1	R	313	-	-	341	-	-	378	343	367	329	-	-	361	378	350	374	-	334	-	-	370
		L	312	-	363	341	364	366	372	-	362	332	340	-	-	381	352	-	-	336	-	-	-
Sacrum	2	R	(103)	-	-	-	-	108	115	-	93	113	-	(101)	96	-	107	-	-	(108)	-	-	-
	5	L	103	125	125	112	131	121	114	-	123	115	119	112	-	-	116	-	-	107	-	-	120
Pelvis, ischium		R	96	-	-	-	-	-	110	-	104	108	102	-	110	106	104	109	-	95	-	-	-
length		L	91	99	-	-	102	101	107	-	102	99	-	-	108	102	100	-	-	88	-	-	-
pubis		R	93	-	-	-	-	-	109	-	106	110	102	-	110	106	104	107	-	95	-	-	-
length		L	90	96	-	-	101	103	102	-	102	107	-	-	106	98	100	-	-	88	-	-	-
I:P index		R	96.9	-	-	-	-	-	99.1	-	101.9	101.9	100.0	-	100.0	100.0	100.0	101.9	-	100.0	-	-	-
		L	98.9	97.0	-	-	99.0	98.1	95.3	-	100.0	108.1	-	-	98.2	96.1	100.0	-	-	100.0	-	-	-
cotylum		R	38	42	-	42	39	45	38	44	37	39	37	40	39	38	41	40	-	35	-	-	41
breadth		L	35	42	-	42	43	43	38	-	39	39	35	40	38	-	-	-	-	37	-	-	41,
inc. isc.		R	29	-	-	22	22	38	31	34	30	27	-	30	38	38	37	30	-	34	-	-	34
breadth		L	30	44	-	23	22	46	40	-	35	27	28	33	38	-	-	-	-	37	-	-	33
C:I index		R	131.0	-	-	190.9	177.3	118.4	122.6	129.4	123.3	144.4	-	133.3	102.6	100.0	110.8	133.3	-	102.9	-	-	120.6
		L	116.7	95.5	-	182.6	195.4	93.5	95.0	-	111.4	144.4	125.0	121.2	100.0	-	-	-	-	100.0	-	-	124.2
Clav.-Humeral index		R	49.3	-	-	47.7	-	-	46.8	47.4	40.8	49.2	48.0	45.7	50.0	43.4	46.2	43.9	45.3	52.4	-	-	-
		L	50.7	-	-	50.2	-	47.7	46.3	48.7	45.4	51.5	-	-	51.4	45.5	46.8	42.3	-	53.6	-	-	-
Radio-Humeral index		R	75.0	-	76.2	77.0	77.7	-	78.5	77.6	74.3	72.5	-	73.5	78.7	74.6	75.4	76.0	-	78.2	-	-	-
		L	76.0	-	-	77.2	75.5	74.6	80.1	-	74.8	74.1	-	-	78.8	75.6	78.7	74.1	-	77.5	-	-	-
Tibio-Femoral index		R	81.1	-	-	79.7	80.1	78.5	82.5	80.4	82.6	79.3	81.9	82.2	80.9	80.6	80.4	-	-	82.4	-	-	-
		L	80.7	81.8	-	78.9	-	78.3	82.1	-	82.5	-	-	-	81.5	80.5	79.1	-	-	82.8	-	-	-
Stature (acc. to PEARSON)			156.8	166.3	172.0	161.2	166.7	169.4	170.2	161.5	169.0	160.2	163.0	164.0	168.2	170.5	165.0	171.7	171.0	158.0	165.0	-	168.5
Stature (acc. to BREITINGER)			161.2	169.3	177.0	165.0	170.0	171.8	173.0	165.2	172.1	164.0	166.9	168.3	171.0	173.0	168.5	174.7	173.5	163.0	168.0	-	170.5

Table 4

Individual female post-cranial measurements (20 - x years)

MARTIN No. \ Grave No.		43	45	46/a	47	59	60	62	64	65	72	76	77	81	86	90	92
Clavicula	1 R	-	-	128	125	-	133	-	134	-	133	147	145	138	-	143	-
	L	-	-	129	-	142	135	-	139	132	136	151	-	-	-	142	-
	6 R	-	-	30	36	33	35	-	32	-	33	35	34	31	-	32	-
	L	-	-	29	37	33	37	-	32	30	34	34	-	-	-	31	-
Humerus	1 R	288	-	308	285	331	-	-	306	290	311	316	300	286	288	296	-
	L	-	-	304	274	323	299	-	303	283	303	315	-	287	-	286	-
	2 R	285	-	303	280	330	-	-	301	289	308	312	296	282	284	292	-
	L	-	-	299	268	317	298	-	298	282	300	311	-	284	-	281	300
	4 R	57	-	60	53	58	59	-	60	53	59	-	-	59	52	53	-
	L	-	-	59	53	58	59	-	61	51	59	-	-	59	-	54	-
	7 R	59	-	59	56	64	60	59	58	56	61	60	57	61	54	55	-
	L	-	-	58	55	62	60	-	57	55	59	59	-	60	53	52	-
	10 R	43	-	42	39	46	43	42	42	41	43	41	-	42	40	41	-
	L	-	-	42	40	44	43	-	42	40	43	42	-	41	-	39	-
Radius	1 R	211	-	237	-	237	-	243	234	217	231	-	209	-	218	-	-
	L	203	-	235	-	-	216	-	-	216	229	231	-	208	-	218	-
Ulna	1 R	-	-	259	-	258	236	-	252	235	244	249	-	-	236	243	-
	L	-	-	-	-	-	238	-	250	235	243	252	-	227	-	238	-
Femur	1 R	-	-	434	395	441	406	419	407	383	412	424	407	395	395	413	-
	L	384	-	430	394	440	-	-	410	385	409	422	-	401	398	416	439
	2 R	-	-	430	393	438	403	417	404	379	411	421	404	391	390	409	-
	L	383	-	425	392	438	-	-	407	382	407	419	-	398	392	414	434
	6 R	27	-	27	26	29	28	30	24	24	27	27	23	27	23	24	-
	L	26	-	25	26	27	-	30	24	23	26	27	23	27	23	24	26
	7 R	27	-	26	25	30	25	26	28	24	29	28	25	28	26	27	-
	L	27	-	25	26	30	-	26	30	24	29	28	25	28	25	27	26
	9 R	31	-	32	28	33	31	35	35	28	33	34	30	33	31	32	-
	L	32	-	33	30	34	32	-	33	29	35	35	31	33	32	32	-
	10 R	26	-	26	25	27	24	29	23	24	24	26	23	25	21	24	-
	L	25	-	24	24	26	25	-	23	24	22	26	22	25	21	23	-
	19 R	42	38	43	40	45	42	42	45	39	44	44	44	43	40	42	46
	L	42	-	44	40	45	43	-	45	39	45	45	42	43	-	42	46
	21 R	-	64	73	70	80	73	-	77	71	73	77	68	73	73	76	-
	L	73	-	72	70	78	-	-	76	69	73	77	-	74	73	75	-

Table 4 (cont. 1)

MARTIN No.		Grave No. 94	96	97	99	100	108	110	112	118	119	120	127	129	132	133	134
Clavicula	1 R	-	125	139	138	143	-	146	-	141	133	128	-	139	-	-	136
	L	-	125	142	146	145	-	153	149	-	-	134	137	139	-	-	-
	6 R	33	34	30	39	30	33	34	26	29	34	35	34	35	-	-	32
	L	34	33	29	41	30	35	35	36	-	-	34	36	31	-	-	32
Humerus	1 R	-	288	-	-	301	291	325	307	304	319	294	293	280	-	-	286
	L	-	-	287	282	308	-	321	306	301	-	283	290	279	-	296	-
	2 R	-	284	-	-	297	-	322	304	298	316	287	290	276	-	-	280
	L	-	-	282	277	303	-	316	302	294	-	276	288	276	-	294	-
	4 R	-	51	54	57	57	-	62	-	55	60	50	57	53	58	-	50
	L	-	49	-	57	57	-	63	58	55	60	51	-	53	-	-	-
	7 R	60	58	52	62	60	60	69	59	55	59	54	60	54	58	-	51
	L	58	55	50	62	59	59	68	58	55	57	53	58	54	58	57	-
	10 R	-	41	-	-	39	40	47	40	39	40	40	40	41	-	-	-
	L	-	-	38	44	40	-	44	-	39	-	39	-	41	-	39	-
Radius	1 R	-	-	224	209	232	219	245	223	-	236	212	224	218	-	231	219
	L	-	212	222	205	236	217	243	225	218	233	206	-	215	-	-	-
Ulna	1 R	-	-	-	231	252	-	269	243	-	-	233	238	236	-	242	237
	L	-	-	-	-	-	-	264	244	-	-	-	-	232	-	-	-
Femur	1 R	-	390	-	390	416	411	428	423	-	424	-	406	394	411	414	408
	L	-	393	393	-	420	415	429	425	-	430	370	407	394	-	418	411
	2 R	-	388	-	387	413	405	425	420	-	423	-	401	390	-	410	405
	L	-	389	392	-	415	409	424	422	-	427	370	-	392	-	413	408
	6 R	27	25	24	26	28	27	29	25	25	25	-	23	23	25	26	25
	L	27	25	25	-	27	27	28	26	-	25	26	24	23	-	28	24
	7 R	24	25	24	26	27	25	29	26	24	29	-	26	25	25	25	25
	L	24	25	26	-	26	25	29	29	-	29	23	26	24	-	26	25
	9 R	35	33	30	33	33	28	35	33	31	34	-	30	29	30	32	31
	L	33	34	30	31	32	30	35	35	-	33	28	30	30	-	32	32
	10 R	22	22	23	24	25	27	25	24	21	24	-	22	21	24	23	20
	L	23	23	29	23	24	26	25	29	-	22	23	22	22	-	25	21
	19 R	-	42	39	46	43	42	46	42	43	42	-	-	39	42	43	43
	L	-	42	38	-	43	41	47	43	-	42	-	43	39	-	43	42
	21 R	78	70	-	72	73	74	81	75	-	73	-	72	-	-	-	-
	L	-	70	71	-	74	74	82	75	-	74	73	-	70	-	-	-

