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PLEISTOCENE ENVIRONMENT IN HUNGARY

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ENGINEERING GEOLOGICAL, EXPERIMENTAL AND METHODICAL STUDIES

PREFACE

The 12th congress of the International Quaternary Association will be held in Ottawa, Canada. The Hungarian National Committee of the INQUA has been regularly publishing selected studies for congresses on the achievements of its members. Papers in English appeared in numbers of the Földrajzi Közlemények, bulletin of the Hungarian Geographical Society (in 1969, 1973, and 1977). For the 11th congress in Moscow the Geographical Research Institute Hungarian Academy of Sciences published a separate volume entitled 'Quaternary Studies in Hungary'

Regarding the topics of the sections and special meetings of the 12th congress in Ottawa, selected studies by Hungarian researchers of the Quaternary are published in two volumes. The present one has the title 'Pleistocene environment in Hungary' and includes pieces of fundamental research in paleogeography in the broader sense of the term, in sedimentology and paleoecology on the one hand and engineering, experimental and methodological research concerning the changes of the Pleistocene environment and their implications to the Holocene on the other. Several papers investigate the geological duration, formation and boundaries of the Pleistocene. The papers involving the environmental, archaeological, ecological-sedimentological changes during the Holocene are also published by the Geographical Institute under separate cover.

The experts of the Hungarian Quaternary mean to promote international exchange of experience in the INQUA with regard to both fundamental and applied research, with mostly Hungarian observations and partly with proposals of international relevance.

The contributors of the volume wish success to the organizers and participants of the 12th congress.

Budapest, March 1987

Márton Pécsi
president of the
Hungarian National
Committee of INQUA

PALEOGEOGRAPHICAL, SEDIMENTOLOGICAL AND ARCHEOLOGICAL STUDIES

M. Pécsi (ed.)
Pleistocene environment in Hungary
Geographical Research Institute
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Budapest, 1987

REMARKS ON THE CORRELATION OF EUROPEAN, NORTH AMERICAN AND ASIAN LATE CENOZOIC LOCAL BIOCHRONOLOGIES (1)

M.KRETZOI

ABSTRACT

Author attempts to correlate the Upper Cenozoic terrestrial biochronological systems for Europe, China and North-America. The opportunity of and need for this correlation is justified by the recent results of both European and Chinese mammalian faunal paleontology.
The correlation allowed the following (partly tentative) parallelizations: Upper Agenian--Xiejiaan--Upper Arikareean; Upper Orleanian--Shanwangian--(Upper) Hemingfordian; Upper Astaracian--Tunggurian--Barstovian; Eppelsheimian--Bahean--Clarendonian; Baltavárian--Baodean--Hemphillian (p.p.); Ruscinian/Csarnótan--Jinglean--Upper Hemphillian/Lower Blancan; Villafranchian/Villányian p.p.--Youhean--Blancan p.p.; Lower Biharian--Nihevanian--Irvingtonian p.p.; Toringian--"Malanian"--Irvingtonian p.p./Rancholabrean. The most reliable and accordant in size of all is the parallelization of the two periods with Hipparion fauna.
In the comparative faunistic work, faunal historical considerations motivate a finer distinction than Holarctic and Oriental realms, achieved by the division of the latter into two and separating the Central Asian elevated continental core, and justify the identification of Eurosiberian, Palasian, North-American and (with the emphasis on the closer Eurosiberian relations of the Indian part) Sinomalayan macrounits.

* * *

Increasing interest in the geohistory of vast continental sedimentary regions both in Europe and Asia led to local terrestrial (primarily mammalian) biochronological systems (1853-1985). The multiplicity of local chronologies/stratigraphies necessitated correlations between these local systems. This is the reason of the many papers dealing with correlation on both continental and intercontinental scale. Two recent papers establishing and summarizing the local terrestrial chronology of the late Cenozoic in China made also correlations with that of Europe (LI,Ch.-- WU,W.-- QIU,Zh. 1984; XUE,X. 1984). At the same time, the present author published a number of papers discussing the European Late Cenozoic mammal chronology and its correlations (KRETZOI,M. 1983a, 1983b, 1984a, 1985a,1985b; KRETZOI,M.-- PÈCSI,M. 1982), one of which deals with the possibility of correlation of European and Chinese local chronologies (KRETZOI,M. 1985b). Many parallel conclusions are very satisfying, even if some points need a more detailed explanation or even a comparison by one or the other side. Of great importance, however, is the better understanding of the Chinese faunal succession in order to solve many questions still unclear or even misleading in interpreting European--N-American faunal exchange and correlation. Only a better knowledge of the Chinese faunal evolution will throw light on the origin and evolution of many taxa still considered to be "rootless" within both the European and the N-American faunal sequences. The new results of recent Chinese paleontological research led us to a better and more natural model of Eurasian--N-American faunal interrelations as more consolidated basis for a chronological correlation of this vast intercontinental historical-biochronological unit.

EUROPEAN--CHINESE CHRONOLOGICAL CORRELATIONS

XIEJIAAN/AGENIAN CORRELATION

The 14 mammal taxa of the biostratotype locality Xiejia l.f. are mostly Late Oligocene or transitional to Miocene forms, as *Sinolagomys*, *Tataromys*, *Plesiosminthus* and *Tachyoryctoides* - and *Eucricetodon* too. One genus, *Brachypotherium* is a type appearing in Europe only within the Middle Burdigalian (Middle Orleanian). Another genus, *Oioceros*, is a member of the *Hipparion* faunae in the Middle East. Its appearance in the Agenian of China could burst all of our ideas on the monophyly of the Bovidae. These very important discrepancies greatly weaken both the correlation between the mentioned two local ages and the concept of the Xiejiaan age.

SHANWANGIAN/ORLEANIAN CORRELATION

The 9 local faunae (Fangshan, Puzhen, Xiacaowan=Hsiatsaohwan, Shanwang , Jiulongkou, Dongshapo, Lengshuigou, Zhangbei, and Danshuilu) referred to the Shanwangian and correlated with the European Orléanian are much less controversial in composition than the former, although not without problems.

Comparing with the European Orléanian, the most striking differences are the following: First of all the appearance of the Ovine *Oioceros* in these faunae, already recorded within the *Xiejiaan*, too. The same is true of the unusually early appearance of a *"Chilotherium"* species, a highly specialized Pliopithecine (*Dionysopithecus)* and a very primitive Proconsuline type *(Platodontopithecus)* represented by a similar if not identical form *(Ataxopithecus*, KRETZOI,M. 1984b) in the Hungarian Middle Eppelsheimian (Lower Vallesian) *Hipparion* fauna of Rudabánya. The very early appearance of Giraffids in China is also remarkable, if we consider the African origin of the group. The mixed occurrence of Early Miocene to Late Miocene forms (in the European sense) in the Shanwangian faunal age needs further evidence about the faunal composition of this time unit and more data to evaluate the differences in the appearance of some forms as real chronological (or ecological) marker-taxa.

The most sharp-cut boundary in the Late Neozoic Chinese sequence in mammal faunae is the so-called "*Hipparion* datum".

In E-Asia, where the dominant role of Hipparions is weakened by the rhinos, this boundary is only acceptable if the faunal sample is rich enough. The other weakness of this *Hipparion* datum is that it must be strengthened by the presence of an entirely Miocene fauna accompanied by one of more *Hipparion* species (KRETZOI,M. 1985b).

In other words, the earliest fauna with *Hipparion* will be the *Hipparion* datum - until an earlier is not found. Therefore all the faunae without *Hipparion* must be classified as of prae-*Hipparion,* or Astaracian age. In the chronological table of LI,Ch.--WU,W.--QIU,Zh. (1984) 15 local faunae (Xiaolongtan, Zhongxiang, Erlanggang, Koujiacun, Tunggur, Tongxin, Qinan, Xianshuihe=Hsienshuiho, Lierpu, Diaogou, Shennongijia, Ledu, Chaidamu=Tsaidam, Hsishui--Taben buluk, Pingliang and Jining) are placed in the Tunggurian/Astaracian, of which only one, namely Tunggur shows a broader taxonal sample (27 taxons), the others remain below 8 taxa. Therefore only Tunggur is evaluable chronologically, a fauna differing from early *Hipparion*-faunae but in the absence of *Hipparion*. In this respect, it recalls the European Early Eppelsheimian (Monacian) faunae without *Hipparion*. Crucial for timing the migration of the Dryopithecines from E-Africa to E-Asia is the age of the fauna of Xiaolongtan unfortunately with only 7 taxa - partly not characteristical for aging and partly controversial in composition; *Hexaprotodon* is unknown in Asia, both Siwaliks and Indonesia, prior to the Villafranchian - hardly contrasting with some other forms mentioned from the locality, as mainly *Palaeochoerus*. The other localities referred to the Tunggurian are too poor in taxa for giving an exact age. In sum, the otherwise colourful age (called Astaracian in Europe) needs a broader sample to be subdivided in China. Only the Tunggur assemblage represents the Tunggurian s. str., correlating broadly with the Oeningian=Sarmatian s. str. to the post-Astaracian in terms of the European sequence.

BAHEAN/EPPELSHEIMIAN(=VALLESIAN) CORRELATION

As is shown by the earlier samples (collections by the Sino-Swedish, Sino-French, and other expeditions) the old Eppelsheimian = "Vallesian" *Hipparion*-faunae are rarer in China than the Baltavárian (="Turolian") associations in the northern and northeastern regions (KRETZOI,M. 1985b). This is reflected in the faunal samples of the new Chinese excavations (LI,Ch.--WU,W.--QIU,Zh. 1984) too.

The three faunae referred to the Bahean/Eppelsheimian are difficult to characterize - even the type fauna, Bahe is too small in number of taxa to fix it in the "Old *Hipparion* age". In this respect, the numerous and sometimes abundant faunae of Honan and Hopei, or an important number of the *Hipparion*-faunae of Shanxi and some of Shaanxi (Liuhe, Bahe, Bulong, ?Chai-Chang-kou, Chen-Kou-wan, Chiao-Chia-kou, ?Chia-Yü-taun, Chili loc.66., Chingko-Hsien loc. 48, Chü-Tse-Wa) are much better. "Honanian" for example would be perhaps a more appropriate age name. The primary characteristics of the faunal complex (as discussed by the present author some months ago, KRETZOI,M. 1985b) are the presence of only small forms of Agriotheres *(Galeotherium="Ursavus")*, rarity or lack of Ictitheres and Hyaenines, and true Machairodonts among Carnivores, increasing number of Rhinocerotid taxa *(Brachypotherium, Stephanorhinus, Acerorhinus,* first true *Chilotherium)*, appearance of Chalicotheres, diversified and dominant presence of Hipparionines,? last appearance of Anchitheres, early Suid types as *Korinochoerus, Chleuastochoerus* and lack of characteristic suid forms of the *Hipparion*-assemblages as *Microstonyx*, dominant in the Baodean, poor Giraffid fauna, rich representation of primitive Cervids *(Cervavitus, Eostyloceros etc.)*, low number of Bovid taxa, all belonging to primitive types, as Tragocerines and brachyodont gazellas *(Procapra)*. Browsing rhinos, frequent Cervids in contrast to grazing forms argue for a bush-forest vegetation of the regions represented by the localities of this age. The forest dwelling character of this faunal complex was first underlined by M.SCHLOSSER (1903) and worked out in details by B.KURTÉN (1952) - a feature characterizing the European Eppelsheimian *Hipparion* faunae, contrasting with the later (Baltavárian) grassland environment associations. The primitive character of this *"gaudryi"*-faunae (KURTÉN,B. 1952) ensure their chronological distinction from the *"dorcadoides"*-faunae of Baltavárian correlations.

BAODEAN/BALTAVÁRIAN(=TUROLIAN) CORRELATION

The rich samples of the "late" *Hipparion*-faunae both in earlier and recent collections (Zanda, Gyirong, Nyalam, Lufeng, Balouhe, Xinan, Lantian, Wudu, Jingchuan, Qingyang, Huoxian, Tuchengzi, Ertemte, Yushe "Zone 1", Dalai Nor, Chaidamu=Tsaidam p.p., Manas, Urho, Wenquan, Duodaoshi, Chi-Chia-Kou, Chi-Tsu-Kou, Chiton Gol, Fu-ku-Hsien loc. 51, Ho-chü-Hsien loc. 114, Hou-Liang, Hsiao-Hung-Chü, Hsiao-Szu-Chia-Ling, Hung-Chiao-Ni-Ke-tan, King-Yang-Hsien loc. 115, 116, Malang, Mancusun, Olan Chorea, Pao-Te-Hsien=Baode loc. 30, 31, 44, 108, 111, 112, 113, Pei-Hou-Kou, San-Ta-Kou, Shia-Shiang loc. 22, Wa-Yao-Po-Kou-Nei) ensure not only their distinction from the older (Bahean) ones, but their correlations with the European Baltavárian faunas too. In a broad correlation the only problem is the great diversity between the faunae of this age, showing an extraordinary high variation in taxonomical respect and in dominance rates changing with time and in range. A more detailed subdivision of the Chinese Baodean *Hipparion*-faunae in subages is therefore desired.

A taxonal revision of some important groups such as Carnivores, Rhinocerotidae, Hipparions, Suids, Cervids and Antelopes will bring this result. For the time being we will be satisfied with the well-founded chronological parallelization of the Chinese Baodean with the European Baltavárian ("Turolian"). The increasing aridisation following the Eppelsheimian-Bahean more forested environment was obviously the consequence of the disappearance of the Inner-Asian--N-Chinese "Lake belt" corresponding to the disappearing Paratethys and the "Messinian salinity crisis" in the Mediterranean in Europe. The difference between the three parallel processes is to be explained by the more gradual desiccation of the Chinese Lake-belt than that of the Paratethys ("Messinian salinity crisis") in the European Mediterranean, or the continentalization in the Carpathian Basin. This is the first reason of the less sharp-cut correlation of the upper boundary of the Baodean, whilst the second one is simply the basically different origin of the post-Baltavárian, i.e. Ruscinian faunal type embracing nothing but new forms invading to Europe from the south of Asia, very unlike to the Jinglean type assemblage.

JINGLEAN/RUSCINIAN CORRELATIONS

The faunal assemblages of the post-"red bed" or post-*Hipparion* faunae are very difficult to characterize, due to a confusion in stratigraphy caused by earlier excavations and collections on one side, and the difficulties caused by the slow faunal transformation mentioned above on the other, manifested in the survival of the Castorids *(Dipoides, "Eucastor")* and some antelopes ancestral for this taxonal complex. Not better than the lower, the upper boundary of the age is arbitrarily marked by the rather supposed than documented lack of Equines and Elephantines, becoming dominant with the beginning of the Quaternary. But even this more theoretical boundary marked by the first *Equus* s.l. and *Elephas* s.l. is the weak point of the characterisation of the age fauna - and remains so until more local faunae make possible to determine it sharper. The less humid character of the Chinese Jinglean, however, is the basis of a new difficulty in separating the Jinglean from the Quaternary: in Europe the warm wet Ruscinian has a "Subhimalayan" type fauna sharply differing from both the preceeding Baltavárian and the succeeding Villafranchian-Villányian, whilst in the Chinese area these three ages show ecologically - and therefore taxonally - only small differences, giving only a tentative lower and upper boundary of the Jinglean.

Comparing the fauna of a European and a Chinese Ruscinian/ Jinglean locality we can understand the deep difference between the two areas with a basically different zoogeographic history; extended Caspian--NW Siberian transgression and radical shrumping and disappearing of the Paratethys barrier and parallel changes in the Tethys belt put an abrupt end to the Sino-Siberian connections of Europe and opened a Subhimalayan one, resulting in a wave of southeastern immigration, reaching as far as Southern England and replacing the *Hipparion*-grassland ecosystem by Subhimalayan forest to forested savanna conditions. Simultaneously in China the bush-steppe conditions of the *Hipparion*-faunae prevailed during the whole time of these three ages and remained over the non-glacial parts of the whole Quaternary more or less semiarid in climatic conditions. It should be mentioned, however, that the climatic differences between North and South China became - as is seen by a comparison of the faunae - sharper only during the Pleistocene, namely between territories with an approximate boundary marked by the Yangtse-line. The difference in the ecological conditions between Europe and Asia, primarily E-Asia resulted in differences between East and South Asia, too, because S-Asia remained with Europe in a more intimate connection, not only in the Ruscinian/Jinglean, but partly in later periods too, whilst E-Asia and S-Asia remained mainly separated until the end of the Quaternary,when the great Ganges--Tsangpo/Brahmaputra alluvium overbridged this barrier (KRETZOI,M. 1938, 1956). This is the reason for the late dissolving of the Late Neozoic Sino-Malayan zoogeographical province and the very late, practically only recent mergence of India and the Malayan region into an "Indomalayan" unit.

The time span between 2.4/2.5 My and 0.7 My is a matter of discussion both in Chinese and European stratigraphy. Less disputed is its aging in the biochronologic sequence of faunae. In Europe it can be divided into three well separable faunal types: the first is characterized by the presence of primitive Arvicolids and " arvicoloid" Cricetids such as *Baranomys*, *Trilophomys*, and *Dolomys* a.o.escorted by Ruscinian type macromammal forms, but lacking of the rich Murid fauna of the Ruscinian, both in number of taxons and in dominant number over the Cricetid-Arvicolid elements. In the last consequence (REPENNING,Ch.—FEJFAR,O. 1977) this period is the Villafranchian in restricted sense. The second faunal phase is that of the *Mimomys*-explosion (KRETZOI,M. 1969), with a very diversified *Mimomys*-fauna and the first rootless Arvicolids (*Lagurodon*, *Prolagurus*, *Allophaiomys*). This faunal type ends with a general restriction in the taxonal diversity of the fauna and some indications of a general cooling. This faunal complex is called in the latest publications Villányian s.str. The third faunal complex is well characterized by the extinction of practically all Ruscinian remnants of the Villafranchian-Villányian accompanied by the *Microtus* explosion in the Arvicolid fauna, beginning with the dominance of *Allophaiomys* (accompanied by the last survivals of *Mimomys*),and the sudden emerging of the different *Microtus*-branches, becoming dominant within the Quaternary - and extant - micromammal fauna of the Holarctica. This is the Early Biharian fauna, followed by the first arctic impact (Mindel-Elster) in the Upper Biharian.

The weakness of this three-grade succession is that it is not accompanied by equally detailed aging in the macromammal fauna. This is the reason of our hesitation in correlating an *Equus*-datum or an *Elephas* s.l.-datum with the detailed micromammal chronology ("vole chronology"). The only well correlable point in the micro/macromammal aging is the coincidence of the extinction of practically all macromammal types not surviving to the end of the Pleistocene on the Villányian/Biharian boundary of the micromammal chronology.

If we compare the Chinese biochronology of this time span with that of the European, we are meeting with a great similarity in problems: first of all - not to mention the problem of the Jinglean-Youhean boundary discussed above - the mixture of Choukoutienian and Nihewanian forms in the "Nihewan complex" and than (as a not less difficult problem) the distinction between the pre-Nihewan and Nihewan part (?Villányian) of the faunal complex of the Youhean, or more precisely the time span between Youhean and Choukoutienian.

Later faunal ages, following the Choukoutienian are complicated by increasing problems of glaciations and - perhaps in greater extent - by the increasing difference between South and North China in climatic-ecologic conditions as repeatedly pointed out by H.D. KAHLKE (1961, etc.). In other words: South China is too much influenced by the Malayan-Indonesian faunal area - whilst North China became more and more distinct from the Sino-Malayan faunal composition.

* * *

Overlooking the problems arosen from a comparison of Chinese and European local faunal evolution and biochronology, some questions emerge, not to be answered on the basis of a simple comparison of faunal lists, but much more as questions to be answered by results of an intensive future work on actual fossil materials. The number of these questions is evidently great; some of them will be discussed in the following paragraphs:

Insectivores are less complicated in the extant European fauna; not so in the East Asian associations, with a series of Late Tertiary survivors. Therefore, Chinese Late Tertiary to Early Pleistocene Insectivores, primarily Soricids and in some respects also Talpids are promising for the study of refined taxonomical-phylogenetical studies; Soricid evolutionary trends are poorly known. Archaic E-Asian living representatives and Chinese fossil relatives can surely help to a better understanding of this "difficult" group and its expansion over four continents.

Tertiary Sciurid sample is insufficient to bridge the gap in our present knowledge on the European-North American historical dynamics of the family. Surely, the Chinese materials will lead towards a more diversified picture of this family. Marmotines are the most important group having Inner to Eastern Asian backgrounds and a rather close connection with N-America's Sciurid evolution.

Though more isolated in the Chinese sample, Eomyids are very useful elements of a more precise European-Chinese biochronological correlation.

Basic importance is to attach to a more detailed and primarily careful comparison of European and Chinese Cricetids, which are in Europe index forms of the most of the local terrestrial chronologies.

Of special importance in this respect is a detailed study of the Myospalacids in China (TEILHARD de CHARDIN, P. 1942; KRETZOI,M. 1961), being the best "common language" between Chinese and Northeast Asian terrestrial local chronological sequences. The point to begin with should be a careful distinction of parallel evolutionary trends (*Prosiphneus, Mesosiphneus, Episiphneus, Eospalax, Myospalax, Allosiphneus*) represented by more or less pronounced different evolutionary lineages, but at different dates and thus diminishing the chronological value of most evolutionary levels in the time range of the Myospalacid sample, if not carefully collected.

Arvicolids are the basis of Quaternary mammal microchronology in Europe - the same could be evolved in Eastern Asia, but with some restrictions. They are also important for a closer correlation with N-America. Restricted is the importance of Arvicolids for the Chinese Late Quaternary, while a careful comparison of European and Chinese *Mimomys* forms could be of greatest importance not only for the European-Chinese faunal exchanges in the earlier Quaternary, or even in the Latest Pliocene, but perhaps with greater weight in the study of Mimomyine evolutionary dynamics expanding between Europe--E-Asia--N-America.

Hystricid sample is important for the migration of this family, arriving in Europe at the boundary of the lower/upper *Hipparion*-faunae and not earlier.

Besides the *Hipparion* evolutionary lineages Primates are the most eminent fossil record of China, at least for the Late Cenozoic. Their discussion needs much more space than available in this short review. Therefore only the very early appearance of higher Primates in S-China - postulating a separate migration way from E-Africa - apparently long before the Siwalian immigration - and the World's biggest one-locality sample of Ramapithecines-Sivapithecines (Shihuiba) or the equally eminent sample of Gigantopithecines and Hominines from Middle and N-China must be mentioned here.

Lagomorph remains are important for several reasons: all are early forms of the faunal exchange between N-America and E-Asia and practically in the whole Holarctica. True Ochotonids arrive in Europe not before the end of the Early *Hipparion*-faunae (Eppelsheimian-Baltavárian boundary), i.e. they are contemporaneous with the second exchange between American and European *Hipparion* faunae, enriching the North-American fauna with many typically Eurasian/European types. Exactly the same time is the date of immigration of Leporids to Eurasia (except *Hypolagus*, not arriving in Europe before the Ruscinian).

No data are available to fix the time of arrival of Proboscidea in the Chinese area, appearing in Barstovian times in North America. No more is known about Elephantid intrusion into the Chinese area. Proboscideans seem to play only a secondary role in E-Asia - or at least this region seems to be a secondary scenary of Proboscidean evolutionary dynamics.

Perissodactyls are practically the most important members of the Upper Tertiary faunae in E-Asia, contrasting the Artiodactyl dominance (except *Hipparion*) in Europe. The most characteristical perissodactyl members of these faunae are the rhinos, matching with Hipparions for the dominance. A problem, however, is the extraordinary high number of erected taxa. The proposed high number of species, living within a given age and territory (for example 22 taxa in the Chinese Turolian) obviously needs revision and drastic reduction of specific-subspecific taxonal names. They will partly represent forms related to European ones, or they are partly, if not in majority, Asian, even E-Asian endemisms (KRETZOI,M. 1942a).They produced within the time unit Miocene-Pliocene evolutionary lineages, represented by different generic-subgeneric successions such as *Brachypotherium, Acerorhinus* (=Lower-Middle Miocene *"Chilotherium"*), *Stephanorhinus* (=Miocene-Pliocene *"Dicerorhinus"*), *Plesiaceratherium,?Hispanotherium, Aceratherium, Indotherium ("Beliajevina"), Chilotherium, Shansirhinus, Sinotherium,* i.e. at least 10 genera-subgenera. Growing size, developing hypselodonty, cement deposition in the valleys and islands of the molars, or sometimes increasing molarisation of the premolars are all important data for a better knowledge of evolutionary grades and chronological position of the individual taxa composing the Chinese Rhinocerotid sample. Their importance is extended both in direction of local biochronology and Chinese-European correlation. Siwalik relations are also to be examined in some genera *(Indotherium, Acerorhinus).* N-American correlatives are missing or their North American affinities are at least questionable.

Chalicotheres are present in the Chinese sample in both lines (Chalicotheres and Schizotheres) but not frequent enough to use for parallelizations. The same is true of Tapirs.

Hipparions, the theoretically most important forms of the Bahean-Baodean faunae, are for the moment of little help either for local chronology and intercontinental correlations, due to the crisis in taxonomy of this group. Otherwise they would be the most important and famous members in Tertiary mammal sample. If we risk a judgement based on this group, it is restricted to two more or less already recognized statements: one is the probability of the arrival of the *Hipparion*-invasion in China at the same date as is given by the European *"Hipparion* datum", at the lower boundary of the Bodvaium (Middle Eppelsheimium=Lower "Vallesium"), the second is the high probability of a second immigration of Hipparions from N-America *("Neohipparion")* in the Upper *Hipparion* age (Baodean-Baltavárian). Uncertain is the date of arrival of *Equus* s.l. *(Allohippus, Asinus, Equus s.str.)* from N-America, therefore the "*Equus* datum" is also to be determined in the future. The evidence based on *Equus* is: no faunae with Equus s.l. can be older than the Early Pleistocene. The chronological insertion of some of the Chinese faunae is to be revised on this evidence. The sporadic appearance of *Anchitherium* in a post-Tunggurian fauna - side by side with the dominant Hipparions - is typical for the Baodean/Eppelsheimian, whilst no data for the survival of this group are available from a post-Bahean (Baodean or later) fauna. Therefore, its provenience is a good argument for the pre-Baodean (i.e. Bahean), if accompanied by Hipparions. The problem left is the time of the extinction of *Anchitherium* in E-Asia. In Europe, *Anchitherium* became extinct with the end of the Eppelsheimian (more precisely the end of the Rhenohassian).

Artiodactyls are very different in chronological value, partly caused by the regional difference between Asian and European evolution of the families in question, partly as a result of the high number of local evolutionary lineages of the richer Central Asian Artiodactyl life, except perhaps some antelope groups. Suid evolution looks to be more simple than in S- and W-Eurasia. Cervid branching in the Late Cenozoic is too complicated to be available for evolutionary and zoogeographic speculations.

More in details, Suids are scarcely represented in the Miocene, together with Tayassuids; they are rare in higher parts of the earlier Miocene *(Conohyus, Bunolistriodon, Hyotherium)* local *(Chleuastochoerus)* or archaic *(Listriodon, Conohyus, Korynochoerus)* in Bahean, restricted to *Microstonyx* and *Propotamochoerus-Potamochoerus* in the Baodean, or to the latter and *Sus* in the Jinglean/Ruscinian. If there is any difference between Eastern Asia and Europe, then it is the more dominant role of Listriodonts and the relatively weak representation of bunodont Suids in the faunae, compared with locally dominant provenience of the family in European assemblages, indicating a dominantly more bush forest to dry forest environment in E-Asia.

Giraffids are a more diversified and complicated group, with a distribution in time and space producing much more questions than data. First of all, their very early appearance in E-Asia seems to be in discordance with the much later arrival of this family in European Miocene samples. This fact suggests the possibility of an early (Orléanian) direct connection between Africa and not only India, but Chinese territories too. If this were true, many other groups could have arrived along this hypothetical direct route from Africa to E-Asia and mutual connections are also possible, for example an earlier immigration of Proboscideans via Africa--Subhimalayan Asia--Eastern Asia etc. The later history of the Giraffids in E-Asia is more correlated with that in Europe: the richer and more diverse sample in the Baodean contrasts that of the poorer representation of this family in the Bahean in the same way as the simple *Palaeotragus* fauna of the Eppelsheimian compared with the diversified Giraffid assemblage of the Baltavárian in Europe. At the same time, the local differences are also important: *Honanotherium* dominance in the old *Hipparion* faunae of China contemporary with *Palaeotragus* as the only Giraffid in Europe, while a *Palaeotragus-Samotherium* dominance in the late *Hipparion*-faunae of China contrasts evidently the *Samotherium-Helladotherium* representation in Europe.

Practically the same is the case with Bovids as is with the Cervids. The only parallel between Europe and China is the richer diversification in the gazellas and other antelopes in the late *Hipparion*-faunae (Baodean), and the decrease of the antelope-fauna during the post-*Hipparion*-faunae, with increasing number of Ovines-Ovibovines. Striking difference in Bovid evolution is the very early impact of the prolific evolutionary centre of Palasia - far from being well known.

* * *

Summing this short comparison of Late Cenozoic faunal evolution of China and Europe, I have found the following results and problems to discuss or to be completed:

1. The Xiejiaan sample is to weak to be characteristic of this age and to be compared with any European time unit.
2. The Shanwangian is richer represented by faunae, but too diversified to be compared with the European Orléanian, or to fix its boundaries, which are uncertain even in Europe.
3. The Tunggurian, as is known today, is shorter in time than the European Astaracian, or p.p. post-Astaracian (Monacian) and it seems to be very questionable to delimit this age or to correlate it with subages of the European Astaracian sequence.
4. The splendid sample of the Bahean is clearer than the European Eppelsheimian; a subdivision in subages is a promising task of Chinese paleontology.
5. The Baodean is the richest sample of this time unit - richer than any other faunal group in the Neogene. The imposing number of faunae and individual taxons is highly promising for a more detailed subdivision of this time span in Eastern Asia and for informing about the greatest migration of mammal faunae between the Old and New World.
6. The Jinglean age is well characterized, if some *Equus* faunae are excluded from this very characteristic and in its evolution very specialized time unit of East Asian faunal dynamism - very distinct from Siberian-European processes.
7. Youhean and later Early Quaternary *("Equus")* faunae are satisfactorily dated and correlated within the whole Eurasian sample. Correlation with N-American faunal ages is also promising. Correlations with tropical regions are possible on the basis of radiometric dating, in South-East Asia by eustatic sea-level changes, at least since the Dagu glacial period, tentatively correlated with the European Elsterian/ Mindelian of glacial stratigraphy (Upper Biharian).
8. Cenozoic, eminently Late Cenozoic Eutherian evolution and

faunal dynamics are primarily controlled by two factors: the Central Asian radiation centre and the Beringian "climatic" sieve. The first depends on the evolution of biota in the Palasian region. The brilliant new results of Chinese vertebrate paleontology promote efficiently the unveiling of the evolutionary processes of the life in this vast region.