Table 4 (cont. 2)

Grave No. / MARTIN No.		43	45	46/a	47	59	60	62	64	65	72	76	77	81	86	90	92
Tibia	1 R	304	-	354	304	-	333	-	332	308	322	344	327	330	330	333	-
	I	304	-	355	303	354	331	-	332	309	322	340	323	331	334	336	348
	1/b R	300	-	353	303	-	330	-	327	304	317	343	325	331	330	333	-
	I.	303	-	356	302	355	328	-	329	307	320	345	325	334	332	336	349
	3 R	68	-	-	67	-	71	-	75	68	70	74	-	70	66	67	-
	I.	-	-	69	68	73	72	-	73	66	69	71	-	69	65	72	-
	8/a R	28	28	32	29	33	29	-	31	27	30	30	27	31	29	31	-
	L	28	-	30	28	33	-	-	32	27	31	32	-	30	28	31	31
	9/a R	22	16	22	22	24	23	-	22	22	22	20	19	23	26	21	-
	L	22	-	21	21	25	-	-	24	22	22	20	-	22	22	23	23
Fibula	1 R	305	-	347	302	-	327	-	326	309	318	333	-	326	-	333	-
	L	-	-	351	298	-	-	-	322	312	319	333	-	331	-	335	-
Sacrum	2	-	-	92	94	82	-	-	107	90	111	99	107	-	-	95	-
	5	114	-	116	114	116	-	-	109	99	113	119	115	115	-	119	-
Pelvis, ischium	R	-	-	94	88	-	-	-	95	80	94	-	-	93	-	91	-
length	L	-	-	90	81	-	-	-	87	78	86	90	-	86	-	85	-
pubis	R	-	-	99	101	-	-	-	95	90	99	-	-	102	-	104	-
length	L	-	-	(87)	92	-	-	-	87	82	95	98	88	93	-	98	-
I:P index	R	-	-	95.0	114.8	-	-	-	100.0	112.5	105.3	-	-	109.7	-	114.3	-
	I	-	-	(103.5)	113.6	-	-	-	100.0	105.1	110.5	108.9	-	108.1	-	115.3	-
cotylum	R	-	-	31	33	37	34	-	31	31	34	38	-	35	29	40	-
breadth	L	34	-	33	34	38	-	-	32	30	35	38	34	37	-	39	-
inc. isc.	R	-	-	42	35	41	36	-	38	37	42	50	-	37	38	59	-
breadth	L	46	-	42	41	41	-	-	37	36	43	42	42	-	-	49	-
C:I index	R	-	-	73.8	94.3	87.8	94.4	-	81.6	83.8	81.0	76.0	-	94.6	76.3	67.8	-
	L	73.9	-	78.6	82.9	92.7	-	-	87.0	86.1	81.4	90.5	81.0	-	-	79.6	-
Clav.-Humeral	R	-	-	42.2	44.6	-	-	-	44.5	-	43.2	47.1	49.0	48.9	-	49.0	-
index	L	-	-	43.1	-	44.8	45.3	-	46.6	46.8	45.3	48.6	-	-	-	50.5	-
Radio-Humeral	R	74.0	-	78.1	-	71.8	-	-	77.7	-	75.0	-	70.6	-	76.8	-	-
index	L	-	-	78.6	-	-	72.5	-	-	76.6	76.3	74.3	-	73.2	-	77.6	-
Tibio-Femoral	R	-	-	82.1	77.1	-	81.9	-	80.9	80.2	77.1	81.5	80.4	84.7	84.6	81.4	-
index	L	79.1	-	83.8	77.0	81.1	-	-	80.8	80.4	78.6	82.3	-	83.9	84.7	81.2	80.4
Stature (acc. to PEARSON)		148.8	-	158.2	148.3	160.0	153.0	158.5	154.8	149.5	154.5	157.8	152.5	151.5	152.0	153.0	157.5
Stature (acc. to BACH)		155.2	-	161.9	155.0	164.9	158.7	163.0	159.5	156.0	159.1	161.0	158.0	157.2	157.7	158.5	161.3

Table 4 (cont. 3)

Grave No. / MARTIN No.			94	96	97	99	100	108	110	112	118	119	120	127	129	132	133	134
Tibia	1	R	343	-	-	307	331	336	357	339	335	349	304	344	323	-	-	-
		I.	-	-	324	303	335	343	362	345	340	-	307	-	326	-	-	-
	1/b	R	338	-	-	305	330	335	359	341	339	350	302	340	320	-	-	341
		I.	-	-	320	301	333	341	357	343	343	-	305	-	324	-	340	-
	3	R	75	-	-	69	69	70	75	69	73	69	65	69	65	-	-	-
		I.	-	65	64	65	69	72	74	71	-	67	69	-	65	-	-	-
	8/a	R	29	-	-	31	34	31	32	31	29	29	25	28	25	-	31	26
		L	31	32	30	31	30	34	32	31	-	29	28	29	26	-	28	30
	9/a	R	23	-	-	23	21	25	27	22	20	22	22	22	22	-	24	22
		L	23	22	22	25	23	27	27	22	-	24	25	20	21	-	21	24
Fibula	1	R	-	-	-	-	-	-	-	-	327	-	303	-	318	-	-	-
		I	339	-	-	-	-	338	-	327	332	-	-	-	323	-	-	-
Sacrum	2		-	94	-	-	80	-	-	87	-	-	-	-	100	-	-	-
	5		-	106	112	-	114	-	126	115	-	-	-	118	108	-	119	-
Pelvis, ischium		R	-	-	-	-	-	-	97	88	-	92	-	-	84	-	-	-
length		L	-	-	-	-	-	-	89	83	-	-	-	-	-	-	83	-
pubis		R	-	-	-	-	-	-	112	102	-	101	-	-	93	-	-	-
length		L	-	-	-	-	-	-	103	98	-	-	-	-	-	-	90	-
I:P index		R	-	-	-	-	-	-	115.5	115.9	-	109.8	-	-	110.7	-	-	-
		L	-	-	-	-	-	-	115.7	118.1	-	-	-	-	-	-	108.4	-
cotylum		R	-	36	30	-	35	-	40	33	-	33	-	29	34	-	-	-
breadth		L	-	37	28	-	34	-	-	33	(36)	35	-	28	-	-	39	-
inc. isc.		R	-	39	49	-	42	-	42	47	-	30	-	38	43	-	-	-
breadth		I	-	40	43	-	52	-	-	43	58	45	-	42	-	-	46	-
C:I index		R	-	92.3	61.2	-	83.3	-	95.2	70.2	-	110.0	-	76.3	79.1	-	-	-
		I.	-	92.5	65.1	-	65.4	-	-	76.7	(62.1)	77.8	-	66.7	-	-	80.4	-
Clav.-Humeral index		R	-	44.0	-	-	48.1	-	45.3	-	47.3	42.1	44.6	-	50.4	-	-	48.6
		L	-	-	50.4	52.7	47.9	-	48.4	49.3	-	-	48.6	47.6	50.4	-	-	-
Radio-Humeral index		R	-	-	-	-	78.1	-	76.1	73.4	-	74.7	73.9	77.2	79.0	-	-	78.2
		L	-	-	78.7	74.0	77.9	-	76.9	74.5	74.1	-	74.6	-	77.9	-	-	-
Tibio-Femoral index		R	-	-	-	78.8	79.9	82.7	84.5	81.2	-	82.7	-	84.8	82.1	-	-	84.2
		L	-	-	81.6	-	80.2	83.4	84.2	81.3	-	-	82.4	-	82.7	-	82.3	-
Stature (acc. to PEARSON)			155.0	150.6	151.7	148.5	155.2	153.8	159.5	155.5	155.0	157.7	147.5	153.2	153.2	153.0	155.0	152.0
Stature (acc. to BACH)			156.0	158.3	154.5	155.5	160.2	158.7	163.0	160.2	158.6	162.0	155.5	159.0	157.0	161.0	159.5	158.5

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Archeological age determination of fossil bone samples containing protein based on amino acid racemization and epimerization

By

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Abstract: The authors have adapted a method for determining the ages of fossils, using the method of isoleucine and other protein amino acid racemizations. By measuring D-allo-isoleucine bone samples over 50 000 years, by the fast racemization amino acid D- and L- versions, followed by ion exchange column chromatography separation with chiral silica gel layer the ages of bone findings between 5 000 and 50 000 years could be determined with the error of the analytical method (for D-allo-isoleucine ± 5% and ± 15-20% for the other amino acids). A proposal is made for determining bone samples with the approximate age of 1 000 years, with the possible application of amino acids with sulphur and with fatty acids. With 4 tables and 5 figures.

INTRODUCTION

In 1860 PASTEUR examined asparagine from the point of optical activity. The asparagine was derived from wild pea. In his further works he established that most of the chemical compounds playing an important role in the lives of animals and plants are asymmetric and only asymmetric compounds have optical activity. TERENTEV & KLABUNOVSKII (1957) stated that the life cannot be and has never existed without any molecular asymmetry. There must be some relationship between optical activity and life, as all proteins are built up of only L-enantiomer amino acids, while the configuration of natural sucroses is D. In various experiments simulating the creation of life, the simulation of the primitive reduction atmosphere yielded the synthesization of several amino acids. These were, however, racemic, and in these experiments none of the enantiomers was favoured over the other (STEPHEN-SHERWOOD & ORÒ 1973). In 1908 VAN'T HOFF, and in 1934 KARAGUNIS & DRIKOS succeeded in synthesizing optically active compounds with the aid of circularly polarized light. The problem with these experiments was, however, that polarized light appears in nature only in very extreme circumstances, e. g. as a response to γ radiation emitted during β decomposition (GOLDHABER & al. 1967). Several scientists have reported on the synthesis of D- and L-amino acids or on their decomposition during their bombardment with β particles or with polarized electrons.

In 1968 PONNANPERUMA & GABEL found during the examination of some geological deposits that optically active organic molecules are definite proof of the existence of life during the formation of the deposits. This of course holds only if the optically active organic compounds have not racemized in the meantime. During the past 15-20 years several scientists have examined the amino acid content of meteorites and lunar deposits. Several kinds of amino acids were traceable in these materials, which undoubtedly were formed abiotically; however, the optical activity measurements always yielded a negative result.

In the shells from prehistoric times, as well as in bones and teeth, ABELSON examined the amino acid content for the first time, and published his findings in 1954. The oldest fossil examined by him, a fishbone originating from the Devonian Age, contained glycine,

alanine, glutamic acid, leucine, valine and aspartic acid, despite its age of approximately 360 million years. In his laboratory experiments he found that these amino acids lasted the longest, and under favourable temperature conditions these could be expected to survive as long as several million years. In 1954 ABELSON made the first proposal to use the decomposition of proteins in fossils for the determination of age. He was the first to suggest that some correlation might exist between the decomposition of protein and the assessment of temperature; i.e. he can be considered as the first forefather of geothermometry. The results of his analysis are summarized in Table 1.

Table 1

Amino acid contents of some fossils (ABELSON 1954)

Samples	Estimated age (years)	Amino acid contents $\mu M/g$)	Main components
Plesippus (Prehistoric horse)	Late Pliocene $5x10^6$	0.6	Ala, Gly
Plesippus (tooth)	Late Pliocene $5x10^6$	1.5	Gly, Ala, Leu, Val, Glu
Mesohippus (tooth)	Oligocene $4x10^6$	0.31	Ala, Gly
Masasaurus (Dinosaur)	Cretaceous $100x10^6$	1.8	Ala, Gly, Glu, Leu, Val
Stegosaurus (Dinosaur)	Jurassic $150x10^6$	0.26	Ala, Gly, Glu
Dinichtys (Fish)	Devonian $360x10^6$	3	Gly, Ala, Glu, Leu, Val, Asp

Following the examination of the decomposition of amino acids, VALLENTYNE (1964) made a new proposal in the direction of geothermic methods. This was based on the selective decomposition of amino acids. The 0.01 M aqueous solution of free amino acids were examined between 210-280°C and amino acids were put in 5 groups according to the sequence of their decomposition. The first group was made up of easily decomposing amino acids while groups 4 and 5 contained those with a slower rate of decomposition. The different amino acids were written up in the following scheme:

1. Aspartic acid, cystine, threonine, serine, arginine.
2. Lysine, histidine, methionine.
3. Thyrosine, glycine, valine, leucine, isoleucine.
4. Alanine, proline, hydroxiproline.
5. Glutamic acid.

HARE & ABELSON reported in 1967 that the D-amino acids found in fossils probably originated from the decomposition of L-amino acids. By examining the composition of amino acids in fossilized shells of increasing age they found that the ratio of D-amino acids increases in relation to the L-amino acids as the age increases. In the examined fossils, deriving from the Miocene, the amino acids could be traced only in the form of raceme. HARE & MITTERER (1968) conducted experiments on the racemization of L-isoleucine at high temperatures. By applying the conclusions of their experiments on a fossil shell, the ratio of D-allo-isoleucine and L-isoleucine was found to be 0.32, which enabled them to estimate the age at 70 000 years. This was the first application of racemization (or in this case rather epimerization) in geochronology.

Later the racemization of amino acids was employed in the determination of the age of any materials containing proteins. Among others it was used to determine the age of deposits (BADA & al. 1970, WEHMILLER & HARE 1971), shells (HARE & MITTERER 1968), bones (BADA 1972, DUNGWORTH & al. 1973), teeth (HELFMAN & BADA 1975, 1976) and corals (VEHMILLER & al. 1976), as well as for estimation of the temperatures since their formation (BADA & al. 1973, SCHROEDER & BADA 1973).

To the best of our knowledge the method of racemization and epimerization of amino acids in the determination of age is not used in Hungary. As the need for the application of this method has been raised repeatedly, the Stock-Breeding Faculty of the Agricultural University at Kaposvár in conjunction with the Museum of the County Somogy and with the Anthropological Department of the Hungarian Natural History Museum has initiated the elaboration of a method which is based on the racemization or epimerization of amino acids. This is an up-to-date method and it can easily be matched with the equipment available in the laboratory. Our aim has been to elaborate a method applicable for determining the D- and L-amino acid content of fossils, thereby enabling to judge the age with a reasonable level of accuracy.

OVERVIEW OF THE LITERATURE

The discoveries of the authors mentioned in the introducton gave a tremendous impetus to age determination based on amino acid racemization. However, detailed analysis threw light on the fact that this method - as well as any other - had several disadvantages and improper interpretation of its results might lead to a faulty conclusion. The most significant efforts for the development and application of the method are outlined in the following.

The ratio of the D- and L-amino acids of fossils depends on the method applied in the separation and determination of amino acids. We can obtain varying results in examining free, protein saturated, or total amino acid determinations but the reason for the difference could also be attributed to the differences between the enzyme, the gas chromatographic or high pressure liquid chromatographic methods all having a different type of error. The isolation of amino acids from fossils has become possible by the application of several methods, some of which have certain similarities. Generally the samples are cleaned, washed and the contamination is generally removed by ultrasonic methods (BADA & PROTSCH 1973, WEH-MILLER & HARE 1971). The sample is then dried and milled, after which the homogeneous mixture is ready for the extraction of amino acids. The sample is washed in dilute hydrochloric acid in order to free the amino acids. The mixture containing the free amino acid is removed by filtration from the remaining mixture containing the unextractable amino acids (DUNGWORTH & al. 1975). The free amino acids are then ready for determining the D- and L-amino acids. (In some cases, a desalting may be justifiable.)

The non-decomposable remainder is then hydrolyzed for 22-24 hours at 100-110°C with hydrochloric acid of 6 M, as in the usual process of amino acid analysis. Following the completion, the hydrochloric acid is removed by distillation, the residue is diluted in distilled water and is desalinized. For desalinizing some experts prefer the removal of calcium (WEH-MILLER & HARE 1971), while others apply the feeding of the compound through cation or anion exchanging resin (KVENVOLDEN & al. 1970). It is not feasible to apply alkaline treatment during the preparation of the sample nor during the extraction of amino acids, as these are liable to racemization, and this should certainly be avoided during the preparational phases.