In analysing intercontinental faunal relation (both isolation and connection) we have to deal with four principal factors:

1. climatic zonation,
2. orographic conditions,
3. sea-land relations, and as result of the foregoing three,
4. vegetation cover.

Under the heading of climatic zonation two composing factors, temperature and precipitation are cooperating in different amount and primarily influence vegetation cover.

Orographic conditions act in two ways: as barriers and as local (micro)climatic zonation components.

By sea-level changes we primarily understand what geologists call paleogeographic reconstruction. This is very different from that constructed by zoogeography or phytogeography: geologists are satisfied if they can state the contact of two continental blocks, while biogeography asks for effective terrestrial connections (land bridges) or at least island chains (for the island "hoppers").Therefore, if we accept a land connection as actual, we first demand for effectively tested transmigrant taxons proving a land connection - not only in a geologic sense but by biologically effective bridges. It is perhaps unnecessary to allude to the combination of continentality disturbing zonal (and hypsometric) climatic influences.

Another factor of ambiguity in our paleogeographic reconstructions is the chronologically varying factor of tectonic activities (both in horizontal and vertical sense). The most important - and most uncertain – factor is the hypsometric status of the mountains, acting at different times in different grade as barriers for animal migration and areal extensions. Taking into account this endangering list of disturbing factors suggesting extreme caution, following principal Late Cenozoic paleogeographic units may be accepted within the Eurasian--N-American faunal realm as most probable, both for the geologists and paleobotanists:

1. Eurosiberian area, with the southern boundaries Alpidic system (Pyrenees to Pamir), Tien Shan, Altai and NE Siberian chain to the Bering Strait, with varying areas of S Europe in the Alpine zone.

2. Palasian area, S of the eastern parts of the Eurosiberian area and N to E of the Himalayas and the Burmese-Thai-Vietnam Alpidic mts.

3. The Euroindian area, S of the Eurasian and partly(s.below) of the European part of the Eurosiberian area, or overlapping this. Southern boundaries are the boundaries between Europe and N.Africa embracing variably the island chain in the Alpine island zone between Tethys and Parathetys, continuing in the Tethys-channel zone through Syria, Irak and the Persian Gulf, and the Siwalian depression (rapidly filled up and connecting the Indian-Peninsula with the Asiatic continent).

Most important temporarily acting barriers prevailing upon the migration routes of fauna and flora are:

1. The Uralo-Caspian mountain and transgressional lake barrier crossing the Eurosiberian area from N to S.
2. The Bering Strait marine barrier, mentioned above.
3. The Ciscaucasian marine channel barrier.
4. The North Chinese to Kukunor lake chain barrier - probably in the continuation of the Central/Eastern European--Euxinian--Caspian--Aralian members of the Paratethys-Sea chain.
5. The Suleiman mountain barrier, crossing the eastern flank of the Euro-Indian area between Afghanistan/Baluchistan and India.
6. The above mentioned Siwalik channel before filling up during late pre-*Hipparion* times.

At least we have to remember that the effect of all these "barriers" is very different and changing in time.

CHINESE-EUROPEAN AND CHINESE-NORTH AMERICAN CORRELATIONS:

Living under the pressure of the "Holarctic" concept we are obviously inclined to simplify the studies dealing with trans-Beringian faunal correlations in respect to Eurasia, whilst we do not realise that Eurasia is not a term to be compared equivalently with N-America. Eurasia is a complex of at least three continental units, very diversely connected together at different geological ages: Eurosiberia, Palasia and Euroindia are the units preceeding the present-day Palearctis and "Indomalaya" (KRETZOI,M. 1964). Eurosiberia was actually the "continent" to meet from time to time with N-America (Holarctic connection) and with the Indian subcontinent. Former Malaya was a part of southern Palasia - a continental unit of uncertain limits and influenced by hardly known other impacts. China - as a part of Palasia - participated from the Beringian influence (both European and N-American) only from Northeast Siberia. This complicated and frequently changing sequence of connections and isolations rules the historical-paleogeographical situation, immensely complicating stratigraphical/chronological correlations between these continents.

Other factors influencing connections or even causing barriers are the Quaternary glaciations, acting in two ways: firstly by pulling the boundaries in the area southwards, both in Europe-Asia and N-America and secondarily by causing the lowering or rising of sea-levels due to melting or building up of large ice masses, resulting in great emersions of the continental shelves and land bridges, or in overflooding these land "bridges".

The fact that land bridges were built between Siberia/ Alaska ("Beringia") in the north and in the Mediterranean belt in the south - in alternating periods - is also complicating the process.

In the Late Cenozoic the situation was clearer and more simple. Successful land bridges were built crossing the Tethys between Europe and Africa in the Upper Burdigalian and

Serravallian/Badenian, in the Beringian region in the Upper Miocene/Barstovian, Baltavárian/Hemphillian, Biharian/Irvingtonian and Toringian/Rancholabrean.

Europe and the Middle East as far as to India met surely at the beginning of the Baltavárian/Nagrian, in Ruscinian/Tatrotian, with the restriction that Europe and the Middle East had good connections in other periods too, but this communication did not reach India ("Suleiman"-barrier of Heintz, É.--BRUNET,M, 1982). In this connection it is to remark that *Hipparion* faunae arrived - without *Hipparion!* - the Indian subcontinent in the Late Cenozoic first in the Eppelsheimian/Chinjian and in a second wave (with *Hipparion*) in the Baltavárian/Nagrian.

PALASIAN RADIATION TO W AND E

H.F.OSBORN was the first (1910) to call attention to the deciding importance of the vast region of Inner Asian highlands for the evolution and radiation of the Tertiary mammal fauna. He designated the greater part of the post-Lower Oligocene mammal evolutionary stocks as arosen from this great evolutionary centre.

Later sientific research, though changing some of the ideas initiated by OSBORN, generally confirmed his statements; an important part of our modern mammmal groups appeared first in this region to radiate later to Europe, Africa, India, E-Asia, Siberia and crossed the Bering Strait to N- and finally S-America.

Broad-scale excavations and faunal research work in different territories of China carried out in the last decade brought us to a new level of understanding the faunal evolution in China during the Late Cenozoic. This basic new knowledge in faunal evolution can help us to separate the forms originally qualified as of European or American, perhaps of Siwalian origin, as true Palasian elements joining other faunal associations and migrating between Eurosiberia and N-America.

Although Palasia was the actual cradle of many Paleogene mammalian stocks radiating to both Europe and N-America, this role continued in the late Cenozoic too. We are far from being able to give a more or less complete list of Late Cenozoic evolutionary groups coming from Palasia, but many important groups could even be accepted as recognized - or recognizable - Palasian ones. A provisory list of families or at least genera belonging to these can be given in the following enumeration:

1. Though it began in the Oligocene, the actual phyletic expansion of Talpidae fall in the early Late Neozoic - a process documented not only by the fossil sample, but by ecological evidences too (fossorial animals prefer grasslands, not wooded areas).

2. Arvicolid origins must be placed with high probability to Palasia, starting from Miocene local cricetid forms, as documented by another cricetid offshot, the Myospalacidae never crossed the boundaries of the region. Neither European, nor N-American origin of Arvicolids and other arvicoloid specializations can be recognized by actual fossil documentation.

3. It is difficult to evolve a theory in respect of the Lagomorph origin; arguments can be enumerated in favour of or against both territories. Probably the role of Palasia is a secondary - Late Cenozoic - radiation centre of western extensions as "stops" between North America and Eurosiberia.

4. Ursids appear suddenly in the Upper Pliocene in Europe, E-Asia and N-America. Supposed phyletic connections with Agriotheriids *("Ursavus")* lack phylogenetic evidence (KRETZOI,M. 1942, 1971). The only difficulty is the arrival of Ursids in Europe with Ruscinian "Subhimalayan" elements, although this contradiction is balanced by the contemporaneous appearance of this family in N-America. Strong argument for the Palasian origin of Ursids seems to be the record of a true Ursid from a Chinese *Hipparion* fauna (QI GUOQIN, 1984).

5. Both Ailurids and Ailuropodids had been often quoted as to be descendants of European ancestors, but all these theories proved to be failures. Both groups can better be bound

to local Palasian stems.

6. Few data are at our disposal to make ideas on the origin of true Hyaenines, therefore I only mention the Mio/Pliocene presence of a very evolved Hyaenine *(Percrocuta)* in the Palasian fauna, beside primitive representatives.

7. The sudden appearance of true (and at the same time very primitive) Machairodonts - *Machairodus* and allied forms - in both European and North American later (Baltavárian--Hemphillian) *Hipparion*-faunae replacing the highly specialized Sansanosmiles in the former and Nimravids in the latter region, is a pressing argument for the palasian radiation centre of these "ancestral" true Machairodonts.

8. The same role as in the case of Lagomorphs can be assigned to Palasia in the invasion of Proboscideans to N-America on the way Africa-Europe-Asia, otherwise some immigrants of the N-American fauna would be rootless in Europe or SW-Asia.

9. Rhinocerotid taxonomy and phylogeny are both weak points in our knowledge, preventing a more detailed theory on the origin of special evolutionary lineages of this complicated family. Therefore only Chilotheres and some allies can be suggested as very probable Palasian genera.

10. Cervids are new immigrants in the New World. The first known N-American true Cervid is of Upper Pliocene (Ruscinian/Csarnótan) age, a member of the "American Cervids". Another branch of deer phylogeny, the Alcinae could be an Early Pleistocene immigrant (KAHLKE, H.-D., verbal information), while the "Old World Cervids" as *Cervus, Rangifer* reached N-America only in the Late Pleistocene.

11. The most spectacular example for a great Palasian radiation centre for mammals are numerous Bovids - and I think - all Caprids (Ovibovines included). It is premature to give a list of the Bovid-Caprid genera suggested to belong to this evolutionary centre. But it can be accepted that all the remarkably hypselodont "Caprids" are (starting deep in the Oligocene) well separated from true (brachyodont) Bovids having been limited in earlier ages to Palasia, from where they radi-

ated with the Hipparions to Europe and later N-America. "Caprids" or Ovibovines of earlier (Late Miocene) date in Africa *(Oioceros?)* are to reconsider before being accepted as such.

All these arguments speak - together with Paleogene survivals - for a well distinct Palasian radiation centre of mammalian evolution, which is of eminent importance for the understanding of European and North American faunal exchange and chronological correlation.

EUROINDIAN CORRELATIONS

European and Indian mammal faunal correlations have been based for a long time on two "pillars": the supposed contemporaneity of *Hipparion* and the "Siwa-Malayan" correlation. This pair of correlations was based primarily on Pilgrims faunal and stratigraphical work (PILGRIM, G.E. 1910 etc.). Secondary correlations were based on the decline of *Hipparion* dominance both in Europe and Siwaliks towards the end of the "Pontian" and Dhok Pathan.

Latest excavations in the Siwaliks and on the Potwar Plateau demonstrated the error in the former parallelization of the arrival of *Hipparion* in Europe and the Siwaliks: no *Hipparion* occurrence could be detected in the Chinji Lower Siwaliks; they arrived in the Nagri beds during the second or later *Hipparion*-faunal age. The second correction of the Siwaliks was possible by the better understanding of the Javan Early and Middle Pleistocene faunae: an intimate connection between South Chinese and Javan faunal complexes could be admitted which explained all the forms of the Early/Middle Pleistocene Javan fauna not understandable from Siwalian connection (like Tapirs and other exclusively "Sino-Malayan" forms in "Indian" relations).

Unsolved remained the origin of the "archaic" forms of the Siwalik faunal assemblage, unfamiliar for both European and Chinese faunae. These are the Prosimians, Creodonts and Anthracotheres - all of Paleogene African origin, or at least survivors in Africa, extinct in Europe long ago. In determining the possible time of immigration new difficulties arose: the Creodonts appear only in the later (Nagrian) *Hipparion* faunae of the Siwaliks, whereas other Creodonts, present also in the European Early/Middle Miocene, are not lacking from the Indian Lower Miocene. Since nothing is known yet from the Indian Peninsula's early fauna, it seems to be acceptable to suppose that the Siwaliks were enriched by African forms - apart from an intimate Paleogene connection - during Early Miocene times (but not simultaneously with Europe) and later to a date similar to or perhaps somewhat preceeding the local invasion of *Hipparion*.

The post-Dhok Pathan--Early Tatrot assemblage is possibly of Subhimalayan local origin to be interpreted as a climatic facies of the Siwalik fauna after undergoing a humid filtering, with some (European) immigrants.

The *Equus* fauna seems to be more an immigrant assemblage of temperate China than an association of S-Chinese (Sino-Malayan) aspect.

The Middle and Late Pleistocene Indian fauna is a mixture of European faunal elements with few Himalayan and some very late Malayan immigrants, even in the W and E of the region.

It is to be emphasized that European-Indian connections prevailed at the end of the Chinjian-Eppelsheimian humid time range (Suids) with a characteristic aridity-sieve (no *Hipparion* in the pre-Nagrian Siwaliks!), followed by a well marked steppe-savanna-connection in the later (Nagrian to Dhok Pathan) ages with European late *Hipparion*-faunae (Early to Late Baltavárian).

Perhaps the most characteristic faunal exchange between India - or more exactly the Subhimalayan monsoon-forest zone - and Europe occurs in the Ruscinian (reaching as far as to S-England). Up to day there is no exact correlation with the Tatrot, partly due to our insufficient knowledge of the Siwalik faunal complex, and partly due to the sporadic migration of Subhimalayan taxa via the Middle East prior to their arrival in Europe.

As a result we can state that Chinji is broadly parallelizable with the European Eppelsheimian, Nagri and Dhok Pathan with the Baltavárian, whilst Tatrot is firmly correlated with Ruscinian, perhaps reaching deep in the Csarnótan. Uncertain is only the correlation of the boundaries, due to the lack of marker taxa within these ages. Instead of mass invasions a more continuous infiltration of important faunal members gives us testimony of somewhat indistinct, although characteristic boundary parallels. Surely, immediate barriers and climatic filters are also responsible for these transitional and not sharp-cut boundaries.

The Pleistocene, beginning with the Tatrot/Pinjor is very difficult to characterise, first because it is mostly known from the Peninsular India and not from the Subhimalayan regions, thus representing very different features. As a second difficulty we can mention the weak status of our knowledge of these faunal assemblages. Superficially it seems so that the Pinjor represents more the later part of the Early Pleistocene (Villányian).

Before finishing this part, some latest studies on Siwalik micromammals and stratigraphical conclusions different from ours must be mentioned. A series of excavations in the Potwar area displayed micromammal forms, especially Murids, comparable with North African Middle Miocene members of the genus *Antemus*, which have been dated by magnetostratigraphic extrapolations much earlier than expectable from our former experience (JACOBS,L.L. 1985, etc.). If these observations could be ascertained, we have to accept an early immigration of Murids in this region, essentially earlier than the European arrival of these forms at the Eppelsheimian/Baltavárian boundary, when some immigrant taxa enriched the variety of African-Indian (Siwalian) faunal exchange. But first evidence for this chronological "rearrangement" must be better founded than by the extrapolation of a single 9.5 My fission track datum obtained from the base of the Potwar series without being able to date the whole sequence - at least through interpolations - with the help of data from the top.

In addition to the stratigraphic problems discussed above, chronological problems of the Siwalik/Potwar Hominoid sample must be discussed tentatively, because of the high importance of the chronological position of these fossils, greatly influencing our concepts on the homonization process.

The problem posed by the chronological status of the Siwalik/Potwar Hominoids is as follows:

Whether the oldest finds of the *Sivapithecus-Ramapithecus* group are Chinjian in age, then they could have migrated from NE-Africa via Arabia directly to India, more exactly to the Subhimalayan region to reach S-China near the boundary of the Bahean/Baodean, or a little later, in the Early Baodean. But, if they are only Nagrian in age, as is shown by latest evidence, then S-China could be populated by this group even earlier from the West, on a route N of the Himalayan zone - a possibility for a direct faunal exchange between the Middle East and China. But were the Siwaliks - at least partly - separated from S-China, the distinctness of the Siwalian *Sivapithecus* (as represented by GSP-15000) - as a typical orangoid form - from the South Chinese *"Sivapithecus"*, a not-orangoid type, becomes evident. Problematic remains the presence of a *"Ramapithecus"*-form in both areas. All these questions have to be answered prior to the theoretical construction of a possible migration route of the (still unknown) Upper Pliocene prehominids leading to the Sangiran-Trinil *"Pithecanthropus"* level and to *Homo* - if the non-Australopithecine origin of man will be recognized (KRETZOI,M. 1976 etc.).

THE EUROSIBERIAN AREA

It is interesting and at the same time very disputable that correlations in both faunal exchange and biochronological units are always worked out between Europe and N-America, never taking in account the great distance and the intercalated continent-wide Sino-Siberian territories. I think here of the vast territory between the Ural Mts., N-Polar

Sea, NE-Siberian mountain ranges, Altai, Tien Shan, Pamir and adjoining mountain ranges of the Alpids (if not running from the Tien Shan directly westwards to the S-Ural). This region with the dimensions of approximately one-and-a-half to two times Europe, demonstrated during the Late Cenozoic a faunal succession differing from that of Central Europe only in climatic respect as subarctic zone of the former. All other differences are caused by the temporally changing impact of the Palasian region in faunal immigrations. Elements originating from the Palasian fauna are in the Late Cenozoic ages primarily Myospalacids, some Arvicolids, many if not all Bovid groups, primarily the Ovibovines, Caprids ("Ovicaprines") and probably some Carnivore groups of yet unknown origin. Besides these groups many other had a secondary "gene-centre" in Palasia, like some Rhinocerotid branches a.o.

Sieving out these Palasian elements from the Siberian faunal body, the territory remains a climatic filter for forms, and even groups able to cross the Bering Strait and reach N-America in the climatically corresponding Alaskan peninsular "bridge-head" or from the North American Boreal zone through Alaska and the Bering peninsula to Eurosiberia.

No groups living under conditions of warmer and humid climate could cross the climatic sieve of Beringia: to mention Late Cenozoic evolutionary lineages, no Dermopters, Tupaiids, Primates (except man's conquer of America to a very Late Pleistocene date), Murids, Hystricids, Hippopotamids, Suids, Giraffids, and many genera of the remaining families could never reach N-America. On the contrary, for a lot of North American families the Bering Strait and the Palaearctis remained closed for ever, like for Platyrrhine Primates, Heteromyids, Erethizons, Antilocaprids a.o.

These view-points are leading in our definition of the Siberian faunal region of the Eurosiberian realm, characterizing it simply as the boreal/subarctic belt of the Eurosiberian realm, with some boreo-arctic immigrants of the Alaskan-N-Canadian zone of North America and some of the boreo-alpine forms of the Palasian region, both stopping at the boundary of temperate and warmer zones of the Eurosiberian unit.

EUROPEAN--NORTH AMERICAN CORRELATION

Faunal interrelations and chronological correlations between N-America and Europe have been favourite topics of paleontologists on both continents since a long time. A very advanced knowledge of the paleofauna on these continents and the intimate relations of the recent faunal composition in the Holarctic greatly stimulated this work. The only important difficulty was posed in this work by the poor knowledge of the E-Siberian paleofauna in general and a nearly total lack of knowledge relating the impact of the Palasian faunal region in this process. Only the discoveries of the last 2-3 decades in China, NE-Siberia and the adjoining Mongolian territories gave some help to come to a better understanding of what we call Palasiatic fauna and its influence in adding foreign types to the immigrant elements from N-America and Europe respectively.

Taking in account the possible Palasiatic influence we can outline the Late Cenozoic faunal exchange between Europe and N-America as follows:

1. First immigration of true Equids to Europe from N-America during the Lower Burdigalian (Gerandium, MN-2a): arrival of *Anchitherium* (but first record in Asia in the Bahean/Eppelsheimian).

2. First Mastodonts in N-America in the Barstovian, after gradual extension to E-NE from Europe (arrived from Africa in the Burdigalian).

3. Explosive intrusion of the *Hipparion*-wave to Eurasia in the Eppelsheimian/Clarendonian via Bering Strait. The *Hipparion* front reached China possibly at the same time (in terms of geology) as Europe on the way through Siberia, and surely later (Nagrian/Baltavárian) the Siwalian region and most probably also Africa. Consequently, the so called *Hipparion* datum is different for Europe, the Siwaliks and Africa.

4. Broader exchange of forms of the European--Siberian and North American *Hipparion* faunae in Baltavárian/Hemphil-

lian times. Some Insectivores and small Rodents accompany the ascertained series of forms like *Sinocastor/Castor*, Agriotheriids, *Simocyon*, many Mustelids (*Plesiogulo*, Melines etc.), possibly Hyaenids *(Ailuraena)*, and perhaps some sporadic antelopes, invading N-America. Meantime the European-Siberian fauna received a *"Neohipparion"*-like *Hipparion* (probably this genus), some Insectivores, rodents and the first true Leporids *(Alilepus* and related forms*)*.

5. More colourful, though not explosive was the Ruscinian/ "Kimballian" interchange of mammal forms. At this date, N-America received its first Arvicolids s.l., Ursids, an Ailurid, Grisonines, and the first Cervids, whereas invaders to Europe from N-America were at first Canids (Nyctereutines etc.) and Camelidae.

6. These slower, more infiltrating migrations were followed by the mass-invasion of *Equus* s.l. group and *Canis* (the wolves) to Siberia--Europe at the beginning of the Pleistocene (Villafranchian/Blancan), while N-America did not accept any European--Siberian invaders this time, if not the Alcines.

7. A well marked new immigration of Eurasian origin overflood North America at the beginning of the Middle Pleistocene (Biharian/Irvingtonian) in form of modern Arvicolids (with rootless molars), Soricids, Elephantids *(Archidiskodon)* and modern Cervids and perhaps other forms (apart from some Palasian elements not to list under the title of European invaders). Only few N-American forms invaded to Eurasia this time *(Xenocyon*, etc.*)*.

8. The last interaction between the faunae of Europe--Siberia and N-America evolved in the Late Pleistocene and extant fauna of temperate-boreal-arctic Eurasia and N-America, not at least characterised by the invasion of *Homo* to the New World. Details of this faunal interchange are well known, and should not be repeated here.

A number of migrations via Bering Strait listed usually as Euro-Siberian exchanges, actually have to be interpreted as migrations of mixed associations of Palasian and Euro-Siberian elements, using the Beringian-Alaskan gate on their way to N-America. These forms and their expansion both to W and NE are discussed in many papers of North American and European scientists who clarified most of the details of this broad-scale faunal exchange. The main Late Cenozoic biogeographic regions are shown in *Figure 1.* A correlation table summarizing the present knowledge is added *(Table 1.)*.

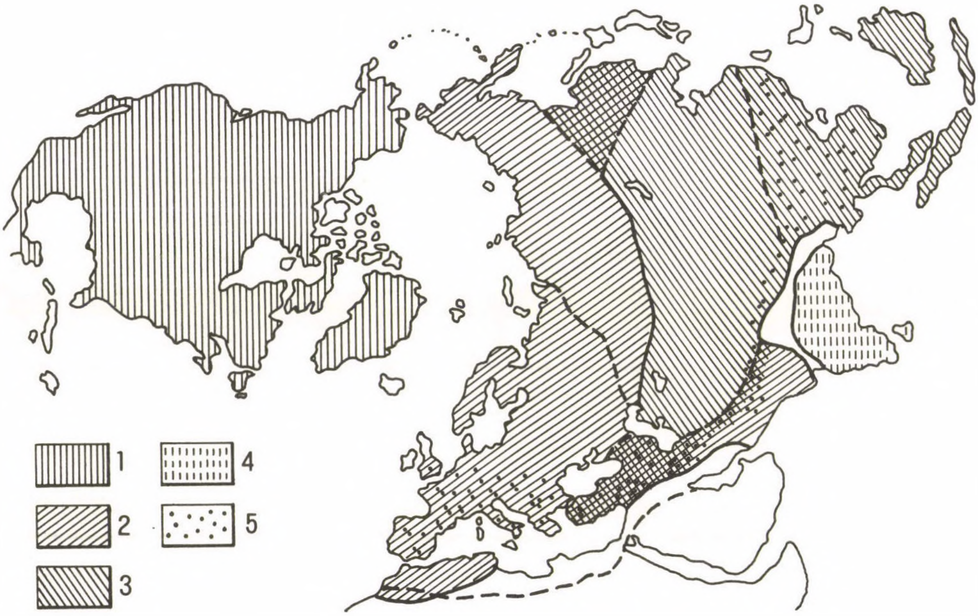

Fig. 1 Main Late Cenozoic biogeographic regions

1 = North America; 2 = Eurosiberia; 3 = Palasia; 4 = India; 5 = Ruscinian belt

Table 1. Chronological correlations

European marine biochronology: Mediterranean	European marine biochronology: Central Paratethys	Terrestrial (mammal) biochronologies – European: Sub-epoch	European: Ages	European: Subage	European: MN/O ind.	Chinese: Ages	North American: Ages	My /tentative/
1, 2		Danubian	European	Toringian	19	Choukoutien.	Rancholabr.	
Emilian, 3				Biharian	18	Nihewanian	Irvingtonian	1
Calabrian				Villányian	17			
Piacenzian				Villafranchian	16	Youhean	Blancan	2
			Barótian	Csarnótan	15	Jinglean		3
Zanclean				Ruscinian	14			4, 5
Messinian	Pannonian	Catalonian	Baltavárian /Turolian/	Bérbaltavárian	13	Baodean	Hemphillian	6
Tortonian				Hatvanian	12			7
				Sümegian				8
				Csákvárian	11			9
			Eppelsheimian /Vallesian/	Rhenohassian	10	Bahean	Clarendonian	10, 11
Serravallian				Bodvaian	9			12
				Hipparion datum				
	Sarmatian	Aragonian	Astaracian	Monacian	8	Tunggurian	Barstovian	13
				Grivian	7			14
Langhian	Badenian			Sansanian	6	?		15, 16
Burdigalian	Karpatian			Pontilevian	5			17
	Eggenburgian		Orléanian	Collongian	4	Shanwangian	Hemingfordian	18
				Romievian				19
				Tuchořicean	3b			20
				Wintershofian	3a	?	Arikareean	21, 22
Aquitanian	Egerian			Laugnacian	2b	Xiejiaan		23
				Gerandian	2a			
Chattian				Paulhiacian	1			24, 25

1 = Tyrrhenian, Holocene 2 = Monastirian 3 = Sicilian

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LOESS AND PALEOSOL SEQUENCES IN HUNGARY REFLECTING CYCLIC CLIMATIC DETERIORATION IN THE LATE CENOZOIC

M. PÉCSI - L. GEREI - F. SCHWEITZER - Gy. SCHEUER - P. MÁRTON

ABSTRACT

A ground mechanical borehole revealed an especially rich series of loess and paleosol in foothill position. The 60 m profile comprises 30 paleosols, 10 loess layers, at least 10 sand layers and about 10 erosion gaps were identified. Continuous sampling was performed and the layers were analyzed granulometrically, pedologically and mineralogically. Paleomagnetic measurements only involved the layers suitable for this purpose.
It was found that in the young loess series (L_1- L_6) humic loess (P_1H, P_2H) and mostly chernozem-like forest-steppe soils (P_3C - P_6C) occur.
In the old loess series (L_7-L_{10}) unconformities are observed, there are five sandy layers (S_2-S_6) and at least 10 brown forest soils (P_7B-$P_{17}B$) are intercalated. In old loess paleomagnetic analyses (L_7, P_{13}, $P_{14}B$, $P_{15}R$) always showed normal polarity, only in the loess layer L_{10} it was reverse.
Below the old loess series, the sequence of red soils and red clays ($P_{18}R$-$P_{29}R$) two major sand layers are intercalated. Part of the red soils, however, also formed on sandy parent materials; their types indicate submediterranean xerophytic forest environments.
The base layers of the profile (56-60 m) are represented by sand, montmorillonitic and bentonitic clay and hydromorphous meadow soil layers overlying the Upper Miocene (Pannonian) sand formation.
During the formation of red soils (in the Csarnótan and Villányian stages of the Pliocene, presumably Gilbert and Gauss epochs), mediterranean and submediterranean climatic conditions alternated. When old loess was formed, warm temperate, etasian forest climate, temperate deciduous forest climate and dry steppe climate of loess formation followed each other. Although there was a general deterioration, submediterranean climate returned for several periods (for instance, at $P_{14}R$ and $P_{15}R$ soil formation).
The chernozems (forest steppe soils) intercalated into young loess and, first of all, the humic loess layers indicating subarctic climatic influence attest to climatic deterioration. The latter are younger than 20 Ka, while the chernozems are not older than last interglacial.

* * *

INTRODUCTION

Hungary lies in the Middle Danubian Basin. Most of its area (60 per cent) is lowland and a smaller part is constituted by low mountains and gently sloping hill regions (40 per cent). The overwhelming part of the terrain (80 per cent) is mantled by Quaternary deposits, among which loess is preponderant.

The flat lowlands are in young (Cenozoic) basins filled by sediment sequences (brackish, lacustrine overlain by fluvial and eolian formations) in several kilometres' thickness. In the basin series Quaternary formations attain thicknesses of several hundred metres and locally even a thousand metres. They are mostly alluvial deposits, on which cyclically buried eolian series accumulated and fossil soils formed.

The thickness of subaerial deposits (alternating gravel, sand, loess and soils) on the pediments and alluvial fans of hill regions and mountain forelands is less than a hundred metres. Their base is usually Upper Miocene (Pannonian) inland lake sediments of sand and clay. Recently, several key sections were described along the basin margin and on alluvial fans, where the subaerial clay, loess and paleosol sequence was almost a hundred metre thick (MÁRTON,P. 1979; PÉCSI, M. 1979, 1982, 1984, 1985a; PÉCSI,M. - SCHEUER,Gy. 1979; PÉCSI,M. et al. 1979; GEREI,L. - REMÉNYI,M. - PÉCSI-DONÁTH,É. 1979). Here a loess-paleosol sequence is demonstrated revealed in cores in a typical position on foothill surface and particularly instructive *(Fig. 1)*. It is the 60 m profile in the Posta valley, S of the town Pécs, near the urban boundary *(Fig. 2)*. In the present paper the results of the analyses are used to answer the question of what changes in the paleoenvironment can be reconstructed from the types of fossil soils and the sequence of loess layers. When establishing the trends for change over time, the results of previous profile analyses were also considered. The profile gives a new opportunity to date the advent of loess and red clay formation in the Middle Danubian Basin.

THE POSITION OF THE POSTA VALLEY LOESS PROFILE

The core drilling was located in the southern Transdanubian Hills, in the foreland of the Mecsek Mountains, on a foothill surface 215 m above sea level *(Fig. 1)*. The foothill is dissected into interfluvial ridges mantled by thick loess. The broad erosional valleys were cut by small streams and derasion valleys (dells) of various size without water-course were adjusted to them. A similar topography is assumed for the loess-mantled foothill during the Upper Pleistocene. Today climate is moderately continental under submediterranean climatic influence. Mean annual temperature is +10.5 to 11°C and annual precipitation is almost 700 mm (with summer and autumn maxima).

The area is characterized by brown forest soils formed under *Quercus cerris* forests before deforestation. By today, they have generally acquired chernozem brown forest soil characteristics in the wake of field cultivation.

The profile was made from the field analyses of continuous samples from a core designed primarily for ground mechanical purposes and the investigation was supplemented by laboratory analyses *(Figs. 1, 2)*. We laid emphasis on precise sampling, as we also aimed at litho- and chronostratigraphical interpretations.

SUBDIVISION AND BRIEF DESCRIPTION OF THE PROFILE

By its lithological and paleopedological properties, the Posta valley profile is subdivided into four units:

1. Young loess series predominantly with chernozems	0 to 23.0 m
2. Old loess series predominantly with interbedded brown forest soils	23.0 to 42.0 m
3. Red soils, red clays	42.0 to 56.2 m
4. Variegated clay, bentonite and grey sand series	56.2 to 60.0 m

Striking feature of the profile is the predominance of paleosols, especially in the lower third, where red soils almost directly overlie one another and they are only divided by some ten centimetres of $CaCO_3$ accumulation horizons.[1]

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1 The loess, soil and sand layers identified through mineralogical-petrological and pedological analyses are lettered and numbered for clearer presentation (Fig. 2).

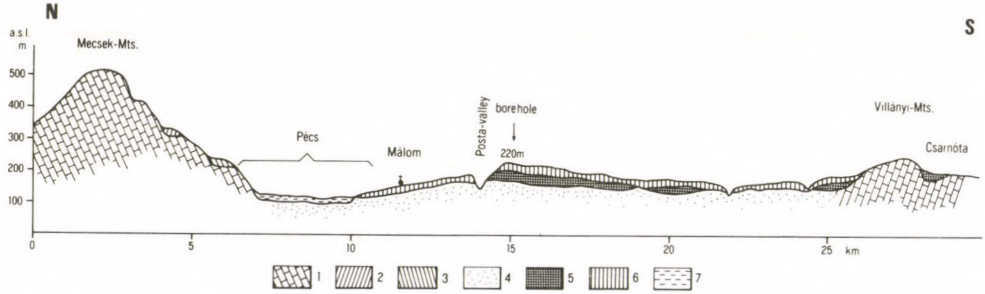

Fig. 1 Geomorphological and geological situation of Posta valley borehole at Pécs (M.PÉCSI - F.SCHWEITZER 1987)
1 = Mesozoic limestone, marl, sandstone; 2 = Upper Miocene marine terrace with Sarmatian limestone; 3 = Upper Miocene marine terrace (Upper Pannonian); 4 = Upper Miocene (Pannonian) sandy formation; 5 = Pliocene reddish paleosols, red clays formation; 6 = Pleistocene loess and paleosol sequence; 7 = Upper Pleistocene-Holocene alluvial sequence

Of the whole profile cyclical sand intercalations are tipical; they occur in each of the four subseries. There are at least five sand layers, where sand fraction amounts to more than 60 per cent and in other six layers it reaches or exceeds 40 per cent. In addition, several paleosols are also formed on sandy parent materials. The frequent sand intercalations can be explained by the position of the profile on foothill surface.

Young loess series. Its lower boundary was drawn at the sandy layer with small pebbles at 22-23 m. This layer indicated as S_2 can even represent an erosion gap in the profile; another erosion hiatus occurs at 8-10 m (S_1 layer). The S_1 layer is quartz sand with much mica redeposited from the Pannonian sand overlying the piedmont by small water.courses.

The young loess series comprises six characteristic sandy loess layers (L_1 -L_6). L_1 is the thickest (6 m); it is rather homogeneous, unstratified sandy loess with medium $CaCO_3$ content. The slightly humic loess in its base (P_1H) is known from several key profiles (PÉCSI,M. - SZEBÉNYI,E. - PEVZNER,M.A. 1979; PÉCSI,M. 1985a). Dated from charcoal remnants, the uppermost humic layer is 16,000 years old, while the lower humic loess (P_2) is 21,000 years old in the exposures of the area (Dunaszekcsö brickyard - PÉCSI,M. 1985a). It seems probable that the slightly humic layer P_2H in the studied profile corresponds to the latter.

The loessy layers in the lower third of young loess (L_3-L_6) are very sandy. There are four chernozem soils interbedded between them (P_3C-P_6C), three of which (P_4C, P_5C, and P_6C) were formed essentially on sandy parent material. The most marked is the soil P_5C, an about 2 m thick chocolate brown chernozem (with calcareous film). The upper part of the soil profile is a soil sediment of small gravel and sand.

The analyses of core samples taken from between 16-22 m revealed fairly clearly that in the lower third of young loess forest-steppe soils of chernozem character formed, as it is also observed in open exposures. Notwithstanding, the correlation or comparison with the stratotype soils in exposures remains unsolved. Certain paleosols (P_3C and P_6C) seem to be truncated profiles, eroded or reworked during or after their formation. Stratigraphy may be aided by the fact, revealed by the analysis of P.MÁRTON, that the sample from about 19 metre in the soil P_5C showed reverse paleomagnetic polarity in three of the four examinations. (It probably corresponds to the Blake event, cca 125 ka).

The young loess series of the Posta valley core comprises two humic loess horizons, four paleosols of chernozem type, six loess layers and two fluvial sand accumulations - altogether 14 formations.

Old loess series. The old loess, after which this subseries was named, is only repeated four times (L_7-L_{10}) in the sequence *(Fig. 3)*, while intercalated sand layers occur in the same number (S_3-S_7). The most remarkable erosional unconformity is represented by the sand layer S_6 at the interval of 37-39 m. The occurrence of ten paleosols (P_7-P_{17}) is striking. Their overwhelming majority are brown forest soils; there is only one red clay soil ($P_{15}R$) and a hydromorphous soil (P_{14}). All of them seem to be autochtonous and have their own illuvial horizons. Most of the brown forest soils overlie sands instead of loess or, in several cases, they were even formed

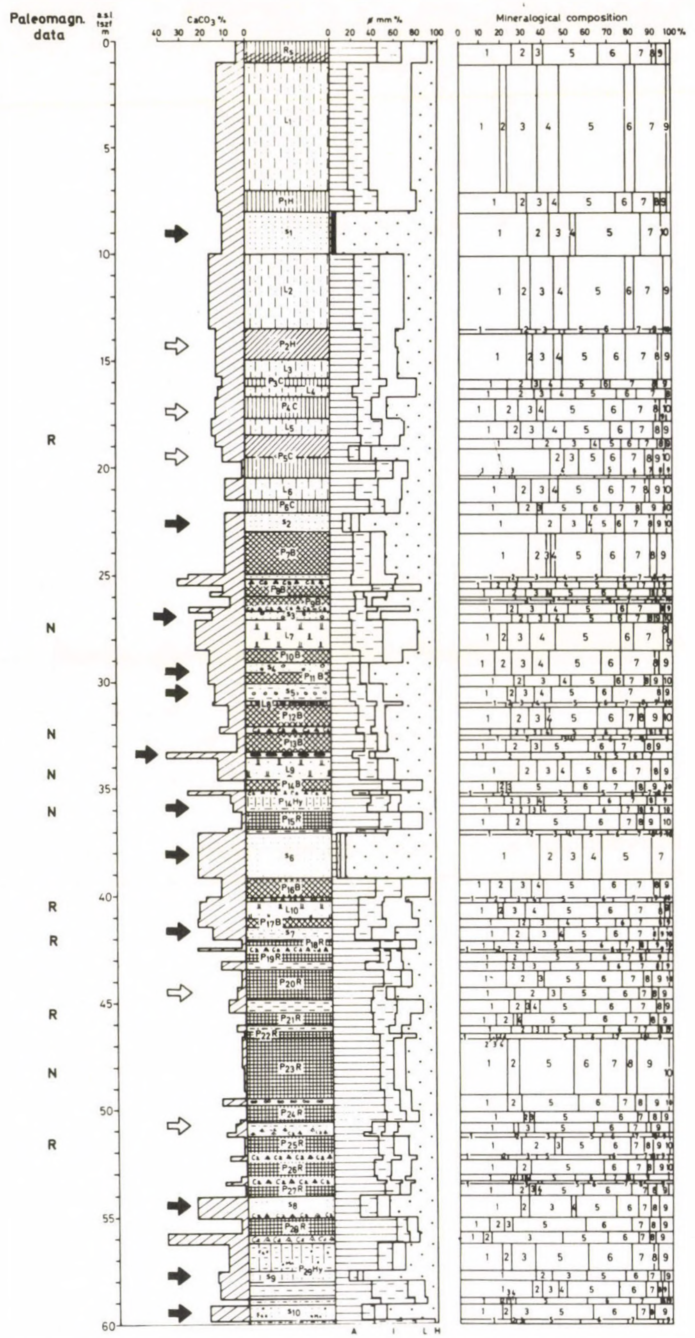

Fig. 2 Loess-paleosol sequence of Posta valley at Pécs. Lithological, paleopedological and mineralogical analyses made by M. PÉCSI-Gy. SCHEUER - F. SCHWEITZER - L. GEREI - Mrs.M. REMÉNYI: paleomagnetical data by P.MÁRTON (R =reverse; N = normal polarity)

on sandy parent material. It is, first of all, valid for soils nos P_7, P_{10}, P_{11}, P_{12}, P_{13} and P_{17}. It is also characteristic that the pairs of soils (soil complexes) directly overlie one another and their separation is only justified by their distinct and well-developed Ca horizons. Therefore, they should be considered separate soil formation intervals by all means.

In the Posta valley profile the uppermost brown forest soil (P_7B) was formed on sand and it is separated from young loess by a fluvial horizon of small pebbles (S_2). No strong evidence exists for the degree of the erosion gap observed here. Lithostratigraphically, this position is occupied in the key exposures (at Mende, Paks, Dunaföldvár and Dunaújváros) by the so-called Mende Base paleosol. Its formation is dated last interglacial (PÉCSI,M. 1982, 1985a; PÉCSI,M. et al. 1979). Lacking other evidence, this correlation is not yet sufficiently founded.

For the time being, the soils in the old loess series in our profile are rather difficult to correlate with the paleosols in the old loess series of previously studied exposures, because there are twice as many paleosols in the borehole as, for example, in the Paks profile.

Paleomagnetic analyses show that old loess and the intercalated paleosols have normal polarity down to 37 m depth. Therefore, they are not older than 0.73 million years.

Red soils and red clays. A characteristic of the series of cca 15 m thickness (from 42 to 56.2 m) is the overlay of brick-red- cherry-red -ochre-red paleosols (P_{18R} -P_{29R}). It is only once that one metre of sandy layer (S_8) is interbedded

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Fig. 2

L_1-L_6 = young loess; L_7-L_{10} = old loess; S_1-S_{10} = sandy layers; P_1H, P_2H = humic loess, embrional paleosols; P_3C-P_6C = chernozem-like forest-steppe paleosols; P_8B-$P_{14}B$ = brown forest paleosols; $P_{15}R$-$P_{29}R$ = ochre-red paleosols, red clays; P_{14}-Hy, P_{29}Hy = hydromorphic meadow soils; A = clay (-2-10 micron); I = fine silt (10-20 micron); L = loess (20-50 micron); H = sand (50-500 micron); 1 = quartz; 2 = felspars; 3 = calcite; 4 = dolomite; 5 = micas + hydromicas; 6 = montmorillonite; 7 = chlorite; 8 = kaolinite; 9 = interstratified minerals; 10 = Al and Fe hydroxides
➡ = significant unconformity; ⇨ = unconformity

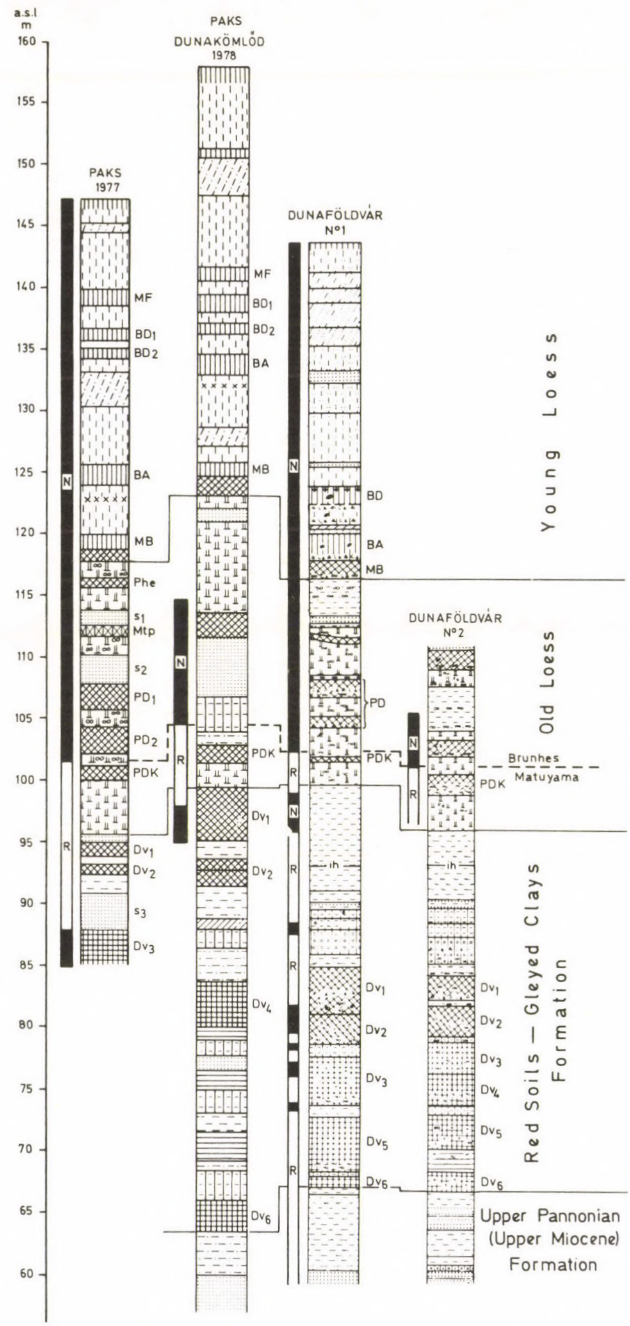

Fig. 3 Loess and paleosol sequence at Dunaföldvár. Lithological, pedological analyses made by M. PÉCSI - Mrs. E. SZEBÉNYI - F. SCHWEITZER; paleomagnetical measurement made by M.A. PEVZNER

between the paleosols, but it also represents strong $CaCO_3$ accumulation *(Fig. 2)*, in other two cases clayey and silty (aleuritic) $CaCO_3$ accumulation horizons of maximum 0.5 m thickness (P_{20}-21 and P_{24}-25) between the red soils. The red paleosols are only divided by $CaCO_3$ accumulations of some 10 cm thickness with concretions. High sand contents (20 to 40 per cent) are typical of all the red soils, even of those (P_{20}, P_{24}, P_{27} and P_{29}) where clay fraction reaches or exceeds 50 per cent. Some of the red paleosols were certainly formed on sandy parent materials (such as P_{27}, P_{24}, P_{21}, and P_{20}). Most of the sand was redeposited by water-courses from Tertiary (Pannonian) sand, but during drier spells eolian reworking could be active too.

Although research into the overlay of red soils has been carried out for more than a decade now (PÉCSI, M. 1975, 1978, 1984; PÉCSI, M. et al. 1979), such a long series of red soils,

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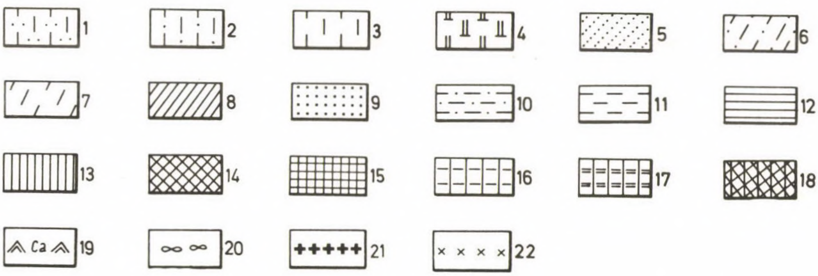
Fig. 3



1 = loessy sand; 2 = sandy loess; 3 = loess; 4 = old loess; 5 = slope sand; 6 = sandy slope loess; 7 = slope loess; 8 = semi-pedolite; 9 = fluvial-proluvial sand; 10 = silty sand; 11 = silt, gleyed silt; 12 = clay; 13 = steppe-type soil, chernozem; 14 = brown forest soil; 15 = red clay; 16 = hydromorphic soil; 17 = alluvial meadow soil; 18 = forest soil (on flood-plain); 19 = calcium carbonate accumulation; 20 = loess doll; 21 = charcoal; 22 = volcanic ash;
MF = "Mende Upper" forest-steppe Soil Complex (29,800 years B.P., Mo.421 and HV 27,855 ± 599 years); BD = "Basaharc Double" forest steppe Soil Complex; BA = "Basaharc Lower" chernozem soil; MB = "Mende Base" Soil Complex (brown forest soil + forest steppe soil); Phe = Paks sandy forest soil; Mtp = Paks marshy soil; PD = "Paks Lower Double" Soil Complex (brownish-red Mediterranean-type dry forest soil); PDK = Paks-Dunakömlöd brownish-red soil; Dv_1-Dv_6 = Dunaföldvár red soils; ih = silty sand; S_1-S_3 = sand

as many as 11, have not been found in the hill regions of the Middle Danubian Basin. The previous experience (PÉCSI,M. 1985b; PÉCSI,M. et al. 1985), however, does not allow us to to assume that the sequence of red soils in the Posta valley profile is continuous and without erosion gaps. A minimum of three or four gaps can be concluded from the core profile; the most marked of them is the sand layer S_7-S_8.

Variegated clay and bentonite series. In the Posta valley profile, under the red paleosol series, two layers of variegated clay with frequent manganese and iron spots, two sand layers (S_9 and S_{10}) and two bentonitic clay layers are found. The sand layer S_9 is dark grey and suffered hydromorphous soil formation together with the overlying variegated clay. The two bentonitic layers are of stratigrapical importance, since they frequently occur, below the red clay series, locally in interfingered shape, on the Upper Miocene (Upper Pannonian) layers. The bentonites mentioned are regarded the weathering products originated from basaltic tuffs under the basic conditions of warm subhumid climate. In several places of the Carpathian Basin they also appear under young basalt lavas. Recent radiometric and paleomagnetic investigations date the basaltic lavas of Hungary to 3-6 Ma (BALOGH,K. et al. 1986; COOKE,H.S.B. et al. 1979; MÁRTON,E. 1985).

The layers between 58-60 m in the Posta valley profile have 51-52 per cent montmorillonite-bentonite in their clay fraction (particles finer than 2 millimicron). These layers are overlain by 11 red soils. This lithostratigraphical position allows dating the beginning of red clay formation back to times immediately after the deposition of Upper Miocene (Upper Pannonian) inland sea sediments, i.e. to the early Gilbert chron (PÉCSI,M. 1985b; KRETZOI,M. - PÉCSI,M. 1982).

MINERAL COMPOSITION OF THE POSTA VALLEY PROFILE

For the description of the series the mean arithmetic values of felspars, calcite, dolomite and montmorillonite were used. In addition, the calcite/dolomite ratio was also calculated *(Table 1)*. This method had been applied for other loess profiles too (GEREI, L. - PÉCSI-DONÁTH, É. - REMÉNYI, M. 1979).

Table 1 Distribution of felspar, calcite, dolomite, montmorillonite average content and calcite/dolomite ratio in the series of Posta valley profile

Series	Felspar %	Calcite %	Dolomite %	Montmoril-lonite %	Calcite/Dolomite
Young loess 0.00-23.00 m	8.23	8.22	4.53	8.53	1.95
Old loess 23.00-42.00 m	8.41	11.50	5.03	8.94	2.29
Series of red soils and red clays 42.00-56.20 m	7.45	7.42	0.83	15.00	8.94
Series of variegat-ed clay, bentonite and sand	4.70	9.33	1.00	17.30	9.33

The average distribution of *felspars* does not differ considerably in young and old loess. In the red clay series the average amount of felspars markedly decreases and this drop is even more significant in the layers of variegated clay and bentonite. The difference can be explained primarily by changes in the intensity of weathering processes.

The differences of *calcite* contents are characteristic in the four series. Their amount is considerable in young loess and it grows by one-fourth in old loess and decreases considerably in the red soils series, while another growing trend is observed in variegated clays and bentonites. Compared with young loess and its soils, the higher amount of calcite under the brown forest soil of old loess indicates stronger $CaCO_3$ accumulation. The red soils contain very little calcite. Their illuviation horizon, however, is rich in Ca-concretions of various size, indicating strong seasonal eluviation of the B horizon of the soil. Eluviation processes accumulated most of the calcite and $CaCO_3$ in the C and Ca horizons of red soils. The repeated increase of calcites in the variegated clay series shows that soil formation here involved eluviation of lesser intensity than in red soils. In the two bentonite horizons the decomposition of calcite reaches larger extent.

There are four or five-fold amounts of *dolomite* in old and young loess than in the series of red clays and variegated clays. This is reflected in calcite/dolomite ratios. In loess packets the amount of calcite is double of dolomite, while in red soils and variegated clay soils the amount is about 9-fold *(Table 1)*.

The rise in the amount of *montmorillonite* in the fossil soils shows a higher intensity of weathering. Thus, weathering is less intensive in the loess series and much stronger in the series of red soils and variegated clay soils.

The distribution of montmorillonites also indicates that weathering is most intensive in the variegated clay soils and in some of the red soils. It is likely to be connected with major changes in redox conditions during the formation of variegated clays and bentonites, exceeding the alterations during red clay formation. The mineralogical descriptions of the layers are included in *Fig. 2,* here evaluated briefly by series.

Young loess series. Calcite is found in all layers and soils. Dolomite is missing primarily from the various chernozems. With the exception of sand S_1, montmorillonite occurs in all layers in varying amounts. To 15 m depth kaolinite is only present in the humic layers (R_3, P_1, and P_2), it is missing from loess. With three exceptions, interlayered minerals occur in all horizons. In young loess the presence and distribution of clay minerals points to weathering of medium intensity. In the upper young loess quartz and micas are predominant.

Old loess series. In accordance with loess nature, calcite occurs in all layers but one. Where it is missing, it is a red clay (at depth of 36.00-36.80 m). Dolomite is not present in two red-brown soils (at the depth of 32.90-33.20 m and 34.50-35.20 m) and in a red clay (at the depth of 36.00-36.80 m). The amounts of calcite and dolomite and their ratios are characteristic of loess.

Except for the thick sand layer, kaolinite and montmorillonite occur in all of the layers, similar to the distribution of interlayered clay minerals. Among clay minerals, the amount of montmorillonite is generally higher in soils than in loess. It is explained by more intensive weathering related to soil formation. In old loess the amount of quartz is much less too, except for the sand layer S_6.

Series of soils and red clays. In the red clay layers the amount of calcite is less than in other layers. It is missing from five samples entirely. Out of 24 layers dolomite only occurs in 8, in small amounts, usually in the illuviation horizons of red soils.

Montmorillonite is present in all layers and shows larger amounts than in either the old or the young loess series. The presence of kaolinite in all layers also indicates that weathering processes shift the medium of the series towards acid environments to some extent. The general occurrence of interlayered minerals also indicate intense weathering and simultaneous mineral transformations. The most outstanding values are found in the red soil P_{23} of 2 m thickness.

Series of variegated clay, bentonite and sand. Calcite is present in all layers, but its amounts are much less in bentonite layers than in variegated clays. Dolomite is only found in two out of the six layers. Montmorillonite has a peak in this series occurring in all layers. This indicates that during reduction processes weathering was the most intensive in this series. Kaolinite and interlayered minerals occur in all layers. In the series, consequently, mineral composition unambiguously attests to intensive weathering induced by reduction processes.

CONCLUSIONS FOR THE SUBDIVISION OF THE PROFILE

Available data do not as yet permit the detailed lithostratigraphical subdivision of the Posta valley profile. The loess chronological or paleopedological comparisons with the previously analyzed profiles is made difficult by the fact that so many paleosols and intercalated sand layers have not been described from any of the key profiles. It has not been disclosed how many paleosols had eolian, fluvial or deluvial parent materials. Neither is it known, how many and how long erosion gaps have to be taken into account.

Thus, only a broad outline can be given of the lithostratigraphical and paleopedological subdivision of the profile. The referring of the 30 paleosols, 10 loess packets, at least 10 intercalated sand layers and 10 erosion gaps of various length into ages seems to be an attractive task. However, the danger of oversimplification could not be avoided now if we should place the loess layers, paleosols and others, by their cyclical reoccurrence on some geochronological scale.

1. Analogies make us suspect that the humic loess layers (P_1H ls P_2H) and the uppermost two sandy loess layers (L_1, L_2) could not originate earlier than 20 Ka BP, the coldest and driest period of the last glacial. Humic loess layers probably date to a somewhat more humid arctic climatic stage, while sandy loess layers are formations of a dry and cold climatic stage of the Upper Würm.

2. The chernozem-like forest-steppe soils (P_3C-P_6C) in the lower half of the young loess series, formed repeatedly, 4 or 5 times are referred by analogy to the Upper Pleistocene, some warmer-wetter interstadial stages of the last glacial. According to paleomagnetic analysis, the samples from the paleosol P_5C are of reverse polarity. Can it represent the Blake event (0.125 Ma)? It has not been proved by other key sections. The last brown forest soil of the profile is P_7B. Paleosols of similar position and genesis have been referred to the last interglacial (PÉCSI,M. 1985a; PÉCSI,M. et al.1980).

3. The chronological classification of the ten reddish-ochre brown forest soils and hydromorphous soils, five loess layers and 3-4 major sand layers is only supported by reliable paleomagnetic data in the case of four or five layers *(Fig. 2)*. The samples have normal polarity. Thus, the red clay soil P_{15R} between 35-36 m is still likely to belong to the Brunhes chron (not older than 0.73 Ma). The sand layer S_6 may represent one of the longest erosion gaps in the profile.

4. The series of red paleosols in the profile can only be correlated with similar series in other exposures (such as the Dunaföldvár boreholes as key profiles) with, even litho-

stratigraphical difficulties. There are five or six paleosols at Dunaföldvár and they also developed on Upper Pannonian (Upper Miocene) formations. In a paleopedological sense, the lower part of the red paleosol series (P_{21}-P_{29}) of the Posta valley profile seems to be represented in the Dunaföldvár boreholes (Dv_1 -Dv_6). The same conclusion appears to be allowed by the fact that both the Dv_2-Dv_3 paleosols of Dunaföldvár and the thick red paleosol (P_{23R}) of the Posta valley showed normal polarity *(Figs 2,3)*.

However, we should emphasize that sedimentation could not be continuous in foothill position; deposition periods alternate with intervals of soil formation and erosion hiatuses of various size can be taken into account. During periods of major erosion the previously formed soils or accumulated sediments could be removed. But during lasting red soil formation slow sheet wash takes place even on an equilibrium slope, while a soil is formed, probably for ten thousands of years. Therefore, great caution is necessary in the interpretation of subsequent paleomagnetic data, since a quasi-complete sequence cannot be envisaged, not to mention that the core samples can be affected by 'dynamomagnetism'.

The experience has been gathered through the analyses of several profiles of similar lithostratigraphy and position. On this basis we believe it probable that the layers (S_6-P_{21R}) with reverse polarity in the upper part of the Posta valley red paleosol series belong to the Matuyama chron (2.4 Ma).

The normal polarity of samples from the paleosol P_{23} does not only represent an event, but indicate the remnants of paleosols formed in the Gauss chron, while the reverse polarity of the soils P_{24} and P_{25} represents a part of the Gilbert chron. This hypothetical conclusion has been promoted by the occurrence of red clays in similar lithostratigraphical and foothill position in other exposures, too (PÉCSI,M. 1985b; KRETZOI,M. et al. 1982).

The lower part of the red soil series (P_{23R}-P_{29R}) and the underlying variegated clay with the bentonitic clay layers are referred to the Pliocene. It is assumed by analogies and on the basis of incomplete paleomagnetic data that the formation of the red clay series prolonged over most of the Matuyama chron, considerable parts of the Gauss and Gilbert chrons, back to cca 4-4.5 Ma BP.

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DEGREE AND RATE OF SEDIMENTATION IN LAKE BALATON

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ABSTRACT

To resolve the problems mentioned in the title, in cooperation with the Scientific Centre for Water Management Research (VITUKI), 14 boreholes were drilled into the lake bottom under the water in 1964 and 1965. The cores resulting from new technology 5 metre electric vibrosounding allowed continuous sampling and the construction of 'closed' pollen diagrams. As a new approach, mathematical-statistical and computer processing of samples for pollen analysis was applied. The pollen diagrams from Lake Balaton were adjusted to those drawn for the more westerly bogs of the foreland of the Eastern Alps partly based on C^{14} dating. Correlation and significance analyses enabled us the parallelization with archeological chronology too (cf. ZÓLYOMI,B. 1980, 1985). The pollen diagrams as well as the numerical data gathered repeatedly, the sediment sequence of Lake Balaton was established with high probability and absolute dating became possible through extrapolation. Seven boreholes with pollen diagram are aligned along the longitudinal section of the lake. Two of them illustrates vegetation history from the Preboreal through the late glacial pollen phases to the present cultural vegetation. The synchronized longitudinal section of the Lake Balaton sediments with absolute ages can be constructed. The thickness of deposits (mostly silt layers) amounts to 4-5 m, 3 m of which is Holocene, their volume is estimated at 2.5 to 3 billion m^3, while the actual water quantity of Lake Balaton is estimated at cca 2 billion m^3. The absolutely dated sequence permitted to establish the rate of sedimentation from the Boreal phase. Siltation increases exponentially with the climate turning more humid, expansion of cultivation, reduction of forested areas and, as a result, the acceleration of soil erosion on the catchment of Lake Balaton. The initial figure of 0.1-0.2 mm per year generally rises to 0.4-0.5 mm per year and it tends to rise towards the axis of the lake too. Deposition is intense in the reedbeds of the north shore, while along the south shore abrasion, longshore drift results in sand and sandy silt accumulation in deeper water, increasing in degree with time. At Siófok its figure is 1.2 mm per year on the average of the last 300 years, while it is more than 1.3 mm per year in the Keszthely bay for the same interval. The value is highest near the eastern bluff, at Kenese it is 1.8 mm per year for the last millenium.