Several methods have been elaborated for the separation and determination of amino acid enantiomers. Initially polarimetry was used, which was mainly applicable to the examination of the racemization of clean amino acids (BADA 1971, 1972; SATO & al. 1970). An enzyme technology was used to determine the D- and L-amino acids in soil (ALDAG & al. 1971) and in some fossils (HARE & ABELSON 1967, HARE 1969, PETIT 1974). This method consists of the oxidation of the D- and L-amino acids, followed by the determination. The problem with the method is that it is not applicable for determining the traces of D-amino acids, and therefore it can be the source of error in the case of L-amino acids originating from enzymes.

MANNING & MOORE (1968) have described an ion exchanging column chromatographic method for the separation of D- and L-amino acids. This is based on the reaction of an L-amino acid N carboxi anhydride on the D- and L-amino acids to be determined. Diastereomer dipeptides are formed that can be used for the ion exchange separation. With this method BADA & PROTSCH (1973) succeeded in analysing aspartic acid from bone in the form of L-Leu-D-Asp and L-Leu-L-Asp diastereomer dipeptide.

One of the best methods for separating D- and L-amino acids - apart from high pressure liquid chromatography - is gas chromatography. The enantiomers can be separated in

the form of a diastereomer-pair prepared by an asymmetric reagent or, alternatively, on the basis of the volatility of the derivatives separation by an optically active phase is possible. CHARLES & al. (1963) used N-trifluoracetil - (±) 2-n-alcohols to prepare diastereomers. This method has been improved with the application of (±) 2-n-butanol by POLLACK and his team in 1965 and KVENVOLDEN with his team in 1971. The first optically active stationary phase in gas chromatography was the N-trifluor-acetyl-L-isoleucine-lauril-ester, synthesized by GIL-AV & al. in 1966. CHARLES & al. (1975) used the N-lauril-L-valil-tercier-butylamide to separate optical isomers. The technique of gas chromatography has been improved to such a degree that the error in determining the enantiomers is less than 5%, and reproducibility is extremely good.

Nowadays high pressure liquid chromatography is used to an increasing degree for the separation of enantiomers. WEINSTEIN & WEINER (1984) have prepared a fluorescent derivative, the 5-dimethyl-aminoaphtaline-1-sulpholin from the amino acids, and with an inverse phase liquid chromatography the N, N'-di-n-propyl-L-alanine (L-DPA) and copper acetate they have been able to separate all the D- and L-enantiomers of all protein amino acids. We believe the method is very nicely applicable for the quantitative determination of amino acids. It is sensitive, quick and with further improvement it can become a routine method comparable to the amino acid analysis.

MARFEY (1984) has also invented a method for the separation of enantiomers which is also based on high pressure liquid chromatography. With the aid of 1-fluoro-2,4-dinitrophenyl-5-L-alanine-amide, which contains a very reactionable fluorine atom, he created diastereomer derivatives from the mixture of D- and L-amino acids. He succeded in separating the derivatives with high pressure liquid chromatography by the application of triethylaminophosphate and acetonitrile eluenses gradient. In his publication he describes the separation of the mixture of D- and L-aspartic acids, glutamic acid, methionine, alanine and phenylalanine but by altering the conditions in an appropriate manner, the possibility of the separation of other amino acid enantiomers also exists.

In order to check the optical cleanliness of biologically active materials KNABE (1984), GÜBITZ & MIHELLYES (1984), GÜBITZ & al. (1982) have elaborated a direct method with high pressure liquid chromatography. It is based on the chiralic column, made up of chemically bonded L-hydroxy-proline-Cu^{2+}. The moving phase is a water solution containing Cu^{2+}. With the application of the above stationary solution it is possible to check the optical cleanliness of all those chemical compounds which form a chelate complex with the Cu^{2+}ions, such as the amino acids. The disadvantage of the method in relation to the afore-mentioned is that only one D- and L-form of a single amino acid can be determined in one measurement.

Due to its very frequent use in geochronology, the analysis of D-allo-isoleucine needs to be mentioned separately. Apart from hydroxiproline, isoleucine also contains two centres of asymmetry. The D-allo-isoleucine formed with time from isoleucine, during the routine application of ion exchange amino acid separation, appears on the chromatogram between the isoleucine and the methionine, by giving a separate, easily evaluable peak. The racemization of the carbon atom with an α position, and the formation of the D-allo-isoleucine during the peptid-synthesis were examined in detail by BODANSZKY & CONKLIN (1967). Among other aspects they considered the effect of hydrochloric hydrolysis and of the different tertiary amines on racemization.

As acidic hydrolysis is the most important step in the separation of amino acids bound in protein, several researchers have examined the changes occurring during hydrolysis; in other words, what is the extent of acid-catalysed racemization. WILTHSIRE (1953) refluxed L-glutaminic acid with 6 M HCl for a period of 24 hours. He found that 3-5% of it will turn into D-glutaminic acid. By hydrolysing horse myoglobin and cow insulin he obtained 6.6-4.6% of D-glutaminic acid. MANNING & MOORE (1968) when examining the racemization of free and peptide bound amino acids found that for some amino acids the measured racemization during the acidic hydrolysis will depend on whether the amino acid in question is free or in a peptide chain, and what is the location among the given amino acid in the peptide chain. MANNING (1971) definitely states that by using free L-amino acid as a control, the degree of racemization occurring during the hydrolysis of protein cannot be accurately predicted.

In spite of this the hydrochloric acid treatment of free amino acids during the hydrolysis of protein is used by some as an assessment of the occurring racemization.

Most authors have found a racemization between 0.1 and 3.7% in these experiments for the various amino acids. BADA & PROTSCH (1973) measured, for the ratio of D- and

Table 2

Rate of racemization of free amino acids during the hydrolysis with 6 M HCl (%)

Conditions of hydrolysis	Time (hours)	Amino acids											
		Ser	Ala	Arg	Val	Leu	Ile	Glu	Phe	Pro	Asp	Lys	Met
Reflux[1]	6	-	22	-	19	5	-	-	-	-	-	-	-
105°C[2]	24	-	1.1	-	0.3	1.3	0.5	-	-	-	-	-	-
120°C[2]	24	-	3.7	-	0.6	2.1	1.4	-	-	-	-	-	-
110°C[3]	24	-	0.5	-	0.2	0.8	0.3	1.9	0.1	1.7	1.7	-	-
110°C[4]	22	0.4	-	1.6	-	-	-	-	1.4	2.2	-	-	-
110°C[4]	18	0.5	-	-	-	-	-	3.3	-	-	3.7	-	-
110°C[5]	22	0.4	1.0	1.6	0.7	1.3	1.0	-	-	2.2	-	3.0	2.2

1. ALDAG & al. 1971
2. NAKAPARSKIN & al. 1970
3. HARE & HOERING 1973
4. MANNING & MOORE 1968
5. MANNING 1970

Table 3

Rate of racemization of amino acids bound in protein during the hydrolysis with 6 M HCl (C)

Protein samples	Conditions of hydrolysis		Amino acids									
	Temperature (°C)	Time (hours)	Ala	Glu	Val	Ile	Leu	Pro	Arg	Phe	Asp	Ser
Bardykinin[1]	110	22	-	-	-	-	-	2.4	1.7	3.9	-	-
Ribonuclease[1]	110	18	-	4.2	-	-	-	-	-	-	4.4	0.2
Collagen of mammoth[2]	105	24	1.2	2.7	0.7	-	1.6	-	-	2.6*	3.0	-
Horse myoglobin[3]	Reflux	24	-	6.6	-	-	-	-	-	-	-	-
Bovine insulin	Reflux	24	-	4.6	-	-	-	-	-	-	-	-

* 48 hours

1. MANNING & MOORE 1968

2. DUNGWORTH & al. 1976

3. WILTHSIRE 1953

L-aspartic acids, 0.07 following the method of acidic hydrolysis. They call the attention to the fact that the racemization occurring during the hydrolysis has to be taken into account when determining the age; the D- and L-amino acid ratios have to be corrected by this figure. The racemization values of free amino acids and those of bound in proteins as obtained by various authors are given in Tables 2 and 3.

A further source of error in acidic hydrolysis may be that asparagine and glutamine are transformed into aspartic acid and glutamic acid during the process of hydrolysis. There is no uniform attitude on whether the fossils contain the two amino acids, nor is there agreement on their disarmination time and the error they can cause in the determination of the ages of the liquide.

After all, these sum up the reactions going on in the process of amino acid racemization as we could recognize sources of errors to be corrected in order to produce a correct measurement technique only with full knowledge of these.

In general the racemization of amino acids can be described as follows:

$$\text{L-amino acid} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \text{D-amino acid}$$

where k_1 and k_2 represent the reactional speed constants of the formation and reformation, from which the equilibrium constant is $K = k_1/k_2$.

The reaction speed can be described by the following general formula:

$$-\frac{d\,[L]}{dt} = k_1\,[L] - k_2\,[D],$$

where $[L]$ and $[D]$ are the L- and D-enantiomer concentrations.