This last datum is exceptional and due to the repeated bluff collapses. There is a considerable acceleration presently as observed by lake basin surveying. During the last 60 years the elevation of lake bottom is 0.4 m on the average (7 mm per year). Stricter measures of environmental protection seem necessary. Further research should aim at the resolution of the remaining contradictions between pollen statistical and geomorphological findings.

* * *

INTRODUCTION

Lake Balaton and its environs are the most frequented recreation area in Hungary. The quality of the human environment is a decisive point in it. Lake Balaton is a shallow lake with an extended and continuous water surface. As it is well known, such lakes 'grow older' and fill up more easily. Thus, the dating of lacustrine sediments in order to determine the degree and rate of siltation are important theoretical and practical issues.

When preparing for the 4th INQUA international conference originally planned to take place in Hungary, one of the research activities was the pollen statistical analysis of the Lake Balaton sediments. From the samples of seven auger boreholes of 10 m depth (numbered B I-B VII), the evolution history of vegetation in the broader environs of the lake was reconstructed from the late Pleistocene to the present (ZÓLYOMI, B. 1952, 1953, 1958).

Another result of the investigation was the dating of the origin of Lake Balaton and its confirmation by micropaleontological evidence. The lake dates back to the late Würm (cca 15,000--20,000 years B.P.). In 1952, some geomorphologists (e.g. BULLA, B.) disagreed with this statement and argued for the last (Riss--Würm) interglacial. Subsequent findings in geographical research have gradually modified their opinion. The essential point is that the date when the lake basin came about has to be distinguished from the origin of the lake itself. It is extremely instructive to look back today upon the wide-ranging interdisciplinary discussion more than 30 years ago (see Acta Biologica Academiae Sci. Hung., pp. 414--430 and previously pp. 399--405).

I identified the first lacustrine sediments as the Gravettien of the loess of Ságvár, south of the lake. Subsequent archeological C^{14} analyses at Ságvár indicated dates of 17,000 and 19,000 years resp., for the later and an earlier settlement of reindeer hunters (GÁBORI-CSÁNK,V. 1960). The correspondence with the most recent geomorphological--microstratigraphical achievements seem to be satisfactory (MAROSI,S. and SZILÁRD,J. 1974, 1977 - 22.000 radiocarbon years B.P.).

METHODS OF SAMPLING AND PROCESSING

In the opinion of hydrologists, the pollen statistical methods are feasible for the reconstruction of the degree and rate of sedimentation. Through their application, a siltation curve was drawn from the data of the borehole B V of 1948 (SZESZTAY,K. 1961, and ZÓLYOMI,B. 1961, LIGETI,L. 1974 - p.12, *Fig. 3)*. It became obvious, however, that a more detailed and exact answer to the question asked can only be given through the analysis of additional boreholes and the application of more developed sampling and processing techniques. To this end, in 1964 and 1965, further 14 lake bottom boreholes were deepened by a 5 m electric vibrosound (B 21 - B - 24, B 28 - B 37) in cooperation with the Research Centre for Water Resources Development (VITUKI). The attached sketch map *(Fig.1)* shows the sites of both the 1948 and the 1964--1965 boreholes.*

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* Further boreholes are also indicated. These were made by NAGY,L., Hungarian State Geological Institute, at my request, by auger but in a manner suitable for pollen analyses at Szigliget, Tapolca basin (T I-T V), and at Fonyód, Nagyberek (NB VI - NB X). Thus, in addition to the 3 cross-sections of the lake basin, a fourth profile reaching over the present shoreline could also be prepared. The pollen statistical analyses of cross-sections have been completed and will be tackled in a forthcoming communication (for preliminary report see ZÓLYOMI,B. ap. BARANYI,S. - BENDEFY,L. 1970, p. 72). We should like to indicate in advance that our investigations suggest that most of the Tapolca basin could not function as a bay of Lake Balaton.

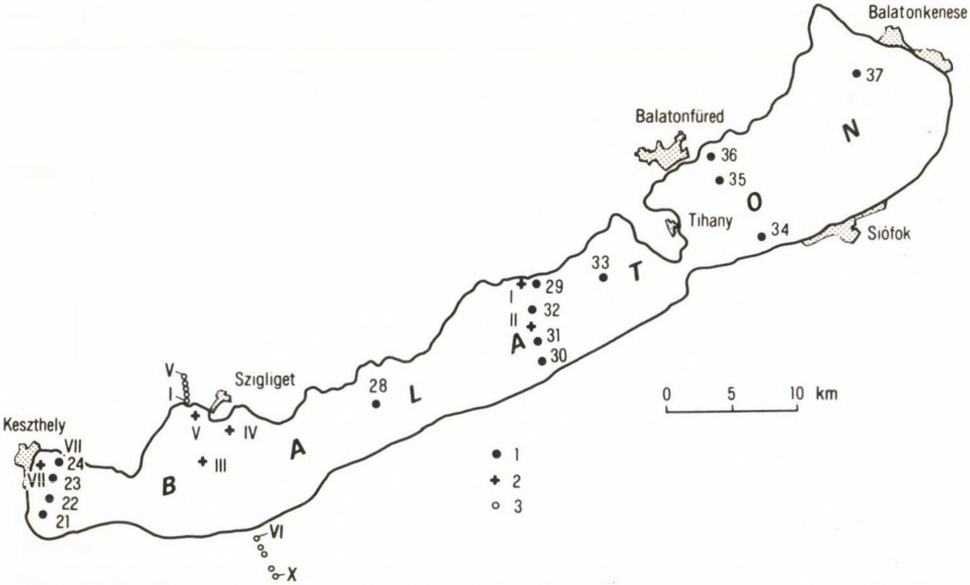

Fig. 1 Location of borehole profiles for palynological investigations at Lake Balaton.

1 = sampling by vibrosounding below water table (1964-65); 2 = auger sampling below water table (1948); 3 = samples taken by 10 m auger in the Tapolca basin and the Nagyberek (1952)

This vibrosound of new type allowed continuous sampling. The material was taken in situ from millimetre to millimetre (in contrast to the mixing caused by the rotational or water-cooled geological drill). In this way so-called closed pollen diagrams could be made. The number of pollen determined by samples and included into calculations was also raised to a thousand. As a new methodological approach, the application of mathematical statistics and computer techniques became possible. Correlation and significance analyses helped correspond the results to the archaeological time-scale (cf. ZÓLYOMI,B. 1971, 1980; ZÓLYOMI,B. and PRÉCSÉNYI,I. 1985). For the individual pollen phases of vegetation history, Firbas' divisions and denominations were used. The Balaton pollen diagrams were adjusted to those from the marshes of the East-Alpine foreland, which were partly dated by the C^{14} technique. (BORTENSCHLAGER,S.

1966, 1982; FRENZEL,B. 1959-1960; FRITZ,A. 1967-1978; FREY,D.G. 1956; GÖTTLICH,K. 1961; GROSCHOPF,P. 1961; HAVINGA,J. 1972; KLAUS,W. 1972; KRAL,F. 1970-1982; KRIPPEL,E. 1963; PESCHKE,P. 1972; SCHÜTRUMPF,R. 1968; SERCELJ,A. 1963-1972; ZOLLER,H. 1961- see further JÁRAI-KOMLÓDI,M. 1969-1971).

POLLEN STATISTICAL RESULTS

Selecting from abundant material, here only the sequence established by the pollen horizons of the borehole profiles along the longitudinal section of Lake Balaton are treated *(Fig.2)*. Of the pollen diagrams of the borehole profiles, lack of space allows us to publish only the numbers B 28 and B 35 here *(Figs.3,4)*. It is necessary to emphasize that the degree of sedimentation is the same in the other diagrams too. Sedimentation of various degree may contact or elongate the diagram.

Let us first consider the two pollen diagrams. The Pleistocene--Holocene boundary is striking in them. In the Pleistocene finiglacial *Pinus* and *Betula* alternatingly dominate. In contrast they subordinate in Holocene. From the Atlantic phase, *Pinus* as well as other coniferous pollen can only be regarded as alien ones of remote origin (the chance for fern transport increases with the more extended recipient water table). The rise in its ratio in the uppermost horizons can be explained by the decline of forest cover in the neighbourhood and by the resulting fall in local pollen production and by recent *Pinus nigra* plantations. Similarly, the ratio of non-arborous pollen (NAP) is mostly outstandingly high compared to tree pollen (AP) in the finiglacial (*Artemisia*, Chenopodiaceae), while their ratio decreases considerably. With the gradual and finally sudden expansion of agricultural cultivation, there is a rise in their ratio.

In the lower layers, in addition to the corroded older, Tertiary (Pannonian)--Early Pleistocene pollen washed in (*Tsuga*, *Pinus haploxilon* and deciduous trees), well-preserved *Pinus cembra* of Würm III age, synchronous with the deposition of

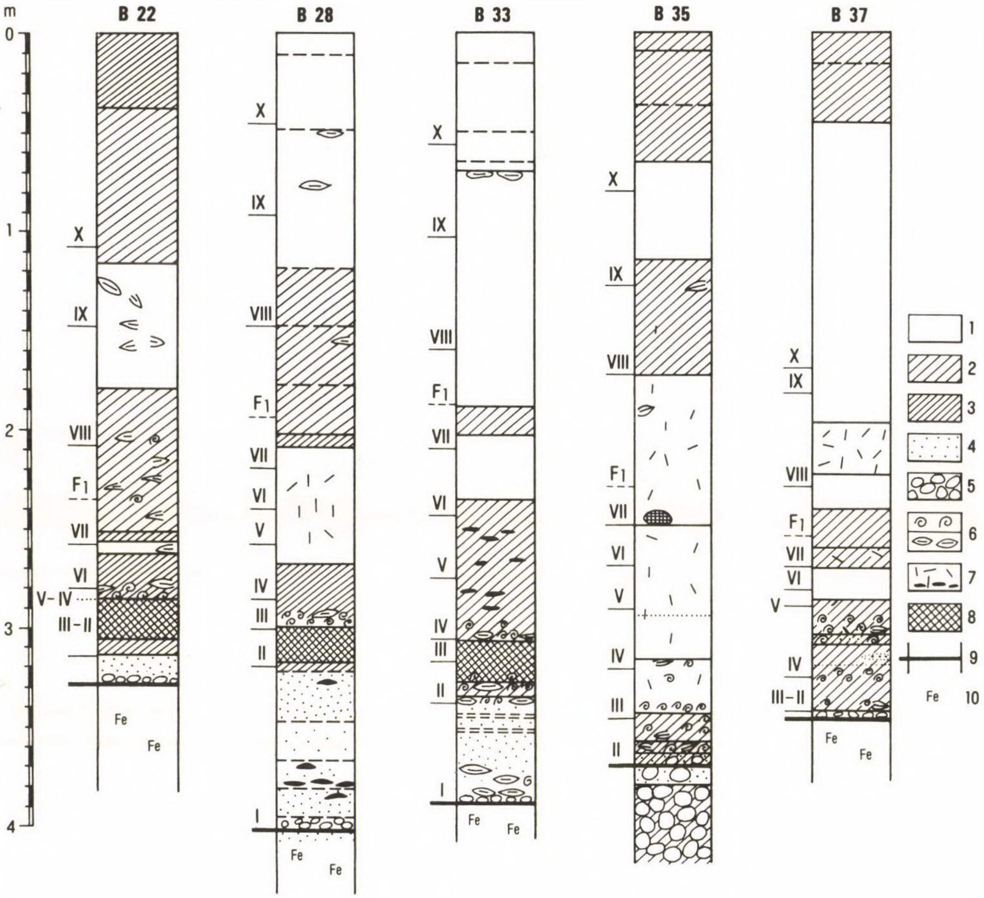

Fig.2 Vibrosounding profiles in the longitudinal section of Lake Balaton

1 = light silt; 2 = medium dark silt; 3 = dark silt; 4 = sand; 5 = gravel; 6 = gastropod; 7 = bivalve; 8 = peat; 9 = beginning of deposition in Lake Balaton; 10 = spots of Fe-oxidation.

the layers is also found. This accords with the data indicated from charcoal in the Gravettien of Ságvár loess (STIEBER,J. 1957). There is also good agreement with the charcoals in the loess Gravettien of the more remote younger Würm III loess along the Danube (the so-called Dunaújváros--Tápiósüly series; *Betula, Pinus cembra, Larix-Picea,* h_1 16,750 + 400 years, h_2 20,520 + 280 years - PÉCSI,M. 1975, 1985). The finiglacial stages identified in other places (Ia - oldest Dryas, Ib Bölling interstadial, 11,300--10,500 B.C., Ic - older Dryas and Alleröd interstadial 10,900--9,000 and finally, younger Dryas) are only partly observed in the longitudinal profiles, while they are more distinct in the pollen diagrams of the borehole profiles in the vicinity of the north lake shore. For their certain distinction, further confirmation, first of all, C^{14} dating, is necessary in the sediments of Lake Balaton.

In the first phase of the Holocene, with the persistent abundance of *Pinus*, thermophile deciduous trees, such as *Tilia*, *Ulmus* and *Quercus* were gradually invading (IVth, Preboreal phase -8,300--6,800 B.C., early Mesolithic). It is followed suddenly by the dominance of deciduous tree pollen, with the maximum of *Corylus* here (Vth, Boreal, *Corylus*, phase- 6,800--5,500 B.C. late Mesolithic).

After that, *Quercus* species became unambiguously dominant under Submediterranean climate with increased precipitation (VIth, early Atlantic phase - 5,500--4,500 B.C., early Neolithic).

Fagus had been present up to that date as carried here from remote areas, but in the following phase an early *Fagus* invasion, the first *Fagus* pollen peak (F^1) is conspicuous, without *Carpinus*. *Fagus* coming from western Balkans (Illyricum floral province) reached the eastern foot of the Alps (KRAL,F. 1979) and Transdanubia earlier than it arrived to the North Hungarian Mountain Range. (Similar to Transylvania, it expanded to the Bükk Mountains only during the Subboreal - cf.ZÓLYOMI,B. 1931; CSONGOR,É. et al. 1982). The invasion is likely to be related to increased precipitation and reduced continentality, which are also indicated by *Tilia* and *Ulmus*

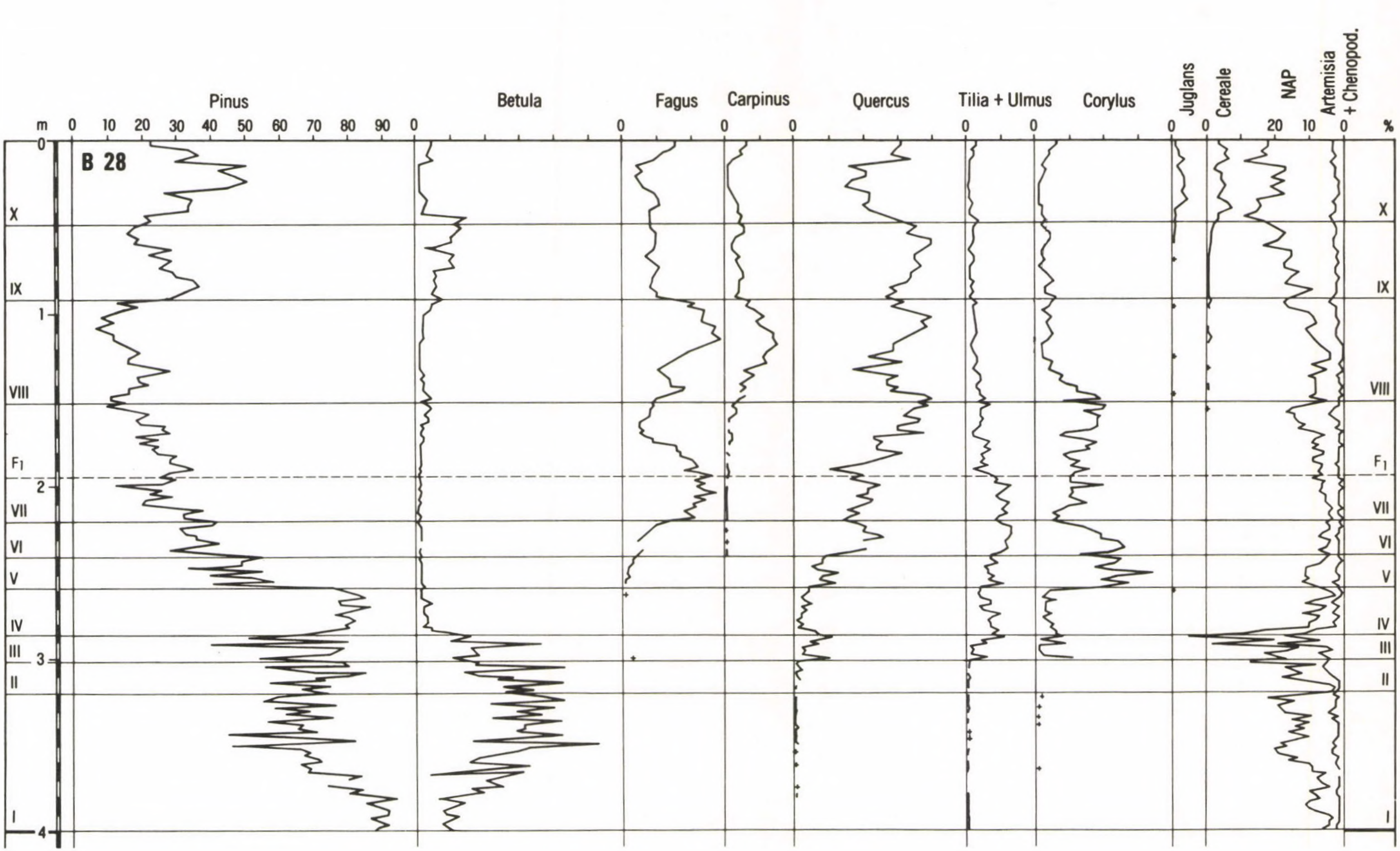

Fig. 3 Pollen diagram of borehole B 28
(AP cca 160,000, NAP 18,000; Picea, Abies, Alnus and Salix pollen percentage not shown)

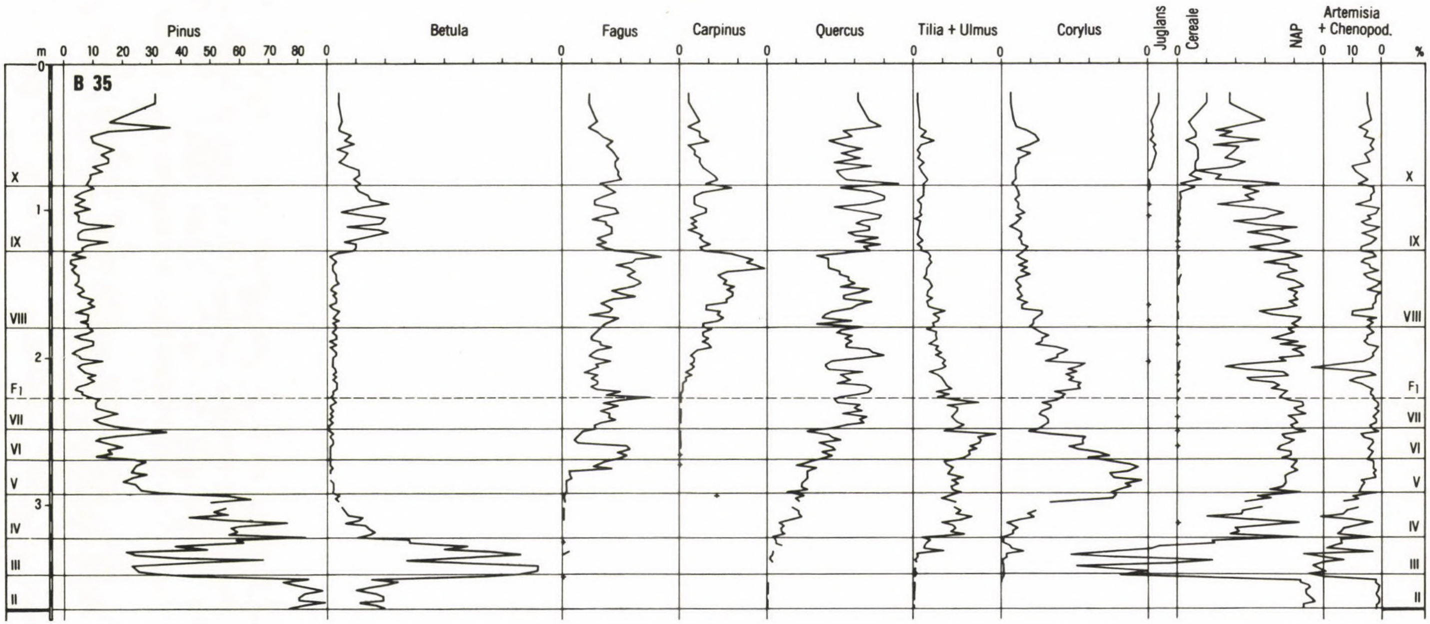

Fig. 4 Pollen diagram of borehole B 35
(AP cca 148,000, NAP 28,000; Picea, Abies, Alnus and Salix pollen percentage not shown)

decline (VIIth, late Atlantic phase - 4,500--3,000 B.C., medium--late - 'Lengyel' - Neolithic, Copper Age I.).

Fagus played a subordinate role subsequently until it expanded again, this time along with *Carpinus* (second *Fagus* pollen peak F^2*). This is somewhat cooler and more humid (VIIIth, Subboreal phase - 3,000-800 y. B.P., Copper Age II and III, Bronze Age - Early Iron Age).

In the next phase *Fagus* declined once again. The increase in the ratio of *Betula* pollen is striking; this is explained by forest degradation by human cultures, first of all, by grazing and forest burning (IXth, Subatlantic phase - 800 B.C. - A.D. 800, Late Iron Age, Roman Age, Age of Migrations).

The last stage is the rapid expansion of land cultivation from the feudal early Middle Ages. With the considerable decline of forests, the ratio of NAP increases. Pollen of cereals and weeds represent remarkable amounts (Xth, cultural, phase - since A.D. 800). It is the period of the Karolings, the 'Mosaburg' of the Salzburg archbishopry - Zalavár, from the last wave of migrations and the Magyar Conquest.

During the last two millenia the continuous presence of *Junglans* buried in lake bottom silt dates back to the establishment of Roman Pannonia (remnants of nuts were found in sarcophagi). This is the beginning of our calendar. The rise in *Junglans* pollen follows that of cereal pollen belatedly, in the 11th--12th cent. From written documents the large-scale cultivation of Zea of American origin started in Hungary in the mid-17th century (1650). Its large, easily recognizable pollen was only found in interpretable number after counting several thousands of pollen.

Repetitions in the necessary number were allowed by the

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* Earlier I mentioned this phase as Fagus I followed by the Subatlantic Fagus II phase. It is better to drop these names entirely and only use the neutral names by BLYTT--SERNANDER with no climatic implications. I have been avoiding the term 'age' for a long time. Contrary to my statements of 1952--1958, the Boreal steppe cannot be justified in the Lake Balaton environs - at least as attested by the recently analyzed pollen data !

abundance of pollen diagrams and data and they promoted the parallelization of the sediment layers of Lake Balaton in high reliability and absolute dating was also possible through extrapolation. The peaks of *Betula*, *Corylus*, *Fagus* and NAP pollen served as very characteristic points of identification.

PARALLELIZED SEDIMENT LAYERS OF LAKE BALATON ALONG THE LONGITUDINAL SECTION

The basis of the survey of the Lake Balaton sediments along the longitudinal profile of the lake is the profile following the deepest points of the bottom constructed by hydroengineers (VITUKI 1961, 1980, 12/1/2/c). The greatest depths of the most recent echo sounding of 1955 were taken into consideration; 0 level is fixed at 104.10 m above the Adriatic sea level. The profiles of our bottom deep boreholes were exactly located somewhat to the north of the line of greatest depths. It was possible since we fixed the sites of the boreholes by surveying (by teodolite, through resection) and because the actual water level data compared to 0 level were registered according to daily reports *(Fig. 5)*.

First, let us overview the petrology of the palynologically dated sediments in the seven borehole profiles *(Fig. 2)*. After Lake Balaton was formed mostly sand or silty sand, less often fine sandy silt deposited. This is in accordance with the climatic and vegetational conditions of the finiglacial. The boundary horizon is of coarse sand with pebbles and mostly dolomitic detritus. The pebbles of primarily basalt and dolomite and less frequently sandstone are of 0.5--1 cm size. In the base of the first sedimentation stage of the lake partly reworked and partly in situ Pleistocene fluvial sand or Pannonian clay or sand follow deposited with large temporal hiatus (unconformity indicating denudation period). The spots of oxidized iron of yellowish--reddish colouring suggest longer mainland period (as it had been claimed by LÓCZY,L. 1913, p. 475). The mainland period is supported by the minimum amounts of pollen of poor preservation. In the borehole B 35 the gravel bed formed previous to the subsidence of the Balaton trench

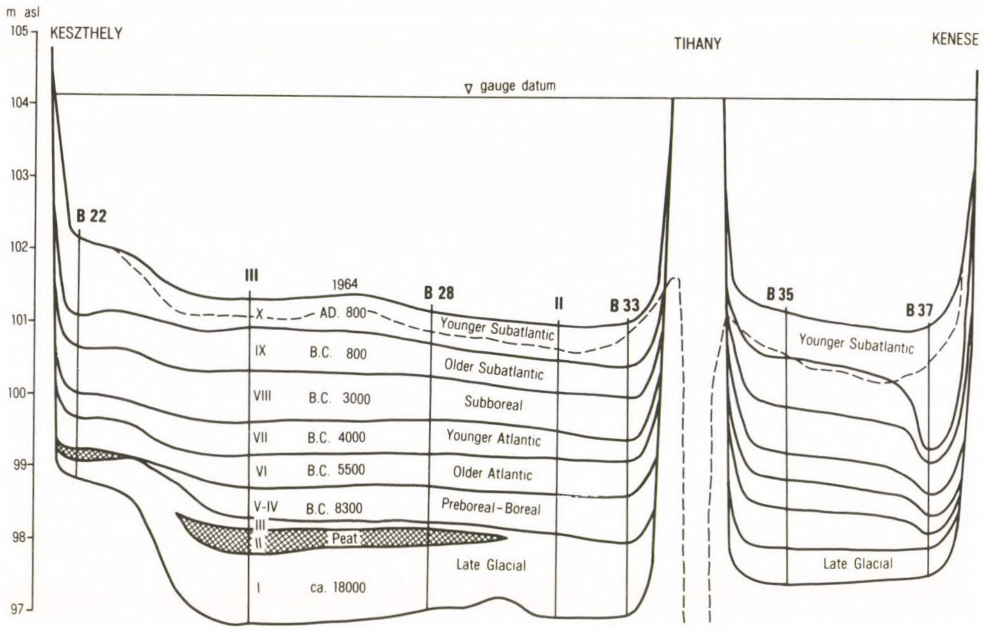

Fig. 5 Longitudinal section of the sediments of Lake Balaton

and described by LÓCZY,L. (1913) was reached in the base of lake deposits. Ventifacts attesting to a dry period were also found.

In the western and middle basin of Lake Balaton the finiglacial (mainly Alleröd) peat extends as far as the middle of the lake. It indicates the considerable fall of water table and the temporary contradiction of water surface. The water level of the lake, consequently, fell to 6 m below the present level between 10,000 and 9,000 B.C. In the eastern half of the lake the peat layer is restricted to the north shore. Pollen density varies in the peat and partly selective fossilization is observed. In the profile B. 22 of the Keszthely bay there is an about 1,000-year long hiatus above the peat in the pollen diagram, which is exceptionally large.

Later sedimentation varies in the various borehole sections in quality and thickness according to position in the lake basin. Thus, for instance, along the margin of the Szigliget bay, there is another upper Preboreal--Boreal peat layer, in addition to the lower (partly Alleröd) one, intercalated in the silt layers of the base and the cover (borehole B V - cf. ZÓLYOMI,B. 1953). Therefore, around 6,000 B.C. another low water level is postulated, 3 m below the present 0 level. In most of the cases, however, it is not a peat layer, but hiatus that corresponds to it in the profiles*.

Continuous and undisturbed siltation can only be assumed since the middle or end of the Boreal phase. The silt in Lake Balaton is light grey, compact, consolidated, partly micro-stratified and locally contains mollusc tanatocenoses. However, it is less consolidated, in the uppermost 50 cm deep layer and, since the lake is shallow, its surface may stir up down to 10 cm depth (called 'sludge' by fishermen). Consequently, also paying attention to the phenomenon of seiche (motions of water caused by differences in atmospheric pressure over various parts of the lake) and the related currents (see the investigations by VITUKI and VLADÁR,E. 1968), this silt provides good average pollen samples. In the littoral zone allowances have to be made for the distortion of the pollen spectrum by in-wash and re-wash (e.g. in the case of B 34).

Concerning further details the figure of the seven borehole profiles is brought again into mind *(Fig. 2)*. Based on the pollen diagrams of the individual borehole sections, the vegetation history time-scale is also indicated on the left of the columns.

Eventually the parallelized and absolutely dated sediment sequence of Lake Balaton could be represented in longitudinal section. Really, vast amounts of sediment have deposited ! Hydrologist estimate the actual water bulk of Lake Balaton as 2 billion m^3. The amount of sediments, mostly silt, ac-

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* In literature my differentiated dating of the Balaton peat layers, which are exact for millenia by pollen spectra, is most often erroneously borrowed (e.g. LÁNG,S. 1974, pp. 18--19.; MAROSI,S.--SZILÁRD,J. 1981, p.22; cf.ZÓLYOMI,B. 1952. pp. 510 and 521, 1953, pp. 390--391 and 404.). In my opinion the confusion was caused by an earlier erroneous dating by KORCSMÁROS,I. (1938) based on remote extrapolation.

cumulated over many thousand years (2.5 to 3 billion m^3) exceeds it remarkably.

It seems that the middle basin of Lake Balaton had been occupied by a lake earlier than the eastern basin and the Keszthely bay were filled by water. The considerable differences in the thickness of late Pleistocene lake sediments can be mentioned here. Pollen analyses suggest a time difference of several millenia. It seems probable that the eastern lake portion united definitely with the western only at the very end of the Boreal phase and the beginning of the early Atlantic phase (i.e. around 5,500 B.C.). Tihany only became a peninsula at that time and only then the presently deepest point of Lake Balaton, the so-called Tihany well (-10.5 m) formed as a result of shuttle currents related to seiche in the Szántód strait. The lasting separation of the eastern basin is apparently supported by the fact that in the Szántód triangular tombolo system Pannonian clay was found to 70 m depth in the immediate base of 2 m Holocene lacustrine deposits (boreholes of the Surveying and Soil Analysis Enterprise - see MAROSI,S.—SZILÁRD,J. 1981, p. 14). Because of the more elevated lake bottom, the lake was shallower in the Keszthely bay from the beginning.

Lack of space prevents me from enumerating further documents of justification. The differences in the mechanism of filling between the north and the south shores can only be hinted at.

A well-known general rule is the location of maximum thickness of sediments in the middle part of the lake basin. In contrast, in the case of Lake Balaton, sedimentation reached its highest degree in the vicinity of the northern shore. This is related to the initial asymmetry of the lake bottom already described by LÓCZY. The Pannonian layers subsided the deepest near the north shore, while they are located high near the south shore. In the area of the north shore the degree of infilling is high during the Pleistocene finiglacial and the Holocene Preboreal and partly in the Boreal phases, while along the south shore it is negligible. However, in the late Holocene accumulation is more balanced, in the Subatlantic phase it is even more intensive on the south side. Prevailing winds and the resulting currents led to the deposition of silty deposits on the north side and sandy sediments on the south (cf. LÓCZY,L. 1913; VLADÁR,E. 1968).

RATE OF SEDIMENTATION

The sediment sequence parallelized with absolute chronology allowed the estimation of the rate of sedimentation too. Since continual accumulation of silt can be taken into account from the mid-Boreal phase (cca 6,000 B.C.), the rate of siltation was calculated from that date. The rate of siltation increases with more humid climate, the expansion of land cultivation, the decline of forests and the resulting acceleration of soil erosion. The initial annual values of 0.1--0.2 mm rise to 0.4--0.5 mm per year, also towards the medial line of the lake. There is an intensive accumulation in the reed-beds of the north shore, while in their immediate foreland in the lake the backwash of collapsed waves (or the application of dragged nets?) reduces deposition. Along the south shore the accumulation of the abraded sand and sandy silt is characteristic in the deeper water. For instance, at Siófok it amounts to 1.2 mm per year on the average of the last 300 years, while the same calculation results 1.3 mm per year for the Keszthely bay. The highest values calculated for the eastern bluff, where the annual average of the last millenium is 1.8 mm at Kenese (cf. the borehole B 37). This latter value results from extraordinary events, bank collapses. The Pannonian rock bodies sliding into the lake are washed away by wave action and their material adds to the sediment. During the last millenium the collapses repeated several times and, consequently, the older layers are compressed.

Taking as an example the borehole profile B 29 near Akali, we demonstrate the rate of sedimentation and the rise of bottom level *(Fig. 6)*. The rate of deposition gradually grows towards the present. Judging from the introduction of *Zea* pollen it is 1.1 mm per year for the last 300 years, while the figure for the previous millenium is 0.6 mm per year. SZESZ-

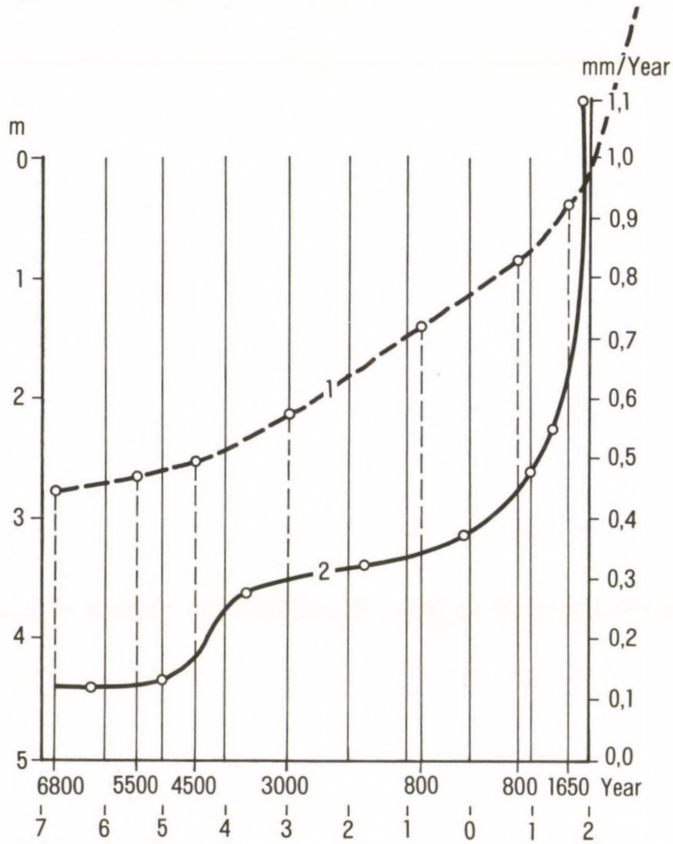

Fig. 6 Degree (1) and rate (2) of siltation based on the Holocene profile in borehole B 29

TAY,K. (1961) estimated 40 cm lake bottom rise during 60 years, i.e. 7 mm per year from comprehensive surveys repeated three times for Lake Balaton (in 1894--95, 1929--30 and 1955--56). The exponential acceleration must have several reasons. Because of the not yet consolidated uppermost silt layer of higher water content, the rate of acceleration is somewhat lesser in reality (see PONYI,J. 1971).

PROBLEMS

The problems concerning the maximum water levels of Lake Balaton can hardly be resolved from the analysis of lake sediments. Allowance must be made for tectonic movements. With my results for the finiglacial (late Pleistocene), I cannot support the about 6--8 m higher water level for that time suggested by others. It seems probable that the bottom level of Lake Balaton was higher than today and, therefore, the high water level is illusory. Recent geomorphological communications also support this view. MAROSI,S. and SZILÁRD,J. published a detailed and comprehensive study on the origin of Lake Balaton (1981). Based on geomorphological and stratigraphical investigations, they dated the development of the lake, agreeing with GÓCZÁN,L (1961), as Würm I--Würm II interstadial (cca 30,000 years). It is the task of further research to resolve the still pertaining contradiction between the pollen statistical and the geomorphological results.

Finally, let me quote in word-by-word translation some lines of my report written 20 years ago, in 1965, for the National Water Management Directorate (p. 18 of the report):

"Besides the siltation of Lake Balaton, another practical problem - especially manifest in the Keszthely bay - is the sapropelic nature of the silt. It is connected with the ever intensifying eutrophication of the lake. In our opinion, the fining-down of the sewage disposed of in Lake Balaton is a practical, hygienic and touristic task which cannot be postponed. The deterioration of the Keszthely bay is shocking: the change is visible in the comparion of the samples of our old, 1948 sampling of surficial silt with the surficial silt samples from the boreholes of the year 1965". The opinion of the expert was disregarded then and considered only belatedly. The prevention of troubles would have certainly needed less investment.

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Mrs.M.HÖRCHER. I am grateful for their fatiguing and reliable work of about two decades. My working-place was the Botanical Research Institute of the Hungarian Academy of Sciences in Vácrátót, where the investigations continued as fundamental research after the final report for the National Water Management Directorate (OVF) was completed in 1969. For making the completion of the work possible, I owe Á.BERCZIK, my successor, thanks. The detailed documentation will be available in the manuscript section of the Library of the Hungarian Academy of Sciences.

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LARGE MAMMALIAN FAUNAL CHANGES DURING THE LATE UPPER PLEISTOCENE AND EARLY HOLOCENE TIMES IN THE CARPATHIAN BASIN

I. VÖRÖS

ABSTRACT

Author gives a review of the Uppermost Pleistocene--Holocene faunal dynamics in the Carpathian Basin based on the large mammal fauna. The faunae of 23 Late Upper Pleistocene, 9 Mesolithic and 264 prehistorical-historical localities were analyzed to reconstruct the succession of 2 Pleistocene (Pilisszántó and Arka) and 4 Holocene faunal phases, correlated with the current archeological chronology and absolute dating. A subdivision of the Pilisszántó phase in two subphases appeared as necessary, refining the knowledge on the Latest Pleistocene steps of faunal evolution in the Carpathian Basin. The description of the subsequent faunal types is given and finally the time of extinction of Pleistocene elements and the invasion of the new Holocene faunal elements are discussed.

* * *

INTRODUCTION

The faunal successions of Upper Pleistocene — Holocene large mammals deriving from the numerous archeological excavations of the past decades show temporal changes that can be fairly well defined. The number of remains of large mammals, mostly of game animals discovered in the course of archeological excavations shows significant differences by settlements and by times.

The taxonal composition and quantitative ratio of the large mammal bone material depend on the composition of the wild-mammal fauna and on the hunting traditions. The quantitative result of hunting, especially in the period of Paleolithic and Prehistoric game hunting reflects the frequency conditions of the hunted stock (KRETZOI,M. 1968).

In Hungary the Holocene large wild mammals have been comprehended by BÖKÖNYI,S. (1959a). Out of the members of the Hungarian Holocene large mammal fauna, the faunal history of *Bos primigenius* (BÖKÖNYI,S. 1962a, 1972; KROLOPP,E.–VÖRÖS,I. 1982), of *Cervus elaphus* (VÖRÖS,I. 1975, 1979) and of the wild equids (VÖRÖS,I. 1981a) is relatively well-known in the Carpathian Basin.

The vertebrate biostratigraphic classification, the classification into faunal successions of the Holocene period was carried out first of all on the basis of faunal succession changes of the small mammals from caves (KRETZOI,M.–VÉRTES,L. 1965). The large mammal marker species as well as the faunal predominance changes of large mammals deriving from prehistoric localities can be fairly well assigned to the Holocene vertebrate faunal phases (KRETZOI,M.–VÉRTES,L. 1965) correlated by pollen zones, archeological ages and absolute chronology (KRETZOI,M. 1961; KORDOS,L. 1977).

The most important questions of the Holocene large mammal faunal history are as follows: when did the new modern Holocene species appear in the Carpathian Basin? What is the time of disappearance of the Pleistocene species? Where can the Pleistocene-Holocene boundary be drawn based on the change of the large mammal fauna? These questions and problems belong to the formal side of complex biostratigraphy but do not concern essential points as climate, vegetation, bird and small mammal fauna as well as their correlation. This needs another study.

To answer the formal questions above the finds of large mammals of 23 Late Upper Pleistocene, 9 Mesolithic *(Table 1,2)* and 264 Prehistoric-Historic sites *(Table 2)* were used.

The sequence of the Late Upper Pleistocene Hungarian localities suitable to faunistic, archeological and stratigraphic studies that is enumerated below derives from the trend of changes of faunal elements to be discussed later.

LARGE MAMMAL FAUNAL CHANGE IN THE LATE UPPER PLEISTOCENE

I. PILISSZÁNTÓ FAUNAL PHASE (KRETZOI,M. - VÉRTES,L. 1965).

Cca. 20,000-15,000 yr BC, Sites No. 1-19. *(Table 1)*

In Hungary, the game animals ("fauna") of the spelean and open-air settlements of the Magdalenien culture in classic sense, as well as the small mammals from owl pellets and the prey animals of carnivorous mammals belong to the Pilisszántó faunal phase of the Late Upper Pleistocene.

The large mammal faunal spectrum of the most important localities is found in *Table 1*. These localities show animal bones that can be evaluated in a differentiated manner from the quantitative (5 to 1713 pieces) and qualitative (3 to 17 species) points of view: remains of game animals accumulated by man, birds of prey and carnivores.

Based on the large mammals the sequence of localities is determined by the logic arguments below:

1. the occurrence of some older faunal element characteristic of an earlier faunal succession;
2. the joint occurrence of these species with arctic-subarctic species;
3. the predominance of arctic-subarctic faunal elements and the lack of older carnivorous faunal elements;
4. the lack of arctic faunal elements;
5. the predominance of subarctic and steppe herbivorous animals.

SHORT DESCRIPTION OF THE LOCALITIES

Site 1. Remetehegy, rock-shelter (KORMOS,T. 1914a), Buda Hills, Lower layer, "red clay, rodent-bearing layer". Den of birds of prey and carnivores. *Crocotta* is an older faunal element. Other arctic and subarctic elements than *Rangifer* are lacking.

Site 2. Bervavölgy cave (MOTTL,M. 1936; KADIĆ,O. - MOTTL,M. 1938a), Bükk Mountains, Upper layer, "light-yellow or yellow clay". "Magdalenien tools", human remains. *Crocotta* and *Ursus*

Table 1 Large mammal fauna of some localities of the Late Upper Pleistocene Pilisszántó-Bajót faunal phase (number of specimens)
+ = the number of specimens is unknown; * = part of the specimens was published; ? = uncertain data (the specimen is lost)

	Remete-hegy LL	Berva-völgy UL	Bivak 3L	Peskö ML	Pilis-szántó I. UL	Peskö UL	Remete-hegy UL	Remete Alsó UL	Bivak 2L	Pilis-szántó II. UL
Phase	P	I	L	I	S	S	Z	Á	N	T Ó
Data BC.	20 000									
Site Nr.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Canis lupus	3	1	-	10	9	2	5	-	-	-
Vulpes vulpes	1	2	2	31	47	1	1	17	-	6
Alopex lagopus	-	-	1	5	4	-	1	-	5	1
Ursus spelaeus	-	5	94	47*	8	74	2	-	56	-
Ursus arctos	-	-	-	3	-	2	-	-	-	-
Meles meles	-	9	-	1	-	-	-	-	-	-
Lutra lutra	-	-	-	-	1	-	-	-	-	-
Gulo gulo	-	1	-	1	2	1	2	2	-	-
Crocotta spelaea	1	6	1	1	3	-	-	-	-	-
Leo spelaeus	-	-	-	6	2	-	-	-	-	-
Felis silvestris	2	-	-	-	-	-	1	1	1	-
Lynx lynx	-	1	1	8	4	3	-	-	1	-
	7	25	98	113*	80	83	12	20	63	7
Equus sp.	2	4	2	2	20	+	-	1	-	9
Hemionus sp.	-	-	-	-	-	-	-	-	-	-
Sus scrofa	-	-	-	-	-	-	-	-	2	-
Cervus elaphus	-	2	-	10	4	-	-	1	2	-
Capreolus capreolus	-	1	-	1	-	-	-	-	-	-
Rangifer tarandus	3	4	4	226	793	46*	8	9	2	16
Capra ibex	-	-	5	3	1	1	-	-	5	-
Rupicapra rupicapra	-	-	-	68	12	19	-	2	-	-
Bison priscus	-	-	2	4	1	+	1	1	-	-
Bos primigenius	-	-	-	-	-	-	-	-	-	-
Ovibos moschatus	-	-	-	-	-	2?	-	-	-	-
	5	11	13	314	811	68*	9	14	11	25
Sum:	12	36	111	427*	891	151*	21	34	74	32

Balla UL	Petényi LL	Vaskapu	Ölyveskö UL	Pilismarót Pálrét	Pilismarót Diós	Ságvár	Szeged-Öthalom	Arka	Jankovich 5-4L	Rejtek I.	Büdöspest UL	Perpác	Mesolithic Sites
P I L I S S Z Á N T Ó									B A J Ó T				PALÁNK
18 000								15 000	12 000				10 000
11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24-32.
+	-	2	1	-	-	4	-	-	1	-	2	-	1
+	1	4	3	1	-	-	-	-	1	1	2	+	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
+	3	-	9	-	-	-	-	-	-	-	-	-	-
+	-	3	-	-	-	-	-	-	3	1	-	+	-
-	-	-	-	-	-	-	-	-	-	-	1	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	+
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-	+	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-
	4	9	13	1	-	4	-	-	5	2	5		1
+	-	-	1	-	4	226	22	+	-	-	1	-	24
-	-	-	-	-	-	-	-	-	-	-	-	-	20
-	-	-	-	1	-	-	-	-	-	19	-	-	+
-	-	-	-	-	-	-	-	-	-	1	1	-	31
+	-	-	-	-	-	-	-	-	-	-	-	-	+
+	-	20	2	390	28	1488	20	+	7	1	-	+	-
+?	-	-	-	-	-	-	-	-	-	-	-	-	-
-	1	14	37	-	-	-	-	-	1	-	-	+	-
+	-	1	-	4	-	-	5	+	-	2	2	-	-
-	-	-	-	-	-	-	-	-	-	-	-	-	322
-	-	-	-	-	-	-	-	-	-	-	-	-	-
	1	35	40	395	32	1714	47		8	23	4		397
	5	44	53	396	32	1718	47		13	25	9		398

spelaeus are older faunal elements. *Cervus* and *Capreolus* are also found. *Rangifer* (4 pieces) reported from the early Würm fauna of the lower "light-brown" layer as well as the *Gulo* (1 piece) probably belonged to the upper layer. Both of them are subarctic faunal elements. This is the first appearance of *Gulo* in the localities studied.

Site 3. Bivak cave (KRETZOI-VARRÓK,S. 1957), Pilis Mountains, Upper layer (UL_2), "yellowish-grey clay", horizon No.3. Den of birds of prey and carnivores. *Crocotta* and *Ursus spelaeus* are the older faunal elements. The latter predominates in the large mammal fauna. *Alopex* and *Dicrostonyx*, as well as *Lepus timidus* in mass also occur.

Site 4. Peskö cave (MOTTL,M. 1944a), Bükk Mountains, Middle layer, "brick-red, microfaunal clay". Magdalenien tools; den of birds of prey and carnivores. *Crocotta*, *Leo* and *Ursus spelaeus* are older faunal elements. Many *Rupicapra*, a lot of *Cervus* are found, *Capreolus* is also present. The tundra species, i.e. *Rangifer*, *Gulo*, *Alopex* and *Dicrostonyx* occur in mass. Rich carnivorous and herbivorous fauna. *Castor* find ("bright-red rodent-bearing layer", ÉHIK,Gy. 1914) is also known. The remains of *Coelodonta antiquitatis* occurring in the middle layer of the Peskö cave is, in my opinion, secondary, and does not belong to the Late Upper Pleistocene fauna, to the Pilisszántó faunal phase.

Site 5., Pilisszántó I. rock-shelter (KORMOS,T. 1915), Pilis Mountains, Upper Layer Group (D_{1-2}), "light yellow" and "darker (reddish) yellow" loess. Magdalenien tools, reindeer meal and pelt depot; den of predatory animals. *Crocotta*, *Leo*, and *Ursus spelaeus* are older faunal elements. In the large mammal fauna the forest, steppe and tundra species are mixed. *Dicrostonyx* reaches here the maxima of its occurrence and frequency. The incisor determined as *"Bos primigenius"* deriving from the upper layer group is that of *Bison*. The occurrence of dental lamella of *Mammuthus primigenius* is secondary in the upper layer group (KORMOS,T. 1915; VÖRÖS,I. 1983a).

The stratotype of the Pilisszántó faunal phase (KRETZOI,M.–VÉRTES,L. 1965) is the upper layer group of the Pilisszántó I. rock-shelter (D_{1-2}).

Table 2 Frequency of large mammals deriving from Holocene archeological excavations (locality) number of specimens

AGES Number of sites	MESOL. 9	NEOL. 51	COPPER 32	BRONZE 72	IRON 27	ROMAN 37	EARLY MIDDLE 18	MIDDLE 27
Equus ferus	1/24	16/32	-	-	-	-	-	-
Hemionus sp.	4/20	7/22	-	-	-	-	-	-
Bison bonasus	-	1/5	-	-	+	-	1/4	2/4
Bos primigenius	5/322	38/4320	23/788	32/861	15/68	12/166	1/25	-
Capra ibex	-	-	-	-	1/1	-	-	-
Alces alces	-	-	1/1	-	-	-	-	-
Cervus elaphus	6/31	40/3426	28/961	53/3786	19/316	24/432	10/482	16/404
Capreolus capre.	+	35/562	16/327	36/365	9/33	19/59	6/94	16/98
Dama mesopotamica	-	-	1/2	-	-	-	-	-
Dama dama	-	-	-	-	-	1/3	-	1/2
Sus scrofa	+	31/1400	25/506	37/993	14/153	14/185	8/148	15/148
Canis lupus	1/1	6/16	2/3	13/30	1/1	3/10	-	3/35
Vulpes vulpes	-	10/51	4/12	9/26	2/21	3/40	3/93	6/10
Ursus arctos	-	3/6	3/3	11/17	4/4	1/2	2/4	2/6
Meles meles	-	6/13	1/3	8/25	4/9	4/10	-	-
Lutra lutra	+	2/2	1/1	2/4	-	1/1	-	-
Martes sp.	-	-	-	2/3	-	-	-	-
Mustela sp.	-	1/10	-	1/1	-	-	-	1/1
Putorius sp.	-	1/1	1/1	1/2	-	2/4	-	-
Leo persicus	-	1/1	3/12	-	-	-	-	-
Felis silvestris	-	8/17	3/6	10/16	3/3	2/5	3/21	3/5
Lynx lynx	-	1/1	-	2/3	2/4	-	-	-
Castor fiber	1/16	11/42	6/9	8/37	2/4	5/6	-	1/1
Lepus europaeus	-	15/37	14/70	20/148	2/30	8/178	5/20	14/268
	414	9964	2705	6317	647	1101	891	995

Site 6. Peskö cave (MOTTL,M. 1944a), Bükk Mountains, Upper Layer, "light yellow" clay. Magdalenien tools. Den of birds of prey. The older faunal elements *Crocotta* and *Leo* are lacking. No *Cervus* and *Capreolus* are found, but *Rangifer*, *Gulo* and *Ovibos* are present. The occurrence of *Ovibos* is considered to be "occasional" by MOTTL,M. (1944a). Nevertheless, VÉRTES,L. reported remains of *Ovibos moschatus* from the excavations in the Peskö cave, thus its extreme occurrence should be taken into account.

Site 7. Remetehegy rock-shelter (KORMOS,T. 1914a), Buda Hills, Upper Layer, "yellow clay, rodent-bearing layer". Den of predatory animals. *Ursus spelaeus* is an older faunal element. *Alopex* and *Gulo* are also present. The *"Bos* seu *Bison"* remains may be faunistically only *Bison*.

Site 8. Remete Lower Cave (JÁNOSSY,D. 1979), Buda Hills, Pleistocene Upper Layer, "yellow clay", horizon No. 11. Magdalenien tool. Den of predatory animals. In my opinion the *Coelodonta* find occurring in the layer is of secondary position, it can be dated back to an earlier period. The two *Gulo* remains found in horizon No.3 of Bronze-Iron age (BÖKÖNYI,S. 1959b) is of Late Upper Pleistocene age.

Site 9. Bivak Cave (KRETZOI-VARRÓK,S. 1957), Pilis Mountains, Upper Layer (UL_1) "yellow clay", horizon No.2. Den of carnivores and birds of prey. In the large mammal fauna *Ursus spelaeus* predominates. Some temperate forest species *(Cervus, Sus, Lynx)* occur. *Gulo* is lacking, *Alopex* is still present.

Site 10. Pilisszántó II. rock-shelter, Pilis Mountains. Pleistocene Upper Layer group: horizon No.7-8 (VÉRTES,L. 1951). Magdalenien tool. In the revised fauna *Rangifer* and *Equus* predominate. This is the last appearance of *Alopex*.

Site 11. Balla Cave (HILLEBRAND,J. 1911), Bükk Mountains. Pleistocene Upper Layer, "yellow clay". Magdalenien tools, human remains, den of carnivores and birds of prey. Age: Groningen - 18,150 ± 200 yr BC (GREYH,M.A. et al. 1969).

Only the "fauna list" of the animal remains of the Balla Cave is reported, the quantity of bone remnants is marked by the attributes "frequent", "rare". In this sense, in the upper layer the *Rangifer* and *Lepus* sp. are "frequent", the occurrence of *Ursus spelaeus*, *Ursus arctos* and of the other carnivores and herbivores is "rare". The *Bos* sp. is a *Bison*, the *Ovis* sp. is *Capra*, with high probability.

Site 12. Petényi Cave (JÁNOSSY,D. - KORDOS,L. 1976), Bükk Mountains. Pleistocene Lower Layer, "yellow clay", horizon P_I. Magdalenien tool, den of birds of prey. *Ursus spelaeus* is present. *Castor* is characteristic species of gallery forests.

Site 13. Vaskapu Cave (KADIĆ,O. - MOTTL,M. 1938b), Bükk Mountains. The complete sequence of the cave: "light-brown, greenish-grey and reddish-brown clay". Den of carnivores and and birds of prey. *Rangifer* and *Rupicapra* predominate, *Bison* occurs. The two most frequent fur animals are *Canis* and *Vulpes*.

Site 14. Ölyveskö hole (MOTTL,M. 1944b), Bükk Mountains. Pleistocene Upper Layer, "light-brown" clay. Den of birds of prey and carnivores. The last occurrence of *Ursus spelaeus*. *Rupicapra* predominates.

Site 15. Pilismarót-Pálrét (VÖRÖS,I. 1983b), Danube Bend, Magdalenien open-air site. *Rangifer* predominates in the preys *Bison* and *Sus* are also present.

Site 16. Pilismarót-Diós (VÖRÖS,I. 1981b), Danube Bend, Magdalenien open-air site. The game consists of *Rangifer* and *Equus*

Site 17. Ságvár (GAÁL,I. 1931; VÖRÖS,I. 1982), Transdanubia. Magdalenien open-air site.

Age: Upper layer Gro 1959: 15,450±100 yr BC; 15,450±150 yr BC

Lower layer Gro 1783: 16,650±150 yr BC; 16,950±100 yr BC

(GÁBORI-CSÁNK,V. 1960, 1970; KRETZOI,M. - VÉRTES,L. 1965). *Rangifer* predominates in the preys (87 %), *Equus* is less (13 %), *Castor*, *Canis* and *Lepus* are also present.

Site 18. Szeged-Öthalom, Southern Great Plain. Magdalenien open-air site. In the revised finds of the culture layer only *Equus*, *Rangifer* and *Bison* remains are found. The *Mammuthus primigenius* and *"Cervus megaceros"* listed in the determination of I.GAÁL (BANNER,J. 1936) do not belong to this layer: older loess fauna elements.

Site 19. Arka (VÉRTES,L. 1964-1965), NE-Hungary. Magdalenien open-air site.

Age: Lower layer Grn 4,038: 15,100 ± 350 yr BC

518: 16,750 ± 190 yr BC

(GREYH,M.A. et al. 1969).

Among the animal bone remains of the culture layer some fragments of *Equus*, *Bison* and *Rangifer* are found.

Based on the investigation of faunal spectra the following general faunistic conclusion can be drawn: the Pilisszántó faunal phase can be divided into two parts: an early and a late period:

EARLY PILISSZÁNTÓ FAUNAL PHASE

Cca. 20,000-18,000 yr BC, Sites No 1-10 *(Table 1)*. The numeric sequence of sites indicates also the chronological sequence.

At the beginning of this phase the temperate forest species *Cervus*, *Capreolus* are already present among herbivores: out of the steppe species the *Equus* and the subarctic *Rangifer* are found. Approaching the coldest so-called W III stadial of the Pleistocene, the subarctic *Rangifer* becomes predominating: the Alpine *Rupicapra* occurs in large numbers, *Capra* is sporadic. The steppe *Equus* and the *Bison priscus* are present during the whole faunal phase. The temperate forest *Sus* and *Capreolus* are very rare, *Cervus* is somewhat more frequent. The only Late Upper Pleistocene occurrence of the arctic *Ovibos* is known from this period (Site 6.).

In this period, in addition to *Canis* and *Vulpes*, out of the carnivores the occurrence of the forest *(Meles, Felis)*, of the taiga *(Gulo, Lynx)* and of the tundra *(Alopex)* carnivores. The last *Crocotta* and *Leo* occur at that time. *Ursus spelaeus* is still relatively frequent. In the occurrences *Gulo* shows close relations to *Lynx*, and *Alopex* to *Dicrostonyx*.

The faunae of the localities below are assigned to the Early Pilisszántó faunal phase: the young faunal assemblage from the mixed-age fauna of the "upper yellow layer" (1912-13) of the Jankovich Cave; the fauna of strata No. 11-6 (1956) of the Jankovich Cave (KRETZOI,M. 1957); the fauna of strata No. 10-4 of the Függökö Cave (JÁNOSSY,D. - KORDOS,L. - KROLOPP,E. 1982/83); the young faunal assemblage from the mixed-age fauna of the Puskaporos rock-shelter (KORMOS,T. 1911); and the fauna of the Lillafüred quarry (KORMOS,T. 1914b).

LATE PILISSZÁNTÓ FAUNAL PHASE

Cca. 18,500 - 15,000 yr BC., Site No. 11-19 *(Table 1)*.

The numeric sequence of localities does not refer to chronological sequence: localities No 11-14 are spelean, those of No 15-19 open-air sites.

The subarctic *Rangifer*, the steppe *Equus* and *Bison priscus* are also predominating. Out of the herbivorous animals *Cervus* disappeared. The occurrence of *Rupicapra* is remarkable. *Sus*, *Capreolus* and *Capra* are represented only by one specimen each.

The number of carnivores is reduced: the forest, taiga and tundra species are lacking. The *Dicrostonyx* also disappeared. *Canis* and *Vulpes* are present. *Ursus spelaeus* is rare and occurs only in mountainous regions. *Lepus timidus* is also frequent.

It can be, thus, stated that in the Carpathian Basin the steppe large herbivores *(Equus, Bison)* and the temperate forest herbivore and carnivore large mammal fauna were changed:

1. *Gulo* and *Lynx* immigrated from the taiga in the early phase (and partly *Lepus timidus)*; the subarctic *Rangifer* and the arctic *Alopex*, *Ovibos (Dicrostonyx)* also immigrated from the tundra. The immigrant fauna elements occur in the Carpathian Basin in form of rapid penetration. At the extreme appearance of *Ovibos*, the *Crocotta* and *Leo* disappear for good !
2. Due to the climate change and to the effect of immigrant elements the forest herbivorous and carnivorous large mammals withdraw.
3. In the late phase, after the recession of arctic and taiga elements only the representatives of an impoverished disharmonic large mammal fauna are present.

The Carpathian Basin proved to be winter grounds for the subarctic *Rangifer* (STURDY,D.A. 1975; VÖRÖS,I. 1982). The herbivorous species are Central European fauna elements by their type and character (VÖRÖS,I. 1982). In mountainous regions *Ursus spelaeus* is frequent, the *Ursus arctos* is rare. The appearance of *Ursus arctos* is restricted to the Bükk Mountains. *Canis* and *Vulpes* might be "cosmopolite" carnivores accompanying the herbivores.