By performing the integration we get:

$$\ln\left(\frac{1 + [D]/[L]}{1 - K'[D]/[L]}\right) = (1 + K')k_1 t + C,$$

where $K' = 1/K = k_2/k_1$. The integration constant - if there is no D-enantiomer present - is equal to 0, otherwise

$$C = \ln\left(\frac{1 + [D_o]/[L_o]}{1 - K'[D_o]/[L_o]}\right)$$

BADA & PROTSCH (1973) calculated for the D/L aspartic acid ratio for recent cow bones a value of 0.07, which was the racemization during the hydrolysis and the processing. From this the calculated value for C at t= 0 is 0.14. For free amino acids in water solution the speed of formation and reformation is equal, therefore $k_1 = k_2$, and the reaction equation can ba simplified as follows:

$$\ln\left(\frac{1 + [D]/[L]}{1 - [D]/[L]}\right) = 2\,kt + C.$$

The characteristic and easy to use parameter of racemization is the half-time. By definition this is the time that 25% D-enantiomer and 75% L-enantiomer are present in the sample. For the half-time we get the following formula, which is derived from the formula describing the racemization speed:

$$\tau = \frac{\ln 2}{k_1 + k_2}$$

or

$$\tau = \frac{\ln 2}{(1+K')k_1}$$

The D/L amino acid ratio for the half-time can be given by the formula:

$$(D/L)_{\tau} = \frac{K}{K + 2}$$

The condition $k_1 = k_2$ is not true for the amino acid most frequently used for geochronology, for isoleucine. The L-isoleucine has an asymmetric centre at both the α and the β carbons. The racemization, or as already stated for the diastereomers the epimerization, only reacts on the α carbon; there was no racemization observed on the β carbon neither during the model experiments nor on the fossils. In the epimerizational equilibrium, the reaction constant for the L-isoleucine formation (k_1) is greater than the reformation (k_2), and therefore the equilibrium constant (K) is greater than 1.

Different authors give a value of 1.0-1.4 for K, but in order to avoid the errors caused, it is advisable to determine for each series of experiments the values for K_{Ile}. Although several experts have proven the assumption of $k_1 = k_2$ for amino acids with a single asymmetry centre, PETIT (1974) proposes that the speed of formation and reformation might be quite different for amino acids of a protein chain. According to this theory in a given protein environment the mutual effects between the D- and L-enantiomers may be quite different, and this can influence the speeds of formation and reformation.

BADA (1971) determined the racemization half-time of some amino acids and the epimerization half-time of isoleucine at pH 7.6 on 0°C and on 25°C. From the amino acids analysed by him the half-time of phenylalanine which had the fastest racemization time was 2 000 years on 25°C and 160 000 years on 0°C. Aspartic acid had 3 500 and 430 000 years, alanine had 12 000 and 1 400 000 years and isoleucine 48 000 and 6 000 000 years for the same values. The results of his experiments proved the fact - well-known for a long time by peptide-chemists - that amino acids containing aromatic side chains (tyrosine, phenylalanine) or indol and imidasol groups (tryptophan, hystidine) had the easiest racemization. It was most difficult to force valine, isoleucine and leucine containing apolaric side chains into racemization. BADA & PROTSCH (1973) found a correlation between racemization in hydrolysis and the estimated age when analysing aspartic acid's racemization in hydrolysis. The results of their examinations are given in Table 4. It could be seen from the data of this table that one percent of racemization in the process of hydrolysis could falsify the age determination with 700 years in the case of aspartic acid.

Table 4

Effect of racemization during hydrolysis of protein on the age of fossil bones (BADA & PROTSCH 1973)

Amount of D-Asp originating from hydrolysis (%)	0	1	2	3	4	5	6.5
Constant	0	0.020	0.041	0.062	0.083	0.105	0.140
Calculated time (years)	22 400	21 700	21 000	20 300	19 600	18 800	17 700

Equation used for calculation: $\ln \frac{1 + D/L}{1 - D/L} - C = 2\, k_{Asp} \cdot t$

$$k_{Asp} = 1.48 \times 10^{-5}\ \text{year}^{-1},\quad D/L = 0.32$$

NEUBERGER (1948) described the following mechanism for the racemization of amino acids catalysed by bases. As the first step the proton in position α is bound by a base and a planar structured anion is formed from the tetrahedral configuration. The anion is later stabilized by the taking up of a proton. According to NEUBERGER any substitution in the carboxyl group increases the racemization because this enables the freeing of the proton in position α. A similar effect can also be reached when an electronegative substituent is tied to a

carbon atom in position β . MANNING (1970) proved the dislocation and recombination of the α proton as the first step of racemization by the measurement of the built-in α positioned tritium. By subsequent experiments these suppositions were proved to be correct, and SMITH & al. (1976) firmly stated that the ratio of relative racemization in a protein could only be assessed by taking into account the simultaneous effect of several factors, such as sterics, neighbour, effect of thinner.

Another assumption of NEUBERGER, according to which the racemization of amino acids in peptide bound is always much quicker than in free amino acids, was also proven later. This applies to reactions catalysed by both acids and bases. It follows that amino acids in dipeptides racemize quicker than free amino acids, and the increasing racemization speed is further increased by increasing the length of the peptide chain. Therefore, one must definitely be able to recognize the racemizational processes of free and bound amino acids.

A totally contradictory observation is that in fossils free amino acids better racemize than amino acids in proteins (DUNGWORTH & al. 1973, BADA 1975). This was explained by HARE (1971) as follows: at the breaking of the protein chain amino acids in activated state show a better tendency for racemization than the bound ones. BADA & SCHROEDER (1972) believe that it is much more probable that the racemization of free amino acids originating from proteins is catalysed by the traces of heavy metal ions, therefore the racemization of amino acids of fossils is a very complicated and complex process, which is effected by hydrolysis and by catalytic effects (BADA 1975). It follows that free amino acids, peptides and proteins go through a different racemizational process, and from the three fractions proteins are most stable from this point of view, as they are not very sensitive to the catalysis of metals. The racemization of free amino acids is mainly effected by the pH (BADA 1972) and by the metal ions (Ca^{2+}, Mg^{2+}). SMITH & al. (1976) have proven that ion strength is a major factor as well, and with its increase racemization increases too.

By evaluating the afore-mentioned it can be concluded, that racemization differs for free, for peptide tied, and for protein amino acids, and that for these three fractions racemization is also affected to varying degrees by environmental conditions. It seems that protein bound amino acids are the least sensitive to pH and ions, therefore, this is the most reliable of the three as a tool in determining ages. However, the fact that under alkaline conditions racemizational processes are speeded up, indicates that alkali extraction should preferably be avoided from protein extraction processes.

In spite of this, free amino acids and peptide fractions can also provide valuable information for archaeologists and anthropologists.

MATERIALS AND METHODS

1. Sample preparation

The sample arriving at the laboratory to be analysed is freed of mechanical contaminations and then washed in running water. It is then dried in a vacuum chamber at room temperature for one night, following which it is ground in a porcelain cup to the fineness of flour. The nonpolar contaminations are separated in a Soxhlet appliance for 6 hours, and after the fumes have been removed a repeated homogenization takes place. The ground sample is suspended in 0.1 M hydrochloric acid, and the amino acids resulting from the decomposition of protein are separated from the sample for a period of one night (approx. 16 hours). Then the sample is filtered in a G-4 filter, the free amino acid fraction is stored in a refrigerator, and the filtered remainders containing the protein are dried and homogenized once again.

The raw protein content of the resulting material is determined in a Kjel-Foss 16-200 type nitrogen analyser, and as a function of the content 100-1000 mg of the material (which is approximately equivalent to 10-20 mg of protein) is hydrolysed with 6 M hydrochloric acid at 110°C for a period of 24 hours. Following the completion of the hydrolysis the hydrochloric acid is removed from the sample by lyophilization, and the silicates separated during the water solution are separated by centrifuging from the liquid containing the free amino acid. The pH of the solution is adjusted with sodium-hydroxide at pH 9, and the separated calcium, magnesium and heavy metal hydroxides are separated by filtering or by repeated

centrifuging from the free amino acids. Following the removal of the hydroxides the pH is immediately adjusted between 6 and 7. and the obtained solution is dried by lyophilization. The resulting material is now ready for the determination of D- and I-amino acids, isoleucine and D-allo-isoleucine.

2. Determination of isoleucine and D-allo-isoleucine

When determining isoleucine and D-allo-isoleucine, the hydrolysed material is diluted in a pH 2.2 citrate buffer, and the 25-50 nanomole concentrate solution is fed to the LKB-4101 type automatic amino acid analyser. The description of the analysis and the applied buffers (CSAPÓ é al. 1986) is the following:

Equipment:		LKB-4101 Biochrom Ltd.
Size of ion exchange column:		500 x 6 mm
Ion exchange resin:		CHROMEX UA-8
Buffer flux rate:		60 cm^3/hour
Ninhydrine flow speed:		30 cm^3/hour
Column temperature:		50°C for 60 minutes, then 70°C till the end of analysis
Buffer A:	pH 3.25,	Na molarity 0.2, 25 minutes
Buffer B:	pH 4.25,	Na molarity 0.2, 60 minutes
Buffer C:	pH 6.45,	Na molarity 1.2, 55 minutes
NaOH:		0.4 M, 15 minutes
Equilibration:		Buffer A, 60 minutes

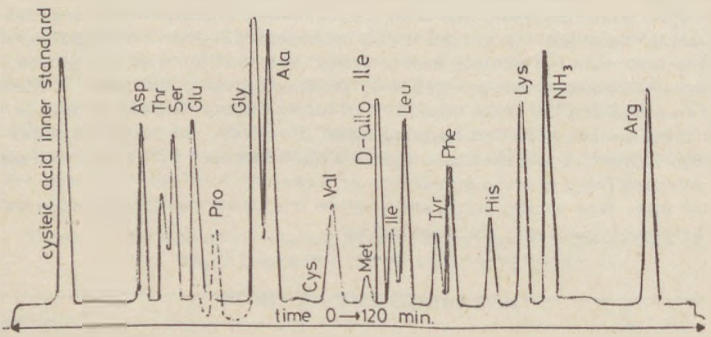


Fig.. 1a The amino acid composition of recent porcine bone + 50 nanomol D-allo-Ile

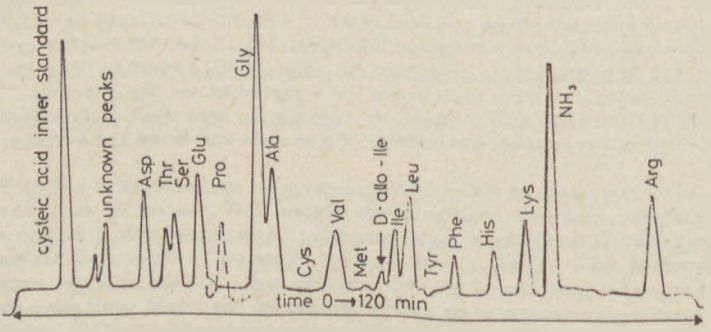


Fig. 1b The amino acid composition of woolly Rhinoceros bone

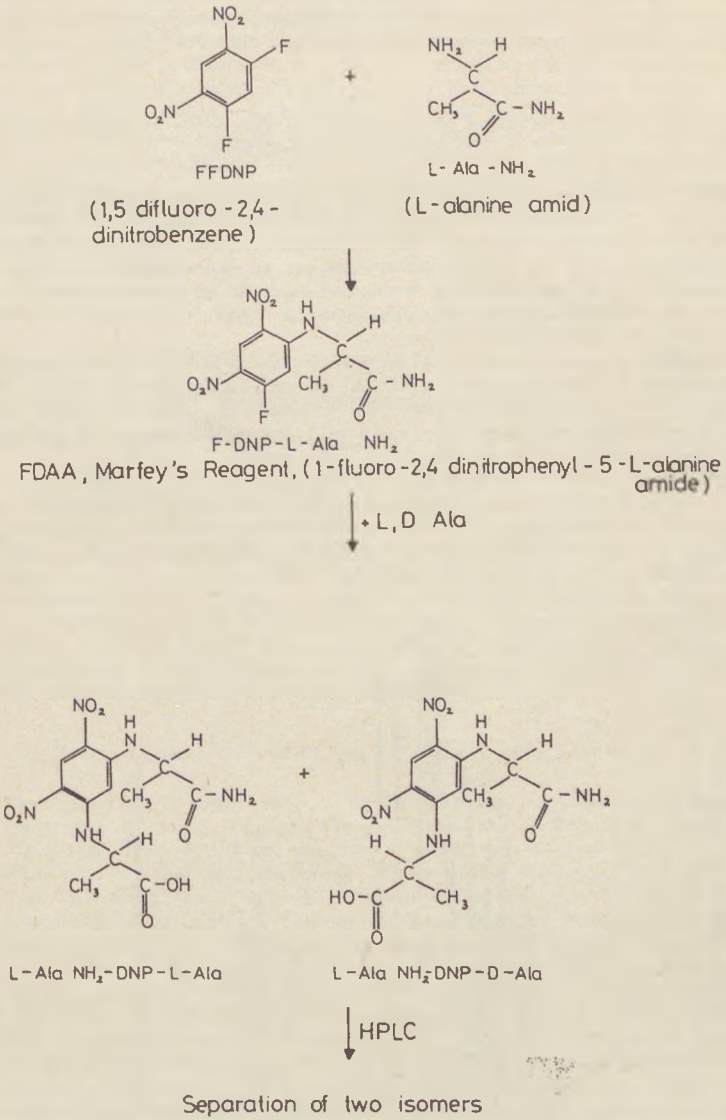


Fig. 2 An outline of the reaction sequence used for this synthesis of FDAA reagent and for the derivatization of L- and D-isomers

D-allo-isoleucine appears on the chromatogram between methionine and isoleucine. It can easily be separated from the neighbouring amino acids, and the peak can easily and precisely be evaluated. The amino acid chromatogram of a typical recent porcine bone is presented in Figure 1. The swine bone naturally does not contain D-allo-isoleucine. At the next step we added 50 nanomol D-allo-isoleucine standard to the hydrolysed material then carried out the amino acid analysis of the bone of an 50 000-year old woolly Rhinoceros bone. The chromatogram is given in Figure 1a and b.

3. Determination of D- and L-amino acids by high pressure liquid chromatography

The most suitable method for separating D- and L-amino acids by high pressure liquid chromatography was elaborated in conjunction with the Department of Organic Chemistry of Eötvös Loránd University, Budapest. The intent was to prepare a method by which all protein forming amino acids' D- and L-enantiomer can be separated from the hydrolysed material. By this method the losses due to manipulation could be minimized (the separation of amino acids, the determination of the separated fractions), while the information value of the result could be considerably increased.

Preparations formed an essential part of our method. The Marfey reagent (1-fluoro-2,4-dinitrophenyl-5-L-alanine-amide, FDAA) was mixed with the L- and D-amino acids in the hydrolysed material to produce diastereomer-pairs of compounds which could be easily separated by reversed phase high pressure liquid chromatography. The reaction equations to produce diastereomer pairs of compounds are given in Figure 2.

At present it is still an unsuperable task to separate and to determine all D- and L-versions of all amino acids in the hydrolysed material in one move (a single run on the high pressure liquid chromatograph). However, to separate individual amino acids or the D- and L-amino acid of combinations containing one or two amino acids is not a problem any more.

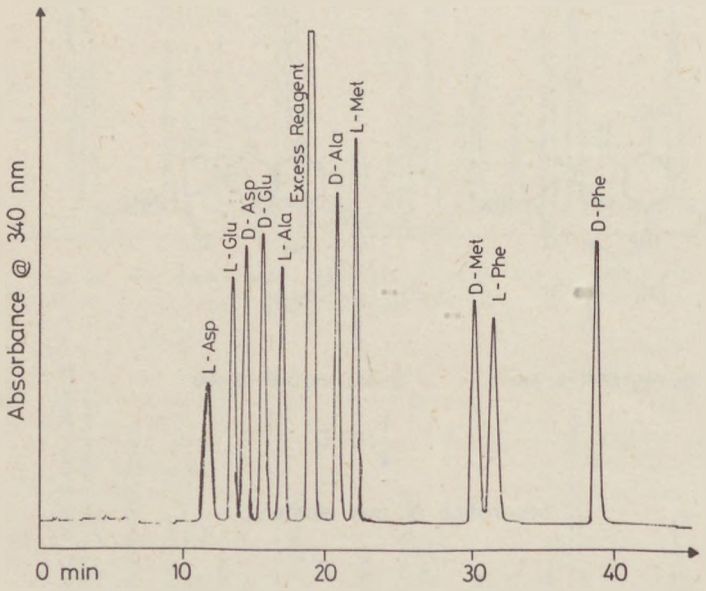


Fig. 3 Separation of D- and L-amino acids on spheri-5, RP-18 10 cm x 4.6 mm I.D. column by reverse phase HPLC.
Conditions: A - 0.05 M triethylamine phosphate, pH 3.0
B - acetonitrile
Linear gradient, 10 to 40% B in 45 min,
2.0 ml/min, 25°C, 340 nm

For these reasons we separated the amino acids being present in the hydrolysed material by the LKB-4101 type amino acid analyser and by LKB fractioner linked to it and then we dried up by lyophilization the test tubes containing the individual amino acids. After this we determined the D- and L-versions of amino acids individually or by mixing up some amino acids using high pressure liquid chromatograph after the creation of diastereomer formations. The separation of the D-and L-versions of aspartic acid, glutamic acid, methionine and phenylalanine is given in Figure 3.