The mixed (forest, steppe, taiga, tundra) large mammal fauna of the Early Pilisszántó phase became impoverished to the late phase and became a periodically immigrating fauna fragment.

The frequency of occurrence of the species based on 19 localities *(Table 1)* is as follows: 18 loc. *Rangifer;* 14 loc. *Equus, Vulpes;* 11 loc. *Bison priscus, Lepus timidus;* 10 loc. *Canis, Ursus spelaeus;* 7 loc. *Rupicapra, Dicrostonyx;* 6 loc. *Gulo, Lynx, Capra, Alopex;* 5 loc. *Cervus, Crocotta;* 4 loc. *Felis, Ursus arctos, Castor, Lepus europaeus;* 3 loc. *Capreolus;* 2 loc. *Meles, Sus, Leo;* 1 loc. *Lura, Ovibos.*

II. BAJÓT FAUNAL PHASE (KRETZOI,M. - VÉRTES,L. 1965)
Cca. 15/12,000 - 10,000 yr BC., Sites No 20-23 *(Table 1).*

Site 20. Jankovich Cave (KRETZOI,M. 1957; BÁCSKAY,E. - KORDOS,L. 1984), 2nd block, layers 5-4, Pilis Mountains. *Rangifer* and *Rupicapra* are present among herbivores. In my opinion, the occurrence of the arctic *Dicrostonyx* in layer 5-4 is secondary, maybe it was admixed from lower strata. The stratotype of the Bajót faunal phase (KRETZOI,M. - VÉRTES,L. 1965) is the layer 5-4 of the Jankovich Cave assigned previously to the Palánk phase.

Site 21. Rejtek I. rock-shelter (JÁNOSSY,D. - KORDOS,L. 1976), Bükk Mountains, sequence of block III, between 140 and 220 cm.
In addition to *Cervus elaphus* and many *Sus scrofa*, the *Bison priscus* and *Rangifer* also occur.

Site 22. Büdöspest Cave (KRETZOI,M. 1927), Bükk Mountains, Pleistocene upper layer, "red-brown" layer. Steppe *Bison priscus* is still present.

Site 23. Perpác Cave (KADIĆ,O. 1940), Bükk Mountains, Pleistocene middle and upper layers, "yellowish-grey-brown, bright-red" clay. The *Rangifer* and *Rupicapra* are uppermost Pleistocene fauna elements.

By the sporadic occurrence of *Ursus spelaeus, Rangifer* and *Bison priscus* it is necessary to assign this faunal phase to the latest Pleistocene. Its large mammal fauna is a disharmonic fragment fauna. Similar phenomenon occurs in case of the small mammals, too (KRETZOI,M. - VÉRTES,L. 1965; KORDOS,L. 1977).

DEVELOPMENT OF THE HOLOCENE LARGE MAMMAL FAUNA

III. PALÁNK FAUNAL PHASE (KRETZOI,M. - VÉRTES,L. 1965)

Cca. 10/9,000 - 6,000 yr BC., Mesolithic, Sites No 24-32. *(Table 1, 2)*.

Site 24. Szekszárd-Palánk (BÖKÖNYI,S. 1962b), Transdanubia. Epipaleolithic-Mesolithic open-air site.
Age: H-408 b+c: 8,400 ± 500 yr BC. (VÉRTES,L. 1962).

Among the game animals the element of the new Holocene fauna, i.e. the *Bos primigenius* appears accompanied by numerous *Castor* and *Cervus*.

The stratotype locality of the Palánk faunal phase is the Szekszárd-Palánk site with *Bos primigenius*.

Sites 25-32. Lower strata of peat layers
The overwhelming majority of the large mammal remains were found in the lower, older peat layers of Alleröd-Preboreal age. Localities: Bolho: *Cervus;* Zalaszentmihály: *Canis lupus;* Balatonkeresztur: *Hemionus* sp. (VÖRÖS,I. 1981a); Mezölak: *Bos primigenius, Cervus, Hemionus* sp. (KROLOPP,E. - VÖRÖS,I. 1982); Császártöltés: *Cervus;* Kecel: *Bos primigenius, Hemionus* sp., (BÖKÖNYI,S. 1972; VÖRÖS,I. 1981a); Szabadszállás: *Bos primigenius, Cervus, Capreolus, Sus, Equus* sp., *Hemionus* sp., *Lutra* (BÖKÖNYI,S. 1972; VÖRÖS,I. 1981a).

The absolute chronological date of the stratotype locality Szekszárd-Palánk of Epipaleolithic-Mesolithic age, as well as the occurrence of *Bos primigenius* of Mediterranean--Ponto-Mediterranean subprovince of the faunal spectrum puts the locality into the Holocene, to its earliest period. The Palánk phase is the earliest vertebrate faunal phase of the Holocene. Among herbivores *Bos primigenius* predominates (aurochs, chronopopulation I), *Cervus, Equus ferus, Hemionus* sp., *Capreolus* and *Sus* also occur.

In the marginal part of the Carpathian Basin and outside the Carpathians, respectively, Mesolithic fauna of similar composition is known (JARMAN,M.R. 1972). In Europe the composition of species of the Late Holocene (Mesolithic) fauna changes only according to the faunal provinces.

IV. KÖRÖS FAUNAL PHASE (KRETZOI,M. - VÉRTES,L. 1965)
6,000 - 3,000 yr BC., Neolithic, 51 Sites *(Table 2)*.

The forest and forest-steppe large mammal fauna is completed and stabilized. Two species immigration periods are known from this period:
1. At the beginning of the Körös phase the Late Boreal--Early Atlantic steppe elements *(Equus ferus, Hemionus* sp.) occur;
2. at the end of the Körös phase, in the Late Atlantic--Early Subboreal (second climatic optimum) *Equus* and to a smaller extent the *Hemionus* appears again; Further elements are the *Bison bonasus* and *Leo l. persicus*. The maraloid *Cervus elaphus*, the East-European *Sus scrofa* attila immigrate in mass into the Carpathian Basin and the *Bos primigenius* reaches its absolute faunal predominance (aurochs, chronopopulation II - VÖRÖS,I. 1981a, 1983c). In the Carpathian Basin the first domestic animals carried by the man also occur: dog, sheep, goat, cattle and later the pig.

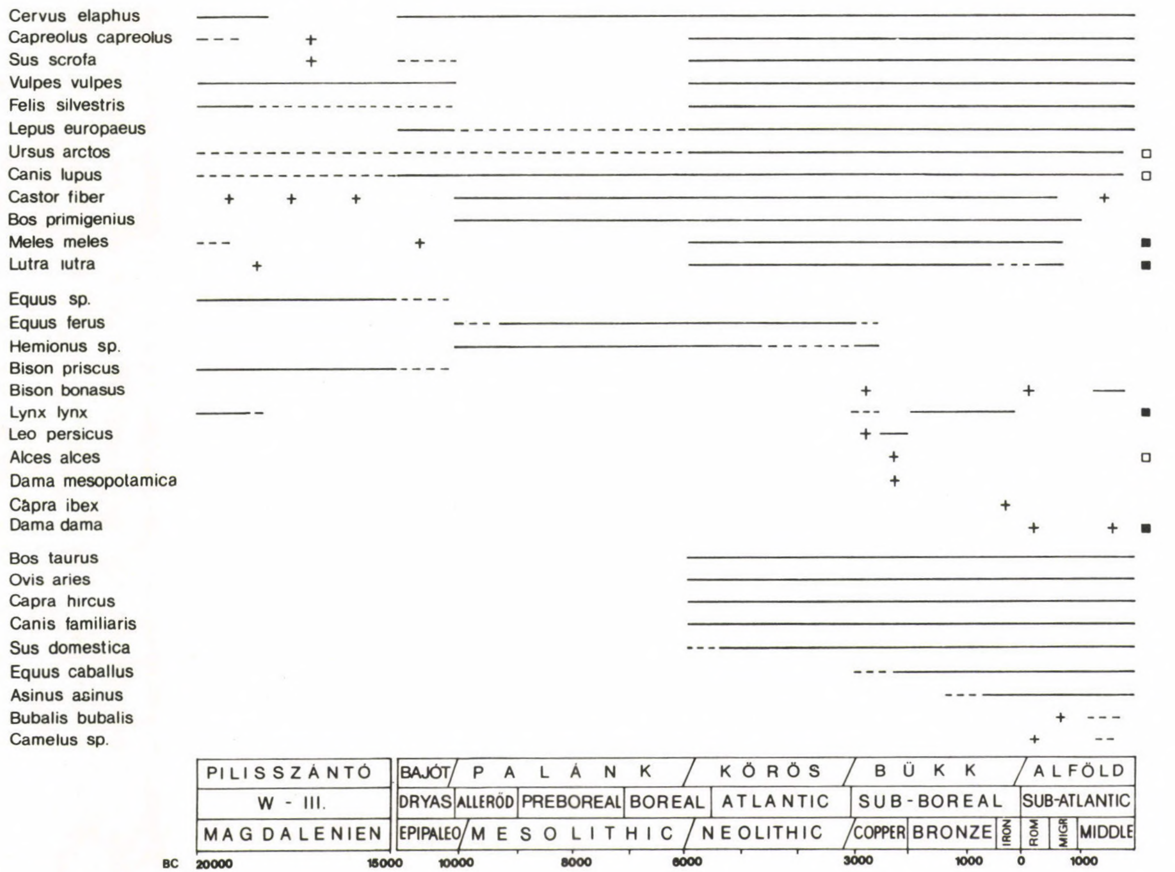
V. BÜKK FAUNAL PHASE (KRETZOI,M. - VÉRTES,L. 1965)
3,000 yr BC. to our times, Copper, Bronze, Iron Ages; 32-72-27 = 131 Sites *(Table 2)*.

At the beginning of the phase (Copper Age) the steppe *Equus* and *Hemionus* disappear. Horse appears. At the end of the first third of the Bükk phase, i.e. 3,000 - 2,500 yr BC., extreme supplementing species are the *Leo l. persicus*, the *Dama mesopotamica* and the *Alces alces* (VÖRÖS,I. 1983c; TOPÁL,Gy. - VÖRÖS,I. 1984). The only remain of domestic zebu of the Carpathian Basin is known from this period.

At the middle of the Bükk phase (Bronze Age) the number of *Bos primigenius* decreases (aurochs, chronopopulation III), while that of *Sus* increases. During the Holocene the occurrence of forest carnivores is greatest in this period.

At the end of the Bükk phase (Iron Age) the occurrence of both herbivores and carnivores decreases in the game. In the piedmont of Alps *Capra ibex* occurs. Donkey appears. In the

Table 3 Appearance and disappearance of Holocene large mammals based on archeozoological data. □ colouring elements in the recent mammal fauna, non-resident; ■ member of the recent fauna



Bükk Mountains the *Bison bonasus* occurring in mass but without archeological age-defining finds the preliminary absolute chronological dating puts to this phase *(Table 3)*.

VI. ALFÖLD FAUNAL PHASE (KRETZOI,M. - VÉRTES,L. 1965)
Since AD to the 16th century, Roman Age, Migration Period--Early Middle Ages, Middle Ages; 37-18-27 = 82 Sites *(Table 2)*.

The forest and forest-steppe wild fauna is unchanged. The first *Dama dama* and *Camelus* sp. is known from the Roman times. From the end of the Migration period *Bubalis bubalis* remain was found. In the Carpathian Basin aurochs occurs for the last time at the end of the Early Middle Ages, i.e. in the 9th-10th century (chronopopulation IV) (VÖRÖS,I. 1985) and the *Bison bonasus* appears again in the 11th century.

EXTINCTION OF SPECIES IN THE LATE UPPER PLEISTOCENE AND HOLOCENE IN HUNGARY

Due to climatic reasons, the extinction of large mammals at the end of the Pleistocene can be traced back to two phases as to our recent knowledge:
1. In the Early Pilisszántó phase the forest carnivores and partly the herbivorous ones of the basic fauna were supplanted off the Carpathian Basin. These were substituted by a transitional arctic-subarctic disharmonic faunal assemblage. After the recession of this fauna only a faunal fragment occurring periodically has been present. 2. The Pleistocene large mammals occur only sporadically in the Bajót phase, at the end of the phase these species disappear.

The faunal vacuum developed at the end of the Pleistocene in the Carpathian Basin filled out by new, modern larga mammal faunal elements at the beginning of the Holocene. In the Holocene, the extinction of large mammals due to climatic reasons is unknown, only the anthropogenic depopulation is known. Nevertheless, the occurrence of climate-determined supplementing faunal elements is rather varied *(Table 3)*. These are species of Turanian, Sarmatian, Ponto-Sarmatian, Ponto-Mediterranean, Mediterranean and Boreal subprovince. The occurrence of the domesticated species as well as their ratio to one another in chronological order is rather well-known (BÖKÖNYI,S. 1974).

Due to the drastic deforestations and to the development of secondary culture-steppes with large amounts of pasturing followed since the beginning of modern times as well as in the territory of the Historic Hungary that became seat of war in the 16th century, the natural wild mammal fauna has been gradually impoverished. Nearly all species of the large wild animals are found now in game reserves.

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SEDIMENTOLOGICAL AND PALEOECOLOGICAL INVESTIGATION OF ALLUVIAL (INFUSION) LOESSES AND THEIR UNDERLYING BEDS IN THE GREAT HUNGARIAN PLAIN (HUNGARY)

Mrs.KÓNYA, Z. - KROLOPP, E. - SZÓNOKY, M.

ABSTRACT

The characteristic sediment, i.e. the alluvial (infusion) loess and its underlying beds are studied from sedimentological (structural and microfaciological) and paleoecological points of view in the Nagykunság region, one of the most interesting landscapes of the Great Plain. by means of the structural and textural investigations of the near-surface Upper Pleistocene strata of four brick-yard exposures and by the description of their mollusc fauna, the paleoecology and paleogeography of the region are given. The underlying beds were deposited in the slowly streaming waters of flood plains of constant water coverage farther off the rivers and in the standing waters developed there, respectively.

The texture of the alluvial (infusion) loess proved to be uniform and unstratified under microscope. The rock is always fairly well diagenized, displaying different clay contents. It developed in flood plain environs of changing microfacies with abundant vegetation where periodical drying also affected the faunal composition.

* * *

INTRODUCTION

The studied region, the Nagykunság lies practically in the centre of the Great Plain *(Fig.1)*. Here only Upper Pleistocene and Holocene sediments are found on the surface, Upper Pleistocene blown sand and alluvial (infusion) loess are the oldest formations. In the Early Holocene blown sand, in the Late Holocene alluvium and silt were formed, further recent alluvia follow *(Fig. 1)*. Locally characteristic alkali spots are also found developed in the Holocene too.

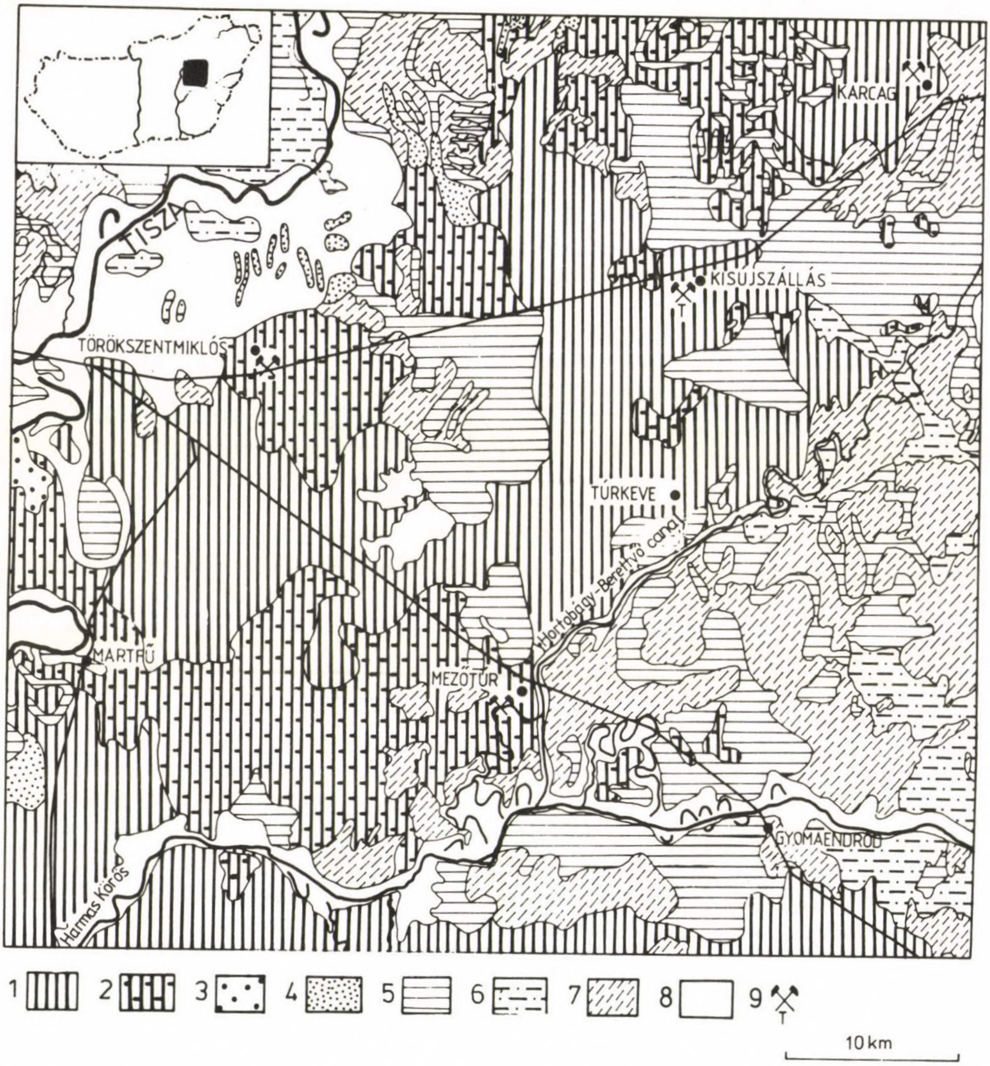

Fig. 1 Geological map of the Nagykunság (ed. BALOGH,K. et al. 1956 and after RÓNAI,A. 1983).
1 = Upper Pleistocene alluvial (infusion) loess; 2 = Upper Pleistocene clayey alluvial (infusion) loess; 3 = Early Holocene fluviatile sand; 4 = Early Holocene blown sand; 5 = Late Holocene alluvial clay; 6 = Late Holocene silt; 7 = Holocene alkali sediment; 8 = recent alluvium; 9 = brick-yard exposure

To study the near-surface formations of the Nagykunság is allowed by numerous drill-holes and surface exposures. The overwhelming majority of the sediments are fluviatile sand, silt and clay, a part of which deposited in flood-plains, in seasonal waters, while the other part developed in permanent standing waters.

Several decades eyewitnessed the geological survey of the region (SÜMEGHY,J. 1937; SIK,K. - SCHMIDT,E.R. - NOSZKY,J. 1941; URBANCSEK,J. 1966; MOLNÁR,B. 1966; RÓNAI,A, 1969, 1979, 1980, 1985).

In the Nagykunság region alluvial (infusion) loess varieties cover large uninterrupted areas. This formation is more compact, sometimes microstratified, occasionally poorer in lime than the typical loess. A lot of transitional types exist between them. These loess-like sediments are of changing thickness, but display thickness of more than several metres only in exceptional cases. Due to the diversity of their grain size composition, conditions of formation and structure, different terms were assigned to it: infusion loess, aquatic loess, soaked loess, reworked loess, flood-plain loessic mud, lowland loess, hydroaeolite, alluvial loess etc. Numerous researchers have dealt with the genesis of this rock typical in the Carpathian Basin (HALAVÁTS,Gy. 1895-97; HORUSITZKY,F. 1932; SÜMEGHY,J. 1937, 1944; MIHÁLTZ,I. 1953; FÖLDVÁRI,A.1956; UNGÁR,T. 1961; MIHÁLYI-LÁNYI,I. - SOHA,K. 1964; PÉCSI,M. 1965, 1967, 1982, 1984; HAHN,Gy. 1977; RÓNAI,A. 1969, 1979, 1980, 1985). In the Great Hungarian Plain it occurs mainly in the alluvial lowland of the Tisza, where it covers several ten thousand square kilometres. It overlies the flood plains and the surface of the alluvial fans lying several metres higher than the flood plain level. The thickness of the loess-like sediment of variable clay and sand content is 1 to 3 m. In accordance with the radiocarbon data it is 18-24 thousand years old, i.e. of Late Upper Pleistocene age (PÉCSI,M. 1982, 1984).

Its origin is bound to marshy flood plain with rich aquatic vegetation. The accumulation of the former sediment in water is also proved by its petrology and compaction (PÉCSi,M. 1965), Its mollusc fauna reflects a characteristic environment. Under the climatic conditions of loess formation the sediment underwent the loess formation process and became diagenized. The formation is locally covered by a thin mud or clay layer, sediments of extremely high floods and accumulated during the Holocene (SOMOGYI,S. 1967; BORSY,Z. - MOLNÁR,B. - SOMOGYI,S. 1969; MAROSI,S. - SZILÁRD,J. ed. 1969). The Holocene relief is dissected by numerous Upper Pleistocene "islands", which have avoided erosion and which often merge with the Holocene relief or emerge from it only by several dozens of cm height.

Formations similar to the alluvial (infusion) loess are also found in the recent flood plains of the Great Plain. These are of fluvial origin and were deposited over the large flood plains in intermittent lakes or marshes remaining after the floods. In the course of geological mapping these were described as loess mud (RÓNAI,A. 1985).

The alluvial (infusion) loesses overlie the fluviatile layers in their base mostly without a sharp boundary.

The Upper Pleistocene clayey sediments and alluvial (infusion) loesses of the Nagykunság are important building materials in the Great Plain. The Karcag brick-yard is the most important of them and that of Kisujszállás, Mezötur and Törökszentmiklós can also be mentioned (RÓNAI,A. 1985). These were the exposures that produced our samples.

OBJECTIVES AND METHODS

The pits of the brick-yards mentioned above being under continuous operation allowed the investigation of the samples from large surfaces, with oriented sampling and using large quantities of material.

The sequence of the exposures was sampled by 25 cm. Nevertheless, changes of layers altered microstratification or faunal character motivated more frequent sampling and, taking into account the possibility of making thin sections, oriented samples were also taken. The major part of the sample of 6 to 8 kg was used for washing. Washing was carried out in a sieve of 0.8 mm. Exposures were sampled meeting the requirements of modern malacology applying statistic methods and the samples were processed in this sense. Sporadic microfaunal investigations were carried out previously, too, in the near-surface sediments of the Nagykunság. Nevertheless, these were not performed in continuous sequences either (KROLOPP, E. in: RÓNAI,A. 1969).

During field works special attention was paid to the observation and photographing of the formations generated by syn- and post-geological processes, to the mode of stratification, to the fossilization phenomena and to the secondary geological features (concretions, gas-pores and microfaciological properties).

1. TÖRÖKSZENTMIKLÓS EXPOSURE

Geology: The pit cuts the alluvial (infusion) loess lying on the margin of the Nagykunság loess. The loess is 3 mm thick and overlies the homogeneous fluvial (flood-plain) sediments known down to 5.5 m *(Fig. 2)*.

The underlying bed is fine silt with coarse silt displaying locally horizontal, parallel microstratification and cross-bedding of small angle. In this sediment formed in quiet, slowly flowing water much tubular limonite concretions and circular limonite precipitations occur formed after the defunct plant remnants, reflecting the former rich aquatic vegetation. In the photos taken under microscope the process of subsequent filling by limonite could also be studied.

Out of the alluvial (infusion) loess of the four exposures the deposit of this locality is most typical both macro- and microscopically. From the sedimentological and paleontological points of view it overlies the underlying beds with sharp boundary. Its texture is uniform and its clay content varies between 20 and 25 per cent. $CaCO_3$ concretions, limonitized plant pseudomorphs and characteristic terrestrial and aquatic molluscs are frequent in it.

The molluscs of the sequence: in the samples 27 mollusc species were found (1129 pieces, *Table 1*).

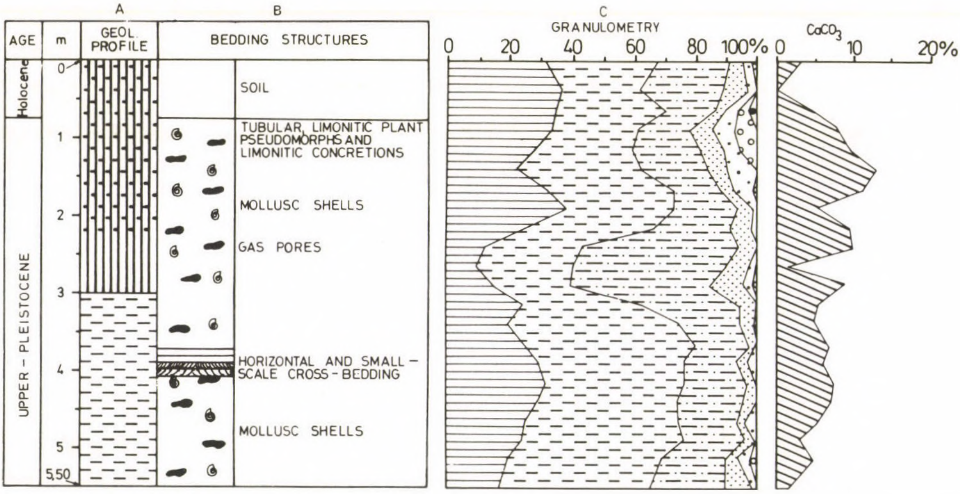

Fig. 2 Geological profile of the Törökszentmiklós brickyard (Legend see at Fig. 7).

In the flood plain sediments between 3.0 and 3.5 m only a few mollusc were found that represented 7 species. Out of the 5 aquatic species 2 proved to be fluvial species. Similarly to the sedimentological observations this also reflects a fluvial environment. The statement is confirmed by the fact that only two terrestrial species were found (three pieces).

The fauna of the alluvial (infusion) loess from 3.0 m up to the surface, especially of the part between 1.25 and 2.50 metre is very rich so it was suitable to carry out quantitative investigations for percentage composition. The statistic evaluation suggests that the terrestrial species represent the smaller proportion of the fauna *(Fig. 3)*.

In the layer between 2.0 and 2.25 m the proportion of the terrestrial species suddenly increases and becomes as high as more than 50 per cent. This supports the relatively rapid change of the former environment, i.e. the site became temporarily dry.

This phenomenon is repeated between 1.25 and 2.0 m, but to a smaller extent.

Based on the mollusc fauna the age of the sequence is Upper Pleistocene (KROLOPP,E. 1973). The matter of this exposure was studied by PÉCSI,M. et al. from the lithological point of view. The radiocarbon age of the sample taken from the interval of 2.2 to 2.6 m proved to be 20.000±330 years (PÉCSI,M. et al. 1979).

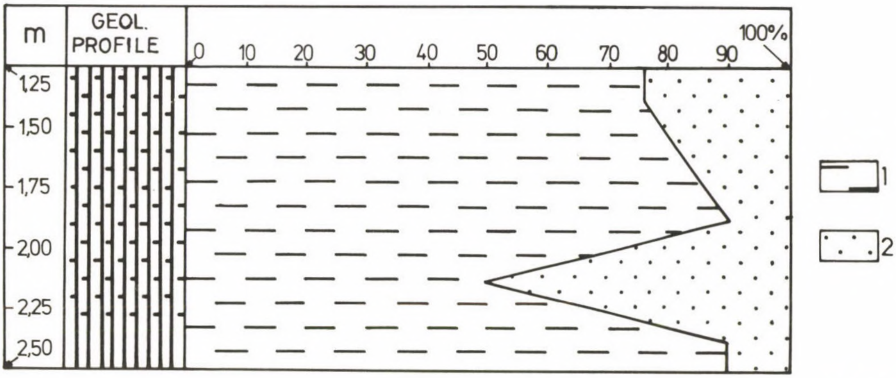

Fig. 3 Percentual proportion of individuals of aquatic and terrestrial molluscs occurring in the alluvial (infusion) loess of Törökszentmiklós. - 1 = aquatic species; 2 = terrestrial species

2. KISUJSZÁLLÁS EXPOSURE

Geology: The profile discloses the Upper Pleistocene sediments down to 7.75 m *(Fig. 4)*. The major part of the fluvial (flood-plain) sequence is unstratified, but shows locally horizontal parallel microstratification. The former rich vegetation is indicated by the limonitic plant pseudomorphs of vertical position. In the sedimentary environment that was intact of flows, under the stagnant airless water the sediments became more abundant in organic matter. Faunal accumulation referring to mass decay also accurs. Periodical marsh formation is proved by the presence of bean iron ore. The subaquatic rotting processes generated a lot of gas pores. It is characteristic of the fluviatile sequence below the loess that gypsum crystals of several cm size occur nearly in all samples. Gypsum substituting the dead plant remnants of vertical

Table 1. Distribution of the mollusc fauna of the Törökszentmiklós exposure as a function of depth.

Species / Depth	Aquatic																	
	Sphaerium corneum (L.)	Pisidium amnicum (MÜLL.)	Pisidium sp. indet.	Valvata pulchella (STUD.)	Valvata cristata MÜLL.	Bithynia leachi (SHEP.)	Stagnicola palustris (MÜLL.)	Radix peregra (MÜLL.)	Galba truncatula (MÜLL.)	Aplexa hypnorum (L.)	Planorbarius corneus (L.)	Planorbis planorbis (L.)	Anisus spirorbis (L.)	Anisus vortex (L.)	Anisus septemgyratus (ROSS.)	Gyraulus albus (MÜLL.)	Gyraulus riparius (WEST.)	Armiger crista (L.)
0.00-0.25 cm																		
0.25-0.50 cm																		
0.50-0.75 cm																		
0.75-1.00 cm																		
1.00-1.25 cm				1		1												
1.25-1.50 cm			1	5		1	3		3			12	23			1		
1.50-1.75 cm			17	96		18	36			1	6	63	67		4	2	1	
1.75-2.00 cm			12	53	7	137	35				7	12	6	1	2	1	4	1
2.00-2.25 cm			13	16	2	13	17	1			4	26	1	1				
2.25-2,50 cm			10	1		59	3				2	4	10	1		1		
2.50-2.75 cm			1	1		2					2		1					
2.75-3.00 cm						7												
3.00-3.25 cm						2												
3.25-3.50 cm		+																
3.50-3.75 cm																		
3.75-4.00 cm			1			1												
4.00-4.25 cm	4	1																
4.25-4.50 cm		+																
4.50-4.75 cm	4	+																
4.75-5.00 cm																		
5.00-5.25 cm		+																
5.25-5.50 cm		+																

+ = fragment

Aquatic		Terrestrial													
Segmentina nitida (MÜLL.)	Bathyomphalus contortus (L.)	Succinea putris (L.)	Succinea oblonga DRAP.	Succinea elegans RISSO	Cochlicopa lubrica (MÜLL.)	Pupilla muscorum (L.)	Vallonia pulchella (MÜLL.)	Limacidae indet.	Trichia hispida (L.)	Monachoides rubiginosa (SCHM.)	Total	Aquatic		Terrestrial	
												Specimen	%	Speci-men	%
		1									1			1	
			2						1		5	2		3	
	3	9	2				2	1	1	2	69	52	75.36	17	24.64
1	14	65	1				1	1		1	395	326	82.53	69	17.47
1	8	33	1								321	287	89.41	34	10.59
	2	98									194	96	49.48	98	50.52
	2	5	2		1	2				1	104	93	89.42	11	10.58
		8									15	7		8	
				1							8	7		1	
											2	2			
				2			1				3			3	
											3	3			
											5	5			
											4	4			
										Total	1129	884	78.30	245	21.20

position is of microcrystalline structure. The formation of gypsum can be related to the former extreme ground water table fluctuation, to the periodical desiccation and to the strong evaporation from the subsurface layers (RÓNAI,A. 1979).

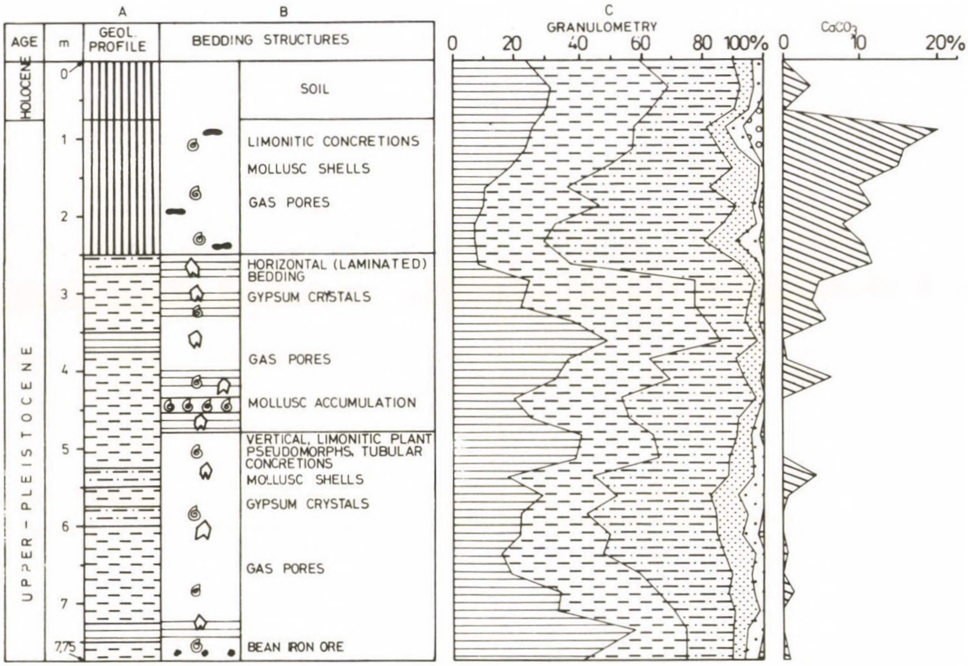

Fig. 4 Geological profile of the Kisujszállás brickyard (Legend see at Fig. 7)

The alluvial (infusion) loess of 2.5 m thickness is fairly well separated from its underlying bed, in its upper section the clay fraction shows higher values reflecting the former inundations. In thin section the rock displays a homogeneous texture. The presence of sparse mollusc fauna can be explained by dissolution of shells. The material of the frequent calcareous concretions was supplied by the dissolved $CaCO_3$.

Molluscs: In the sequence 405 mollusc shells were found. Between 2.5 and 7.75 m the sequence consisting mainly of flood-plain sediments displays sparse mollusc fauna, only one terrestrial species was found in addition to six aquatic. This could be caused partly by the dissolution of shells proved by the greater number of upper shells of *Bithynia leachi*.

The alluvial (infusion) loess developed up to 2.5 m contained 13 aquatic and 5 terrestrial species. Its upper section is more abundant concerning the number of individuals: here 10 aquatic and 5 terrestrial species are found. At the base a transitional layer is found (2.0 to 2.5 m) in which fluvial species also occurs.

3. KARCAG EXPOSURE

Geology: the fine-grained fluviatile sediment at the base of the exposure is the formation of flood plains far from the river beds *(Fig. 5)*. At the time of its formation periods with more abundant precipitation also existed, i.e. when in the flood plains not only periodical inundation occurred but as a result of longer inundation of water periodically lacustrine sedimentation also took place. The peat layers also support this (RÓNAI,A. 1979). The sediments of the section of 3.0 to 6.5 m are hardly stratified, contain gas pores and much concretions. The concretions are of different origin. In the holes of the dead plant remnants the limonitic solutions generated concretions of annular structure, somewhere else mosaic-like concretions cemented by limonitic material occur in the clays. Hollow concretions showing the traces of dehydration shrinkage after precipitation also occur.

The alluvial (infusion) loess is of uniform texture and of variable clay content and is fairly well diagenized. This formation is overlain by a 0.5 m thick flood plain, marshy sediment that contains large amounts of bean iron ore.

Molluscs: 174 individuals were determined in the profile. The flood-plain sediments of the lower part of the exposure (3.0-6.5) contain sparse backwater fauna. Nevertheless, most of the layers are free of fauna. This phenomenon can be explained by subsequent dissolution, since only the opercula of *Bithynia leachi* preserved in greater number.

In the alluvial (infusion) loess between 0.5 and 3.0 m a poorish fauna displaying low species and individual number (6 aquatic and 3 terrestrial species) occurs.

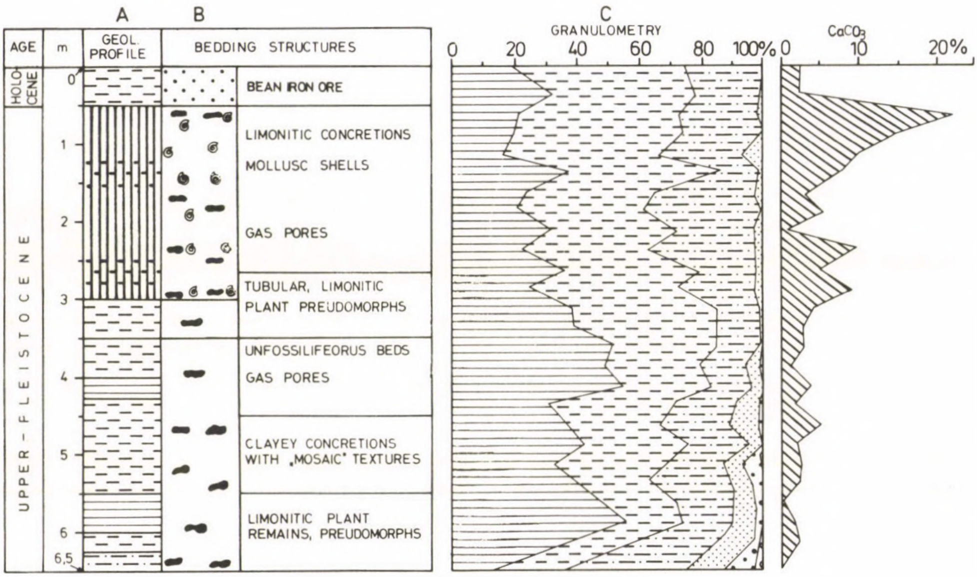

Fig. 5 Geological profile of the Karcag brickyard (Legend see at Fig.7)

The Holocene alluvium overlying the Pleistocene formations is characterized by backwater and terrestrial species (1 and 3 species respectively). The impoverishment of the fauna could be caused by the periodical aridity of the region and by subsequent dissolution.

4. MEZÖTÚR EXPOSURE

Geology: The profile lying in southern Nagykunság revealed the near-surface strata of the Upper Pleistocene down to 8.25 metre *(Fig. 6)*. The deeper fluviatile sequence is characterized by more varied grain-size and mode of stratification than in case of the previous exposures. The silty section of the sequence is characterized by horizontal parallel micro-stratification with very thin beds. This indicates quiet flood plain sedimentation by water farther off the river bed. The sediment contains concretions and limonitic plant pseudo-morphs. The photos taken under the microscope also show a texture characteristic of the flood plain sediments, with gas pores, microstratification and limonitic precipitations.

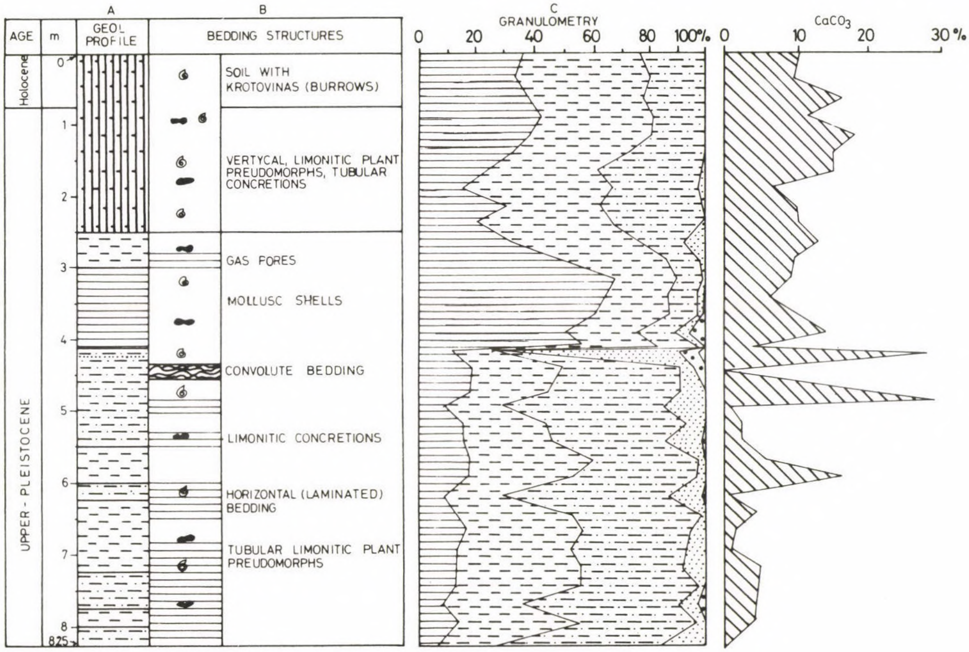

Fig. 6 Geological profile of the Mezötur brickyard (Legend see at Fig. 7)

The laminae of the silt between 4.3 and 4.5 m were subject to convolute deformation due to the uneven loading and to the mud-slide in plastic state. The development of this phenomenon could be also affected by the higher content of fine-grained sand.

Concerning all the studied profiles, the 2.5 m thick alluvial (infusion) loess shows the greatest transformation here. Its texture was formed by the fine-grained sediments transported by the former floods and by long-lasting waterlogging. The rich vegetation contemporaneous with the sediment accumulation is evidenced by the hollows after vertical plant remnants and by the tubular limonite concretions.

Molluscs: 75 individuals were identified in the exposure. In the lower fluvial flood-plain fine-grained sediments of the section (2.5 to 8.25 m) the species and individual number of the fauna is poorish: 16 aquatic and 2 terrestrial species were found. In the depth interval of 6.25 to 6.5 m fluvial species also occurred. From 4.15 m downwards the formations refer to fluvial (flood-plain) environment. In the clayey sediment between 2.5 and 4.15 m the more abundant fauna refers to backwater marshy environment.

In the alluvial (infusion) loess from 2.5 m up to the surface only some specimens of only 3 aquatic and 3 terrestrial species occurred. Out of the latter ones the Pleistocene species *Vallonia tenuilabris* (BRAUN) was found between 1.25 and 1.5 m.

SEDIMENTOLOGICAL AND PALEOECOLOGICAL CONCLUSIONS

Having reviewed the material of the exposures it can be stated that the fine-grained fluviatile sequence constituting the base of the alluvial (infusion) loess consists of sediments indicating quiet aquatic environment with locally lasting water logging and with local marshes. In many cases the sediment also displays the features of lacustrine sedimentation.

In the region overgrown by abundant marshy vegetation a rich mollusc fauna existed. Nevertheless, due to the effect of subsequent processes the shells were dissolved in some localities. In this young Pleistocene sedimentary sequence the rotting and stagnant-water processes left their imprints and the gas pores were also preserved. The periodical change of groundwater table, the repeated dissolution of salts are proved by the gypsum crystals known from the Kisújszállás sequence.

In the area in question the alluvial (infusion) loess developed in a thickness of 2.5 to 3 m with rather varying fine-silt and clay contents. Its texture was affected by the floods of the former rivers and by the enduring water logging. In the course of floods fluvial sediments could also intercalate into the sequence.

The dust fallen upon the wet relief or directly into the water cannot take on the structure of loess either in the surface since the dust material loses its calcareous crust and porous structure due to the repeated moistening. The typical loess is also liable to collapse; the same applies for alluvial (infusion) loess since it is immediately influenced under subaquatic conditions and later it is loaded, too. After repeated or longer soaking its original volume is reduced and its structure is also changed (PÉCSI,M. 1965; HAHN,Gy. 1977; RÓNAI,A. 1985).

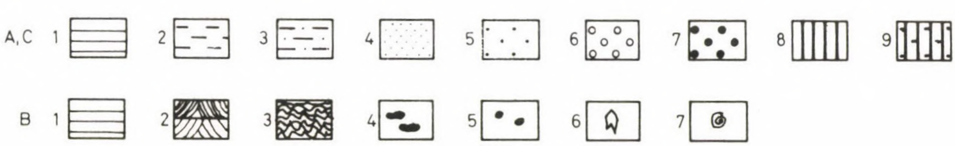

Fig. 7 Complex legend to the sequence of the four exposures. (To Figs 2, 4-6)
A, C: 1 = clay ($<$ 0.005 mm); 2 = fine silt (0.02-0.005 mm); 3 = coarse silt (0.02-0.06 mm); 4 = fine sand (0.06-0.1 mm); 5 = fine-grained sand (0.1-0.2 mm); 6 = medium-grained sand (0.2-0.5 mm); 7 = coarse sand (0.5-2.0 mm); 8 = alluvial (infusion) loess; 9 = clayey (infusion) loess
B: 1 = horizontal parallel stratification; 2 = cross-bedding; 3 = laminae endured convolute deformation; 4 = concretion; 5 = bean iron ore; 6 = gypsum crystal; 7 = mollusc remnants

The mollusc fauna is sensitive to changes in the biotope (SZÓNOKY,M. 1963; LOŽEK,V. 1964; KROLOPP,E. - SZÓNOKY,M. 1984). The malacological assemblage found in the profiles fairly well reflects the conditions of sedimentation by the species and specimen composition (1783 pieces). The fluvial environment as well as the flood-plain environment permanent water coverage and of periodical inundation can be fairly well distinguished on the basis of faunal changes.

Changes can be best traced in the Törökszentmiklós profile of most abundant fauna, so the complete malacological material of this profile is demonstrated *(Table 1)*.

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QUATERNARY MALACOLOGICAL RESEARCH IN HUNGARY BETWEEN 1982--1985

E.KROLOPP

ABSTRACT

During the time elapsed since the 11th INQUA Congress, the intensive malacological research of the Quaternary is indicated by the number of publications (37) appeared during the period from 1982 to 1985. Research was aimed at the taxonomy of the Pleistocene and Holocene implications of Quaternary malacology.

* * *

Quaternary malacology as a separate discipline emerged some decades ago. Although in the Quaternary research, intensified around the turn of the millenia, the analysis of molluscs was central, it only remained a tool for the reconstruction of the Pleistocene environment for a long time. It was not revealed before the investigations of the last decades that Quaternary malacology is an important factor of contemporary comprehensive Quaternary research and it is able to resolve the major issues including problems of stratigraphy.

Following the summarization of the results and further tasks of the Quaternary malacological research in Hungary (KROLOPP,E. 1973, Quaternary malacology in Hungary, Földr. Közlem. 21. (97.) pp. 161-171.), the biostratigraphy of the Hungarian Pleistocene based on its mollusc fauna could also be presented at the 11th INQUA Congress in Moscow (KROLOPP, E. 1982a).

It should be mentioned here that within the framework of the 8th International Malacological Congress in Budapest, a colloquium was organized under the title 'Quaternary malacology and faunal history'. At the colloquium 10 lectures were delivered, supplemented by two separate posters. On one of the excursions mainly fossil mollusc sites, first of all, Pleistocene formations were visited (KROLOPP,E. 1984a).

The recent results of Hungarian malacological research can be grouped around three topics:

1. Pleistocene mollusc fauna
2. Mollusc fauna of Holocene formations
3. Archaeological implications of Quaternary malacology

1. Revising previously gathered Pleistocene malacological material and analyzing recently collected samples of modern attitude, the inventory of mollusc species recovered from Pleistocene formations in Hungary until January 1st, 1983, and taxonomically identified was completed (KROLOPP,E. 1982-1983). The inventoried 195 taxa (18 pelecypods and 177 gastropods) helped us establish the features of the Pleistocene mollusc fauna in Hungary (KROLOPP,E. 1984b).

Another, stratigraphic achievement of the research of the Pleistocene malacofauna is the biostratigraphical chronology of the Pleistocene including 5 biozones further subdivided into 8 subzones (KROLOPP,E. 1983d). This allows the stratigraphic divisions of the Pleistocene formations with the help of their mollusc faunae *(Table 1)*.

Besides the summarizing works, research continued to receive deeper taxonal, regional, faunal historical and ecological knowledge of the Pleistocene malacofauna.

Among the taxonomical works, the description of the species of the *Gastrocopta* genus recovered from Hungarian and European Pleistocene formations is worth mentioning (KROLOPP,E. 1983b). The regional investigations mainly covered the north-east of Hungary (FÜKÖH,L. 1982b, 1983b; JÁNOSSY,D.--KORDOS,L.--KROLOPP,E. 1984; KROLOPP,E. 1985) and the Great Hungarian

Table 1 Correlation of the Hungarian geo- and biochronological Pleistocene classifications

Chronostratigraphy		Malacological subdivision		Mammal stratigraphic phases		Alpine subdivision	
PLEISTOCENE	Upper Pleistocene /?/	5.Bithynia leachi-Trichia hispida biozone	Semilimax kotulai subzone	Utrechtium	Palánk	Würm	W 3
			Catinella arenaria subzone		Pilisszántó		
			Succinea oblogna subzone		–		W 2-3
					Istállóskő		W 2
			Helicopsis striata subzone		Tokod		W 1-2
			Clausilia pumila subzone		Subalyuk		W 1
		4.Helicigona banatica-Phenacolimax annularis biozone			Varbó	Riss-Würm	
					Sűttő		
		3.Helicigona vertesi biozone	?	Oldenburgium ?	?	Riss	
					Solymár		
					Castellum	Mindel-Riss	
	Middle Pleistocene /Biharium/			Upper Biharium	Uppony	Mindel	
					Vértesszőlős		
		2.Perforatella bidentata biozone			Tarkő		
		1.Viviparus böckhi biozone	Gastrocopta sacraecoronae subzone	Lower Biharium	Templomhegy	Günz-Mindel	
					Nagyharsányhegy		
			Neumayria crassitesta subzone		Betfia		
	Lower Pleistocene /Villányium/		Gastrocopta serotina subzone	Upper Villányium	Kisláng	Günz and Pregünz	
				Lower Villányium	Beremend		
		?					

Plain (KÓNYA,Z. 1984; KROLOPP,E.--SZÓNOKY,M. 1982, 1984), but some of them referred to Transdanubia (F.SZABÓ,I. 1982). The analysis and revision of the Quaternary stratotype sites in Hungary were carried on (KROLOPP,E. 1982c). A special development is the application of thermal analysis on Quaternary malacological material for taxonomic and chronological purposes (SZÖÖR,Gy.--BORSY,Z. 1982; SZÖÖR,Gy. 1983).

2. The malacological investigation of the Holocene formations in Hungary has been a long neglected field of research. Recently, a positive change has been observed in this respect: an intensive research activity commenced. Research was carried on primarily in two areas.

One of them is the North Hungarian Mountain Range, where the rich malacological material of rock caverns permits quantitative microstratigraphical investigations (FÜKÖH,L. 1983d). The investigations have, first of all, resulted in stratigraphical and paleoecological achievements (DOMOKOS,T. 1985; FÜKÖH,L. 1983c; FÜKÖH,L.--KROLOPP,E. 1982-1983, 1984, 1985b), but also produced a novelty in taxonomy (FÜKÖH,L. 1985). The zoological implications are also important (BÁBA,K.--FÜKÖH,L. 1984; FÜKÖH, 1983a). Along with the excavations in the rock cavern, the faunistic analysis of the Holocene travertines in the area has also begun (FÜKÖH,L. 1984).

The other area is the malacological investigation of the Holocene sequences of lakes and streams. Transdanubian (FÜKÖH,L.--KROLOPP,E. 1983; KROLOPP,E.--VÖRÖS,I. 1982) and Great Plain sites (DOMOKOS,T. 1984; FÉNYES,J. 1982; KROLOPP,E.--SZÓNOKY,M. 1982) were equally studied.

The results of the comprehensive research permitted the compilation of the inventory of mollusc species recovered from Hungarian Holocene formations until January 1st, 1985, and identified taxonomically. It included 150 (14 pelecypods and 136 gastropods - FÜKÖH,L.--KROLOPP,E. 1985a). The inventory functions as a starting-point to further investigations, which are also important to understand the recent malacofauna better (FÜKÖH,L. 1982a).

3. During the recent years, a fruitful cooperation has been

achieved between archaeologists and Quaternary malacologists. It led to the development of a particular field in Quaternary malacology, archaeological malacology (KROLOPP,E. 1982d). During investigations of this kind not only the malacological material revealed as a by-product of archaeological excavations were analyzed but, through the quantitative examination of molluscs from the sequence of the site information on environmental factors and their changes could also be obtained (KROLOPP,E. 1982b, 1983c).

At the 8th Congress of Unitas Malacologica, a report has been presented on the achievements and future tasks of Quaternary malacological research in Hungary before an international forum (KROLOPP,E. 1983a). A promising sign for the future is seen in the fact that recently more and more university students have chosen malacology or its application in geology as a topic for their graduate dissertations (KÓNYA,Z. 1983; LAUKÓ,E. 1985).

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PALYNOLOGICAL EVIDENCE FOR MARKING THE PLIOCENE/PLEISTOCENE BOUNDARY IN THE CARPATHIAN BASIN

H. LÖRINCZ

ABSTRACT

Relying on the palynological investigation of the Jászladány borehole belonging to the N-S section across the Great Hungarian Plain, author outlines the history of Upper Pleistocene--Middle Pleistocene flora in the Great Plain geosyncline.
It was found that the profile and other deep borehole data suggest three stages in vegetation history following the warm-wet period (with Alnus) only represented by its ultimate member: another warm period with (Alnus) forests, a warm-dry one with mixed forests and another warm stage with grasslands and dry forests, divided by short spells of dry coniferous forests.
The stages exactly correspond with the Csarnótan I--II-Villafranchian/Villányian-Biharian subdivisions of terrestrial vertebrate biochronology. It precisely indicates the three debated ways of locating the Plio-Pleistocene boundary and provides help for geologists, who have to say the final word in this debate.

* * *

INTRODUCTION

There have been several changes in the periodization of geological formations and in the establishment of boundaries between the periods. This particularly applies to terrestrial stratigraphy, where different opinions and resulting debates arose concerning the time expanse and subdivisions of the Quaternary.

The main problem in locating the Plio-Pleistocene boundary and further subdividing the Pleistocene lies in the two or even three different starting-points of researchers: the first is the study of Pleistocene glaciated areas, the second is the investigation of non-glaciated (tropical and other) areas and the third is the research of the transitional belt between the above, of the periglacial-pseudoperiglacial belt affected by the special conditions of both.

DISCUSSION

The physical conditions in the three belts resulted in a chain of events more or less easily correlated in the chronology of the geological periods involved. These periods differ in the hierarchy of the units used in their chronologies/stratigraphies. To formulate it more exactly: the "ranking" of the individual ages/stages described and applied in glaciology, terrace-morphology, loess-stratigraphy and climatology as well, can be correlated within one belt, but it will be very difficult as soon as, for example the chronologies/stratigraphies of former glaciated and non-glaciated areas are to be compared. The discrepancy looks even more significant in drawing the Pliocene/Pleistocene boundary, increased by the differences in absolute dating of the given boundaries. Today the contradiction between the systems for 'northern' (glaciated) areas (with a Pleistocene period of 0.7 Ma) and for the 'southern' (tropical-mediterranean) areas (with a Pleistocene period extended to 1.8, 2.4 and even 4.3 Ma) is very confusing and locating the Plio-Pleistocene boundary is even more problematic.

Eventually, drawing boundaries and establishing periods are geological-geohistorical problems and involve much subjectivity, disregarding a series of practical considerations. The palynologist does not want to interfere. However, she is able to provide essential data to promote the correspondence of units in the various systems, to their description and a more realistic hierarchy.

The present paper intends to supply palynological evidence for the Upper Pliocene and Lower to Middle Pleistocene from boreholes located in the centre of the Carpathian basin, in the Great Hungarian Plain, in the area of Jászladány 80 km south of Budapest. The basic investigations by B. ZÓLYOMI and M. JÁRAI-KOMLÓDI have revealed the events of the Upper Pleistocene in detail and, therefore, they are not included in this brief survey.

The 18 deep borehole sections in N-S direction made in the lowland mentioned, crossing through Quaternary deposits (to 100-1500 m), reached down to the Upper Pliocene in several cases and the boreholes of 1200 to 1500 m depth ended in the upper part of Pannonian deposits. From the complex survey led by A.RÓNAI (1972,1985), only the palynological conclusions are treated here on the basis of the detailed documentation (LÖRINCZ,H. 1972a,b).

Not aiming at a conventional botanical-vegetation historical study, author supplies information for geochronology and, therefore, does not give the botanical-ecological analyses of the pollen spectra of individual samples and sample groups. Instead, the successions of taxa showing dominance shift of congruent distribution were grouped. In the profile, from bottom to top, they are clearly indicative of dominance changes and their rates. They help us fix the site of major or minor environmental changes in the profile and the periods of essentially similar environmental conditions. Here the ecological and cenological interpretations and vegetation historical implications are restricted to those relevant to geologists in chronology; further details of the analyses will be published elsewhere.

Based on the congruence of the dominance curves, the groups of taxa identified for the profile are the following:

1. *Alnus* (great form taxon), *Fagus* (great form taxon)
2. *Podocarpus*, *Ericaceae*, *Zelkova*, *Keteleeria*, *Nyssa*, *Engelhardtia*, *Cedrus*, *Pterocarya*
3. *Fraxinus*, *Juglans*, *Ginkgo*, Palmae, *Carya*, *Ostrya*, *Tsuga*, *Pinus haploxylon*, *Betula* (great form taxon), *Salix* (great form taxon)

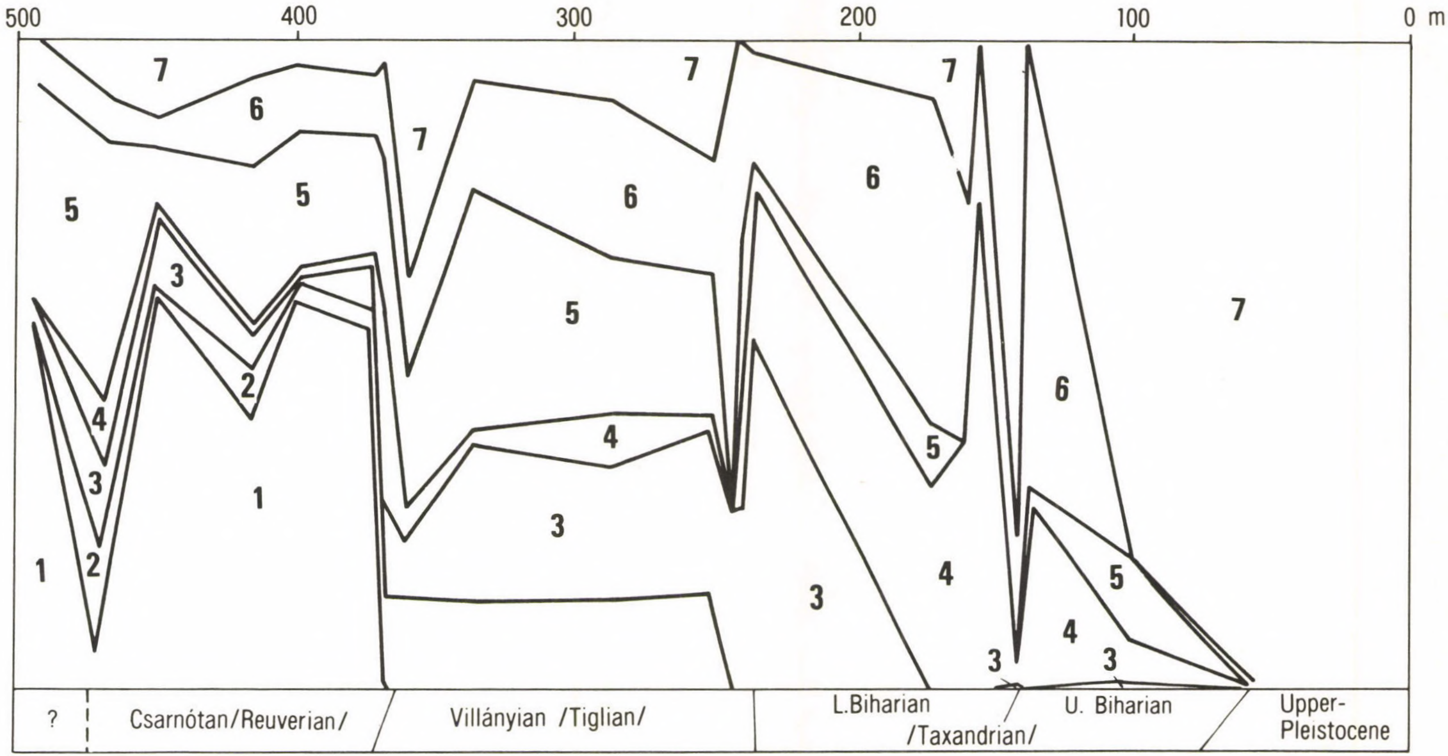

Fig.1 Pollen spectrum of the Upper Pliocene--Middle Pleistocene vegetation in the Jászladány section. 1=Alnus(great form taxon),Fagus(great form taxon); 2=Podocarpus,Ericaceae,Zelkova,Keteleeria,Nyssa, Engelhardtia,Cedrus,Pterocarya; 3 = Fraxinus, Juglans,Ginkgo,Palmae,Carya,Ostrya,Tsuga,Pinus haplo-xylon,Betula(great form taxon),Salix(great form taxon); 4=Conifers without airsac; 5=Ilex,Castanea,Ulmus,Fagus(little form taxon),Tilia,Rhus,Rosaceae,Corylus,Alnus(little form taxon),Carpinus, Quercus,Acer; 6=Juniperus,Pinus cembra,Salix(little form taxon),Betula(little form taxon),Larix, Abies,Picea; 7=Pinus

4. Conifers without air-sac
5. *Ilex, Castanea, Ulmus, Fagus* (little form taxon), *Tilia, Rhus*, Rosaceae, *Corylus, Alnus* (little form taxon), *Carpinus, Quercus, Acer*
6. *Juniperus, Pinus cembra, Salix* (little form taxon), *Betula* (little form taxon), *Larix, Abies, Picea*
7. *Pinus*

In grouping taxa by dominance I often observed that certain taxa, after congruence of shorter or longer duration shift to other type of dominance. These changes should be evaluated, naturally with caution, as alterations in the ecological requirements of the given taxa or in their virulence. This is part of the study of vegetation history. For the time being such taxa are excluded from the groups by dominance.