For the separation we used up 5 umole of crystalline amino acid. It was dissolved in 100 µl volume. To this we added 200 µl 1% FDAA acetone solution and then 40 ul 1 M $NaHCO_3$. We warmed the reaction compound on 40°C for 1 hour then stopped warming and cooled it down. We immediately added 20 µl 2 M hydrochloric acid then after removing carbon dioxide we fed the samples into the high pressure liquid chromatograph. The high pressure liquid chromatograph column was of the following type and size:

Length:	250 mm
Inner diameter:	4 mm
Load:	BST SI-100-S 5 C-18 (Bio Separation Technical Co)

Analysis had the following condition:

Running material:

A:	0.05 M triethylamine-phosphate, pH 3.0
B:	acetonitril

Linear gradient from 10 to 40% B 45 minutes

Speed of flow:	2 cm^3/minute
Temperature:	25°C
Wave length:	340 nm

As it could be seen from the chromatogram the peaks have good separation, evaluation was easy. The situation was not so simple when working with protein hydrolysed material instead of crystalline amino acid. In most cases L-amino acid which was present in a larger concentration suppressed the peak of D-amino acid which was present in much smaller concentration. This way it was made impossible to evaluate it. The D-peak appeared as a shoulder peak of L-peak in the chromatogram at best. At present we are working on the elimination of these faults and of the deficiencies of the method.

4. Determination of D- and L-amino acids in chiral silica gel

In silica gel thin layers the mixture of D- and L-amino acids cannot be separated, not even by the application of chiral reagent. The amino acids first have to be separated from one another. It is then possible to separate the D- and L-enantiomers from the solution by the application of chiral silica gel. Therefore, we separated the amino acids with LKB-4101 analyser and the LKB fractioner. This was followed by the drying of the test tubes containing the amino acids by lyophilization. The remainders containing the D- and L-amino acids were diluted in a solution of methanol-water whose ratio was 1:1, which resulted in the obtaining of an amino acid of 5-10 µl for an approximately a 1% solution. The silica gel thin layer of the Macherey-Nagel company (Düren, GFR) with catalogue number 811055 was treated with a chiral reagent and with Cu^{2+} ions and was activated for 15 minutes at 100°C. This was followed by dropping a solution of 1% in a quantity of 2 ul, and the separation was conducted with a chemical containing methanol-water-acetonitrile in a 50:50:200 ratio. This lasted approximately for 14-15 minutes. Following the drying of the thin layer it was sprayed with a reagent solution containing 0.1% of ninhydrin, and it was then dried in a cabinet at 105°C for 10 minutes. The area of the spot and the intensity of the colour were measured by a Vitatron densitometer at 570 nm, and the result was evaluated by a recorder connected to the densitometer and by an integrator. With this technique the D- and L-enantiomers of all amino acids of proteins can be separated. The exceptions are glycine, which is asymmetric, the tryptophan which totally decomposes under acidic conditions, and the threonine and serine. On the silica gel thin layer the serine and threonine spots of D- and L-overlap which does not allow quantitative evaluation. However, all other amino acids can easily be evaluated at a precision equivalent to the densitometric method. Figure 4 presents a typical

thin layer chromatogram. In the figure the separation of crystalline amino acids' racemized modification can be seen.

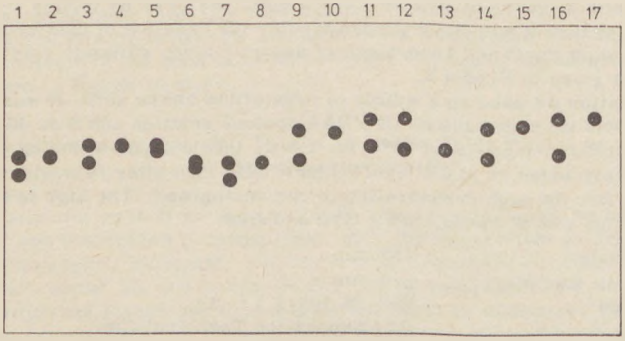


Fig. 4 Chiral plate for control of optical purity by thin layer chromatography based on ligand exchange.
Optical resolution of DL- and L-amino acids on chiral plate produced by Macherey-Nagel

1. D L - Asp	6. D L - Ser	11. D L - Met	16. D L - Phe
2. L - Asp	7. D L - Ala	12. D L - Ile	17. L - Phe
3. D L - Glu	8. L - Ala	13. D-allo-Ile	
4. L - Glu	9. D L - Val	14. D L - Leu	
5. D L - Thr	10. L - Val	15. L - Leu	

Sample volumen: 2 µl 1% solution in methanol or in methanol/water
Developing solvent: Methanol-water-acetonitrile 50:50:200 V/V/V
Developing time: Approx. 20-25 min
Visualization: 0.1% ninhydrin spray

5. Calibration curve for the determination of age

After the selection of the analytical methods and the correction of the errors we could start to determine the ages of the findings. As already mentioned in the introduction, temperature needs special attention. This means that those temperature conditions need careful consideration which the sample has been subjected to, following the death of the organism. As we have only a limited knowledge of the temperature changes and fluctuations which have occurred, the temperature of the reactions during the racemization or epimerization process can only be estimated. It is not possible to determine it exactly, the only exceptions are some extreme case, e.g. the deep waters of the oceans. With this assumption in mind we have looked for a solution as to how we could compare the composition of the sample with an unknown age with another sample whose age had already been determined. Of course, special attention was paid to the fact that the history of the two samples to be compared should preferably be as similar as possible. The most important factors were the depth from which the sample was excavated (temperature!) and the type of soil (pH!), as the process of racemization is mainly determined by the temperature and the pH value.

For this purpose we collected 100 bone samples of known age from various Hungarian museums. These ages ranged from two thousand to five hundred-thousand years. We determined the raw protein content of these samples, as well as the amino acid composition (D-allo-isoleucine) and the ratio of D- and L-amino acids. Based on the degree of racemiza-

tion we have categorized amino acids into three groups. The first group was made up of amino acids with a quick racemization time, which could be used for the age determination of young bone samples (2 000 to 20 000 years). The second group contained amino acids where the half-time of racemization lay between 20 000 and 100 000 years, and which could be used for bone samples aging between 20 000 and 200 000. The last group consisted of those amino acids which could be used for determining the ages of samples over 200 000 years.

For all three groups for all amino acids the D/L ratio was illustrated as a function of time, thereby enabling us to draw 4-5 calibration curves for each group. The first group does not contain amino acids with a long racemization period, while the third one does not contain those with a short period. The second group contains some overlap with the other two groups. After establishing the time function of the D/L amino acid ratio of the groups with different ages, the methods became applicable for the determination of the ages of samples with conditions similar to those of the calibration curve. By determining the D/L amino acid ratio of the unknown bone sample, it was immediately clear to which group the sample belongs. By comparing the D/L amino acid ratio of the calibration curve with the D/L ratio of the unknown sample, the age of this latter can immediately be read. For one unknown sample we usually used 3-5 amino acids to determine the age, and by averaging these ages we were able to determine the real age of the sample.

By applying the calibration curve, the errors introduced by the temperature and pH could be avoided. However, some errors due to the other method of age determination were introduced. The method of age determination based on the racemization of amino acids becomes absolute if we assess the temperature conditions, as in this case the D/L amino acid ratio of the sample is the unknown value, while all the other data - such as the age of the sample - can be calculated from the equation on the spead of the reaction.

RESULTS AND CONCLUSIONS

In our work we elaborated the most suitable procedures within the capibility of our laboratory for determining age based on amino acid racemization. During which we extensively employed the results of the literature. The procedures of age determination are given in Figure 5. The most crucial phases of the procedures are the separation of the free and the protein bound amino acids, the hydrolysis and the separation of the hydrolysed material. The free amino acid fraction obtained by 0.1 mole decomposition is barely applicable for determining age due to the factors affecting racemization (heavy metal ions, the presence or lack of Ca^{2+} and Mg^{2+} ions, pH, ionic strength). The protein fraction seems to be better for this purpose. During the hydrolysis of the protein fraction special attention has to be paid to avoiding all those side effects which may change the amino acids during the process of hydrolysis (oxidation, reduction, racemization, epimerization). To check the changes occurring during the preparational stages, the analysis of a recent pig bone should be performed, and the changes occurring here must be taken into account (racemization, epimerization during the hydrolysis) when determing the age of the sample.

Out attempts were concentrated on two directions. To determine the concentration of D- and L-amino acids the more difficult yet for the future more promising direction as well as the determination of all D- and L-versions of all amino acids in the hydrolysed material in a single move in high pressure liquid chromatography. In this case the manipulatory losses of the sample were reduced to a minimum and we could obtain information on all amino acids present in the sample. At present we can separate only about 4-6 amino acids' D- and L-versions by this method from a given sample. The other way was simple though it meant a lot more work. It was to separate amino acids by ion exchange column chromatography and the determination of individual amino acids D- and L-versions by high pressure liquid chromatography or by chiral silica gel thin layer chromatography. By this method we could establish the D- and L-versions of only one amino acid in one move and so this method was much slower, it consumed more material, it meant an increase of manipulatory losses.

However, the recognition of D- and L-amino acids' ratio was also acceptable with this method.

Fig. 5

Procedures of age determination based on the amino acid racemization

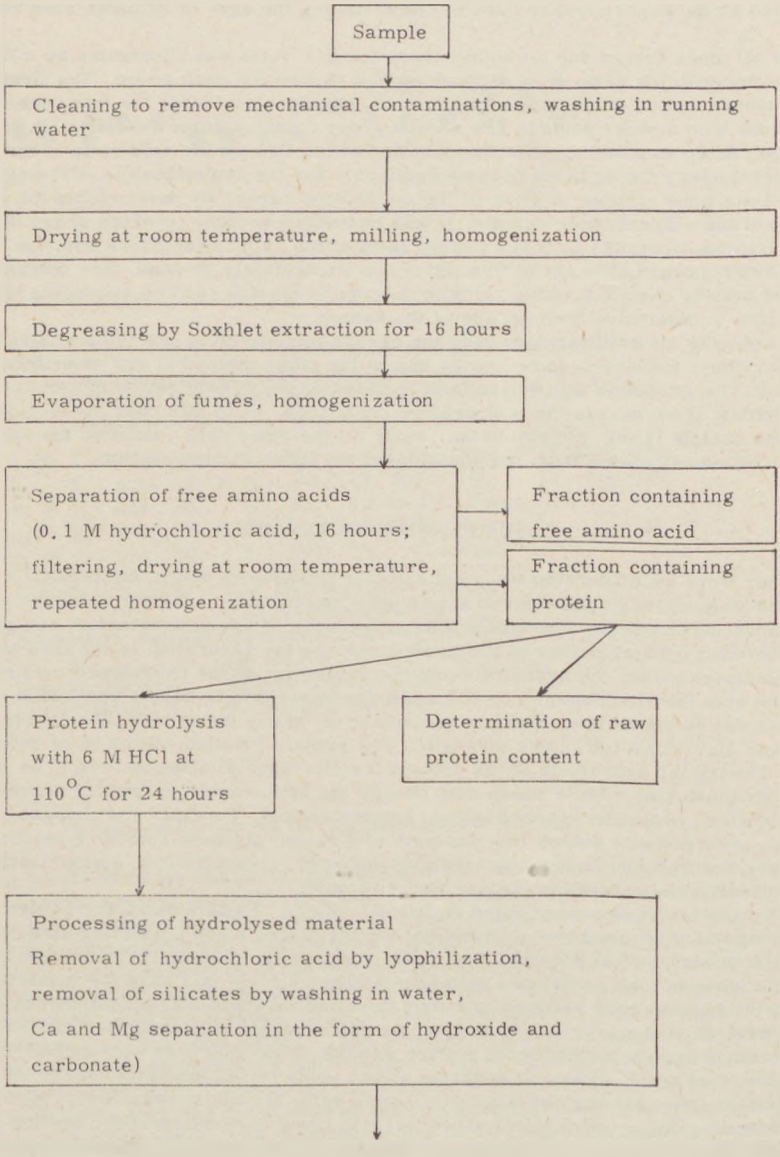
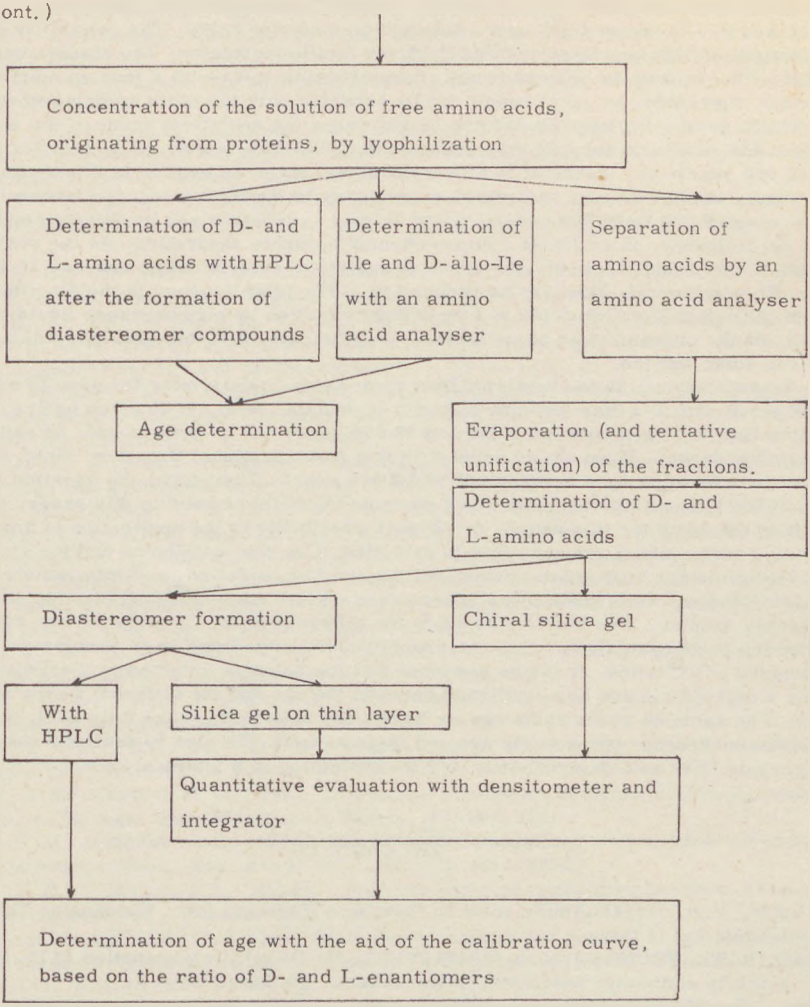


Fig. 5 (cont.)


Concentration of the solution of free amino acids, originating from proteins, by lyophilization
Determination of D- and L-amino acids with HPLC after the formation of diastereomer compounds
Determination of Ile and D-allo-Ile with an amino acid analyser
Separation of amino acids by an amino acid analyser
Age determination
Evaporation (and tentative unification) of the fractions.
Determination of D- and L-amino acids
Diastereomer formation
Chiral silica gel
With HPLC
Silica gel on thin layer
Quantitative evaluation with densitometer and integrator
Determination of age with the aid of the calibration curve, based on the ratio of D- and L-enantiomers

From those described in the chapter material and method the determination of isoleucine and D-allo isoleucine - are conducted on a routine basis. The reliability of age determination is ± 3% for isoleucine and ± 5% for D-allo-isoleucine. The disadvantage of the method is that isoleucine belongs to the group of amino acids with a long epimerizational half-time, therefore, an exact result can be expected only for those samples whose age is over 50 000 years. Between 20 000 and 50 000 years the analytical error of the method for D-allo-isoleucine increases. It may even reach the 15-20% margin. For samples younger than 20 000 years, the traces of D-allo-isoleucine cannot be applied in this range.

Amino acids with fast racemization belonging to the first group can favourably be used for the range 5 000 to 20 000 years, as the D- and L-versions can be determined by a chiral silica gel following ion exchange column-chromatographic separation. As the evaluation is conducted with a densitometer, the error of analytical determination reaches 15-20% in this range. This error can, however be reduced to 1-3%, if we succeed in the simultaneous separation of D- and L-amino acids and their determination by high pressure liquid chromatography. At the present stage of our work it is anticipated that this problem will have been solved in some months.

To summarize, it can be stated that we are able to determine the ages of samples over 50 000 years with D-allo-isoleucine and with isoleucine, with amino acids having a fast racemization time the ages between 5 000 and 50 000 years can be determined, or estimated with the stated accuracy. Even amino acids with fast racemizational time are 'slow' enough to be utilized to determine ages between 500 and 2 000 years. Therefore, the question arises: which of the amino acids or some other components could be used in this range, or how could a solution be found for this range. An obvious possibility is the application of amino acids containing sulfur which are sensitive to oxidation, i.e. the methionine and the cystine. Cystine and cysteine are changed to cystein-sulphin acid by oxidation, and into cysteic acid by further oxidation, while methionine is transformed into methionine-sulphoxide and later into methionine-sulphon. For both amino acids the different forms of oxidation can easily be measured by ion exchange column-chromatography, therefore, there is no problem in checking the process of oxidation. It can be assumed that for samples originating from similar conditions a correlation can be established between the age and the different forms of oxidational states. For samples of the same age we have tried to determine the fatty acid, and to establish some correlation between the age and their amount. We plan to deal with the gas chromatographic fatty acid determination and its evaluation in a future article.

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