Looking at the pollen diagram of the uppermost 500 m of the profile *(Fig. 1)*, it is seen that four sections are distinct:

450 to 370 m: *Alnus* I, *Fagus* I dominance

334 to 260 m: moderately mediterranean climate, mixed deciduous and palm forests *(Alnus* I, *Fagus* I still occur)

226 to 141 m: mixed deciduous forests with southern conifers acquiring dominance (without *Alnus* I and *Fagus* I)

140 to 50 m: continuation of the above, *Pinus silvestris* group attaining dominance.

The pollen spectra of horizons above 52 m are not suitable for interpretation and, therefore, they are not treated here. The spectrum around 497 m, however, should be analyzed along with the section between 450 and 370 m of practically the same spectrum. The unified treatment of the two sections would be feasible if short segments of highly different spectrum - as the one at 468 m - were not characteristic of the whole profile.

Ignoring the uppermost part, the 500 m of the Jászladány profile represents the following palynological units (from bottom to top):

A. (497 m) *Alnus* I dominance with various accompanying forms: *Tilia-Quercus* association. *Acer-Engelhardtia-Rhus* and exotic pines, *Ginkgo*, *Typha* and *Cyperaceae* undergrowth. Warm, relatively humid climate.

B. (468 m) Almost complete disappearance of *Alnus* I, mixed-deciduous forests, occurrence of *Alnus* I - *Fagus* I, southern conifers, Graminae. Drier warm climate.

C. (450-370 m) Dominance of *Alnus I* throughout; almost identical vegetation with zone A, slight oscillation of mixed deciduous forests.

D. (363 m) Sharp boundary, dominance of *Pinus silvestris* type pollen spectrum; the insignificant accompanying deciduous trees comprise forms of moderate to warm climate. The humid climate is confirmed by Cyperaceae and *Typha*.

E. (334-260 m) Another temperate section of 70-80 m length with warm-mediterranean deciduous trees, Gramineae and palms. Dry warm climate.

F. (252 m) Occurrence of modern pollen type (little, type II form taxon) of *Alnus* and *Fagus*, dominance of *Pinus silvestris* type pines, with numerous mediterranean-temperate deciduous pollen.

G. (243 m) Complete absence of *Pinus* dominance, temperate deciduous forest pollen spectrum with southern pines and conifers without air-sac.

H. (226 m) Almost exclusive dominance of the taxon groups 4-5-6, the taxon group 2 *(Engelhardtia, Nyssa, Keteleeria* etc.) disappears, the trend beginning with zone F continues.

I. (223-140 m) Pronounced trend with moderate oscillations from the dominance of taxon group 3 to that of groups 6 and 4, finally with *Pinus silvestris* occurrence.

J. (140 m) This short interval is characterized by complete change in pollen spectrum to *Pinus sil-*

vestris type, completed with the forms of the taxon group 6.

K. (139-52 m) Apart from the reoccurrence (to 5-10 %) of the groups 3, 5 and 6 (96-69 m), almost exclusively pollen of *Pinus silvestris* type is dominant.

Detailed analysis is not possible for the upper part, because of the oscillation of pollen distribution. Here only the remark is made that, subsequent to an exclusive *Corylus* point (at 52 m) after the dominance of *Pinus silvestris* type pollen, the profile ends in a short section limited to the taxon groups 5 and 6. Before turning to the interpretation of the profile, it has to be emphasized again that the sections B, D, F-G-H and J have isolated pollen spectra, and, therefore, they cannot be explained without disrupting the profile. Other investigations also confirm this (KRETZOI,M.–KROLOPP,E. 1972). Comparing the 11 pollen sections outlined above with other investigations of the profile, it is observed that pollen analyses and chrono-stratigraphical research provided similar results.

The most obvious opportunity of comparison is with sedimentological analyses. A granulometric profile was available from the depth interval cca 440-0 m. RÓNAI,A. (1972) identified five main cycles and 10 subcycles in this interval. The subdivisions are the following (tentative dates):

m	subhorizon	horizon	stage
0-35	10		
35-65	9	V	
65-95	8		(Q_3) Upper Pleistocene
95-135	7	IV	
135-170	6		
170-210	5		(Q_2) Middle Pleistocene
210-275	4	III	
275-345	3	II	
345-385	2		(Q_1) Lower Pleistocene
385-420	1	I	

No data are available of the distribution of fossil soils and red clay layers and, thus, they were not tied to the granulometric horizons. Therefore, the only granulometric subdivisions cannot be made correspond with the palynological one. Among the paleozoological investigations, the malacological and vertebrate faunistic findings are comparable with the pollen diagram. In the malacological analysis, KROLOPP,E. (1972) found that the gastropod fauna of the profile can be grouped into three distinct complexes: the first is represented in the 26-60 m of the section, the second reaches from 124 to 255 m, while the third can be found between 366-497 m. In comparison with the palynological data, at three points, very good agreement is found:

1. The intervals A and C of the pollen diagram indicate the same climates as the ecological postulates of the Csarnótan stage of vertebrate paleontology (KRETZOI,M. 1962. etc.).

2. A marked point in vertebrate stratigraphy is the *Mimomys savini* find at 84 m (KRETZOI,M. 1972a, KRETZOI,M.–KROLOPP,E. 1972) of Lower Biharian substage, indicating gradual climatic deterioration from 60 m to below 220 m. The lower part (below 140 m) can be placed to the Betfian warmer phase, where the dividing *Pinus* peak indicates the Nagyharsányhegy cool phase before the Templomhegy warm one.

3. The warm and dry interval between the lower warm and humid part (made correspond with the Csarnótan stage) and the upper warm and dry part of 334-260 m (Biharian) is identified as Villafranchian/Villányian. Finally, the short spells with *Pinus* correspond to the loam-pale clay horizons (in the case of the Biharian loess) intercalated into the series separating the Csarnótan, Villányian and Biharian ages and interrupting the red clay series. They indicate cool phases as also supported by faunal finds.

CONCLUSION

The correspondence between the palynological, malacological and vertebrate paleontological data confirms the place of the first method in the system of terrestrial chronology.

It is important to emphasize again that the primary task of biostratigraphy-biochronology is to call attention to the events in the evolution of the biota which help periodization. The systematization of geological history is not counted among its tasks.

Accordingly, in the 500-65 m section of the Jászladány series (from bottom to top) palynological record shows a lower humid and warm period succeeded with sharp boundary (first possible boundary) by an arid and warm period with still Tertiary elements (second possible boundary). The next is a warm and dry section with oscillations and gradual cooling, without Tertiary elements. Its end is marked by loess formation and represents a third opportunity for locating the Plio-Pleistocene boundary. In the first case the boundary coincides with the Csarnótan/Villányian humid to arid change, while in the second it would be parallelled with the extinction of Villányian/Biharian ancestral floral-faunal elements. In the third the considerable climatic deterioration beginning with the end of Lower Biharian (of glacial nature with loess formation) marks the Pliocene/Pleistocene (i.e. Tertiary/Quaternary) boundary.

Issues other than the presentation of the different opportunities to mark the boundary are beyond the authority of the palynologist.

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FLUCTUATION OF THE LITHIC RAW MATERIAL ACCESS AND UTILIZATION FROM THE PALAEOLITHIC TILL HISTORICAL TIMES

K. TAKÁCS-BIRÓ

ABSTRACT

The raw material procurement of human communities, as well as the aims for utilizing certain mineral resources, the methods and quantities involved in these processes are continuously changing, corresponding to chronological, cultural, geological and geographical factors. The present paper aims at the study of the spatial, functional and temporal aspects of lithic raw materials typically used for the production of chipped stone implements such as siliceous rocks and obsidian in the Carpathian Basin, Central Europe.
Special problems considered include the changes in function, absolute and relative quantities involved, the nature of the raw material source (primary and secondary sources, re-working), and the extension of the supply region, in terms of average as well as maximal distance from the source region.
Apart from the traditional stone tool functions, attributed to prehistoric lithic assemblages, ethnographical and historical evidences on the utilization of the relevant raw materials are equally taken into consideration.

* * *

INTRODUCTION

In spite of much wider connotations, being an archeologist involved in prehistorical lithic studies mainly, "lithic raw material access" for me implies a specific and well definable range of materials, selected for the production of the most ancient tools. The raw material selected for these tools had to suit the tasks to be performed as well as techniques of manufacture. These criteria were met, in prehistoric times, by those hard, homogeneous and splittable raw materials mainly, that were easy to shape by knapping, in the first place, silex varieties and obsidian.

Later technical development and emergence of new needs involved a multitude of other materials in course of time; comprising in our ages practically the whole human environment (TEILHARD DE CHARDIN,F. 1980). The materials used for the production of the chipped stone tools have, in this process, their own history *(Fig. 1)*.

THE LITHIC RAW MATERIAL BASIS OF THE CARPATHIAN BASIN

The Carpathian Basin represents a special ecological unit, especially suitable for paleo-economical studies (SHERRATT,A. 1983). The lowlands of Pleistocene and Quaternary sediments are practically void of lithic raw materials, especially primary ones (PÉCSI,M. 1969; FÜLÖP,J. 1984; SOMOGYI,S. 1984). The complicated tectonical history of the Mid-Mountains resulted in a variegated and geographically separable set of raw materials, more or less distinctly separable source regions for raw materials that can be quite effectively separated in respect of their primary sources (TAKÁCS-BIRÓ,K. 1984b, 1986). At the same time, the Alps and Carpathes, embracing the territory of the Carpathian Basin, prevented the ice-sheet of the glacial periods to penetrate and cover the area with erratic flint of the Northern territories. Thus the raw material procurement areas can be located quite precisely. The main raw material sources of the Carpathian Basin, known so far, are presented on *Fig. 2.* For the compilation of this map, data of KACZANOWSKA,M. (1985); BÁRTA,J. (1979); TAKÁCS-BIRÓ,K. (1986) were used, together with the results of different petroarcheological symposia of Central and Eastern Europe.

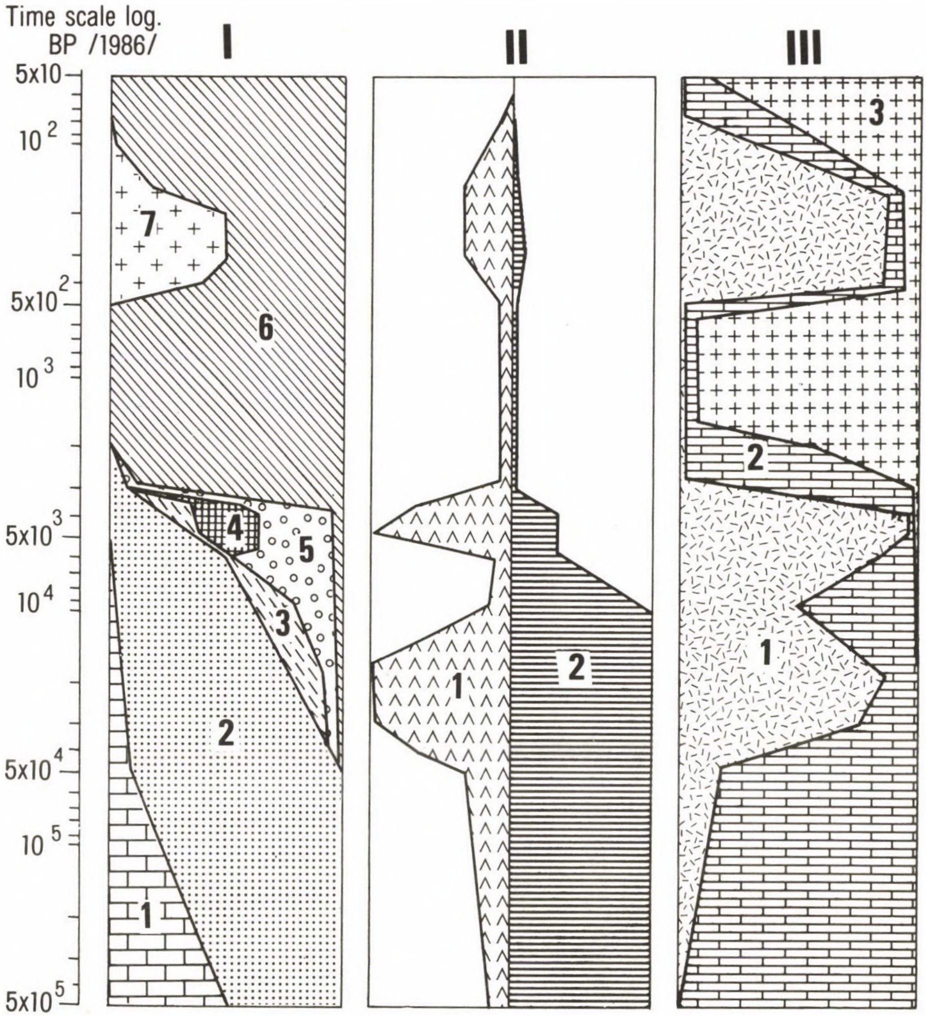

Fig. 1 Utilization, quantity and raw material access of chipped stone artifacts (estimated trends)

I. Scheme of the main functions in course of time. 1 = multi-functional, non-specified tools; 2 = tools connected with food procurement; 3 = weapons; 4 = sickles; 5 = tools connected with artisan activity; 6 = fire-flint; 7 = gun-flint

II. Quantity of chipped stone artifacts. 1 = Actual quantity; 2 = relative importance among the utensiles

III. Raw material procurement for chipped stone artifacts. 1 = primary sources; 2 = secondary - redeposited - sources; 3 = re-use of archeological pieces

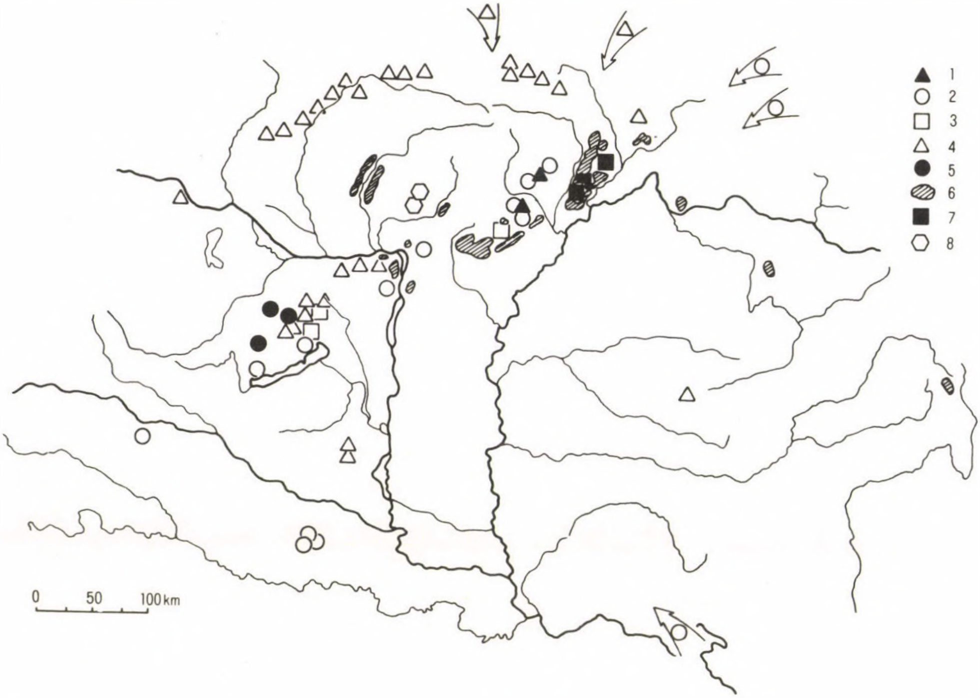

Fig. 2 Raw material sources of the Carpathian Basin for chipped stone artifacts

1 = quartz porphyry; 2 = T chert; 3 = J_1 flint,chert; 4 = J_{2-3} flint, chert; 5 = K flint; 6 = Neogene siliceous rocks; 7 = obsidian; 8 = "nummulitic silicites".

Besides the primary sources, we must consider those of the secondary ones, both natural and artificial. River deposits, molass sediments did play, at some phases of lithic raw material utilization, a most significant role. Artificial secondary sources comprise, in the first place, re-use by subsequent inhabitants of the territory of late descendants, typically for widely different purpose. The ratio of primary raw material sources/secondary ones in itself is very characteristic of a given period and cultural/geographical unit *(Fig. 1/III)*.

TRADITIONAL CHIPPED STONE ARTIFACT FUNCTIONS - Techniques and Raw Material Access

Human development has brought about a continuum of changes in the material culture, reflected well in the function and preparation techniques of chipped stone implements. The first functions can be considered, in a way, the "improvements" of deficient organs of the human body: a substitute for fangs and claws. The technique for the production of these primitive implements is that of direct percussion by hard hammer. The tools themselves are multifunctional, flakes and core implements are equally used. This phase is correspondent to the early pebble cultures, Clactonian and Biface-industries, culturally, while in Old-World chronology, this is equivalent to Lower Palaeolithic. Raw material access is typically local and the raw material deposits exploited are dominantly secondary ones.

The Middle Palaeolithic cultural development is most likely evoked by, in the first place, climatic factors and consequent needs, e.g. clothing and primitive construction. These new tasks had their effect on the refinement of types and techniques of tool production (BORDES,F. 1961). The resultant changes in the raw material access is a wider circle of procurement, and the recognition of the advantages of the "mine-fresh" material, in terms of technological qualities, vs. collected pebbles (RICH,V. 1984; SIMÁN,K. 1983; SVOBODA,J. 1984). The heights of this development were reached probably by the end of the Middle Palaeolithic, coinciding with a definite boom in the population (GÁBORI-CSÁNK,V. 1970;GÁBORI,M. 1976), as well as the first proofs of primitive stone-mining (extraction sites Korlát, Stránska Skála, Budapest), in the Carpathian Basin.

The geographical limits of the raw material procurement area are definitely larger. The rare occasions of raw material occurrences on sites of fairly distant regions - 300-400 kms, Polish material in the Bükk Mts, Tokaj obsidian in Transdanubia with supposed W 1 context (GÁBORI,M. 1976;

VÉRTES,L. 1960,1965) should be reckoned as exceptions, testifying probably individual movements of peoples and by no means regular supply. Collecting from secondary sources and utilization of local materials are, however, still predominant.

In the Upper Palaeolithic, the tendencies started in the Middle Palaeolithic their direct continuation. This period is certainly one of the peaks of the chipped stone utilization in Central Europe. Chipped stone tools served for nearly all classical tool- and weapon functions, that are used, mainly made of metal, up to our days. The diversified typological lists, elaborated for this period at several places locally (SONVILLE-BORDES,D. - PERROT,I. 1954-56; CHMIELEWSKI,W. et al. 1975). It is natural, that the sophisticated techniques are realized using the best quality raw material available preferentially. Supply zones of certain good quality raw materials seem to exist, especially in the Late Palaeolithic ("Gravettian" complexes) (KOZLOWSKI,J.K. 1972-73). The raw material basis is no longer determined by the local stock: the supply zone typical for this period can reach 100-200 kms; obviously in direct dependence of the inhabitations of the lowlands, chasing for big game. Occasional occurrence of raw material varieties, that were likely to function as prestige goods can be demonstrated from the distance of 500 kms as well (TAKÁCS-BIRÓ,K. 1984a; *Fig.3.*). Huge workshop complexes, located near the outcrops of raw materials appear (Cejkov, Arka) BÁNESZ,L. 1967; VÉRTES,L. 1964-65). The utilization of secondary deposits and inferior quality local materials can be observed, to a minor extent, on sites relatively far from the raw material sources, however, even here the good quality silex, originating possibly from primary sources are predominant. The mechanism of the transport - expedition to source areas? barter with specialised artisan groups? seasonal visits to areas of the Flint Sources? - is not clear as yet. An apparent difference, pointed at, from the ecological point of view, by M. GÁBORI, should be borne in mind; the people of the Lower Upper Palaeolithic (Szeletian, Aurignacian cultures)

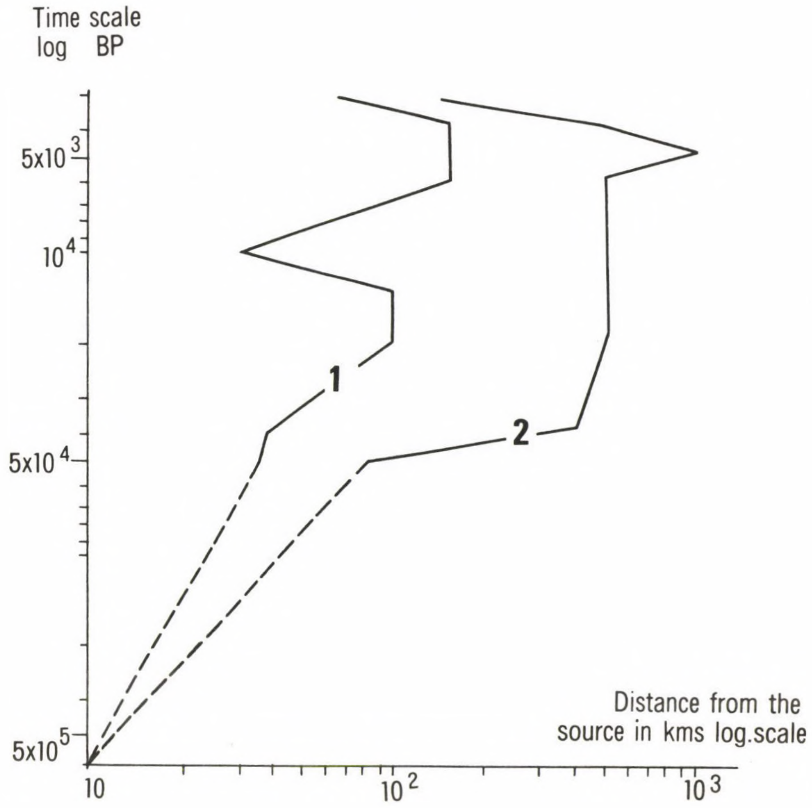

Fig. 3 Distribution radius of chipped stone raw materials on prehistoric sites (from the Middle Bronze Age, the lithic raw material distribution data are not historically significant)

1 = mean value for typical supply zone;
2 = maximal distance of raw material distribution

inhabited the mountainous-forestal regions, coinciding with the raw material outcrop areas, while the Late Palaeolithic people preferred open spaces. The roots of this difference should be sought for in the main game kinds hunted and their ecological requirements; however, the consequences are quite clear in respect of the raw material acquisition as well. The Late Palaeolithic people could develop an efficient and constant raw material supply system, perfectly suited to the high technological requirements.

After the last cold peak of the Würm glacial period, evidences on the inhabitants of the Carpathian Basin are extremely rare, especially in the central parts. The scanty material we dispose of speaks of people living by the rivers, probably more dependant on them as food supply, as well as raw material source and means of transport. The Sered Mesolithic industry (BÁRTA,J. 1965), perhaps the most important locality of this period, seems to consist of Vah and Danube silex pebbles mainly. Dimensions of the stone implements are small. Retouched microbladelets, triangles are used as projectiles - probably for birds and minor mammals. As a new function - at least, for chipped artifacts - hooks appear. The changes in the lithic industry are the proofs of significant changes in the game these people were fed on. This phenomenon is, of course, the result of the climate-dependent migration of the big game towards the North (GÁBORI,M. 1964), resulting the decrease of population often stressed for the Mesolithic of the Carpathian Basin (GÁBORI,M. 1984; MAKKAY,J. 1982).

The raw material procurement area comprises mainly local, and quite often, secondary sources. Prestige goods, however, travel quite long distances along the rivers, in a radius of 500 kms (e.g. obsidian). A more refined chronology of this period would reveal, perhaps, a North, North-Western spreading first, and a subsequent Southern, South-Eastern distribution wave for obsidian, utilized by a new wave of inhabitants (Iron Gate sites, KOZLOWSKI,S.K. 1980). The material available, however, is not yet enough to decide on these problems.

The Neolithic lithic industry presents, first of all, one new function, i.e. the sickles (sickle inlay bladelets) for harvesting crops. The forerunner of the form most typical for them is to be sought in the trapeziform implements of the Late Mesolithic (KOZLOWSKI,S.K. 1980). At the same time, an intensification in the use of wooden implements can be supposed, on the basis of the decrease of the total number of stone tools and tool types in the Early Neolithic lithic assemblages, the deforestation for arable lands, and possibly the high rate of burins among the earliest neolithic implements (TAKÁCS-BIRÓ,K. 1985). This latter statement should be checked, however, by traceological analyses as well. Stone tools that are likely to serve as projectiles are extremely rare in the Early and Middle Neolithic of Hungary, while they are more frequent in the Western LBC assemblages. This might be taken as a sign of more extensive adaptation to productive economy. By the Middle and Late Neolithic, the chipped stone tools seem to regain their importance, as seen by the quantities involved, the diversified and finely elaborated tool types, the appearance of new and special forms made of chipped stone, like the needle and the saw, besides types resembling Late Upper Palaeolithic and Epipalaeolithic forms. Contrary to the scanty Early Neolithic assemblages, the chipped tools of the Late Neolithic are numerous and specified (BÁCSKAY,E. 1976). Distinct types for certain functions, as well as regionally characteristic forms can be found since the end of the Middle Neolithic (Late LBC cultures).

In terms of procurement areas, distances and quantities, the Neolithic brought about possibly the most perfect supply system for lithic raw material utilization. Even in the Early Neolithic, excelling with its poor lithic industry, an effective mechanism of supplying the lowlands with good quality raw material had been in practice, testified by the existence of lithic raw material stock-piles from the Balkans (KACZANOWSKA,M. et al. 1981) as well as an effective distribution system for obsidian, with distribution centers and trade roots detectable (KALICZ,N. 1985; TAKÁCS-BIRÓ,K. 1985) mainly on the territories to the East of the Danube. Local sources are fully exploited and raw material of the best quality widely traded by the end of the Neolithic; there is a definite relation between tool type and raw material preferentially used for its production. The raw material quality is generally optimal, possibly due to mining and raw material extraction sites. Workshop complexes of large extension and distinct phases of working appear, proving that the production of chipped stone tools at this period was subjected to special artisan activities, among which a possible division of labour can be supposed. The balanced, rational distribution of raw materials as well as the absence of weapons speaks for a peaceful development. Trade posts, set along the lines leading to special raw material outcrops can be observed (KUTZIÁN,I. 1972; PATAY,P. 1976).The scene is dramatically changing, however, by the end of the Late Neolithic, on the territories to the East of the Danube. The mass inflow of North-Eastern raw materials, as well as distortions of the originally Tokaj-centred raw material acquisition of the Lowland peoples (Szakállhát, Tisza cultures) are, seemingly, of historical importance. In the early Copper Age, parallel to the spreading of copper implements - especially weapons - their stone imitations, and minutely worked projectiles of silex, produced by alternate pressure flaking are appearing. The forms often resemble Mesolithic geometrical types. Differences within the chipped stone tool kit are probably most apparent at this period, e.g. in dimensions. Besides the long knives and blades made of, typically, the "translucent brown flint" of North-Eastern origin, spread along the Tisza affluents, tiny arrow-points of very fine workmanship appear. On the Transdanubian parts, it seems that Late Neolithic forms and techniques are preserved much longer, possibly till the beginning of the first great cultural unit spread in the whole Carpathian Basin, i.e. the Baden culture. We know very little of the lithic industry of this culture as yet; the existence and importance of chipped stone industry, however, has been demonstrated by J.KOREK, together with possible Northern connections (KOREK,J. 1986).

The period between the Late Copper Age and the Middle Bronze Age are probably the last important period in the utilization of chipped stone tools for "traditional" stone tool functions. In this period, however, the stone tool raw materials are already insufficient to detect the contacts of the population, as stone tools play a very subordinate role in the economy. Arrow-heads possibly preserved some reputation (BÁTORA,J. 1982), and stock-piles can be met occasionally (MOZSOLICS,A. 1967). We meet stone tools, utilized in the traditional "stone tool functions" occasionally till the Iron Age (SIMÁN,K. 1983).

RAW MATERIAL OF THE CHIPPED STONE IMPLEMENTS - used for different function

The rocks suitable for making stone artifacts were, in spite of the substitution of the stone tool kit by metals mainly, used for some functions seldom mentioned in Central Europe up to our days. An investigation of function and distribution should touch upon these utilizations as well. Besides those of modern industrial potentials of using these pure and hard materials (e.g. for abbrasives, fine powder mills, jewellery etc.), more historical evidences are examined here, that is fire-flint and gun-flint. This part of the paper was possible to compile based on most recent studies, hopefully followed by further investigations of, J.HÁLA, with some further evidences of archeology and history added.

FIRE-FLINT

Its utilization is likely to be traced in the remote past, when, together with pyrite, they are likely to serve for lighting fire. The first clear evidences of using flint as fire-flint have been met from the graves of the "Barbarians" from the Roman period. Fire-making kit is among the indispensable utensiles of nomadic peoples. It is not by chance, that flint for making fire is associated with the graves of such peoples like the Sarmatians, Avars, Magyars etc., and that flint was among the everyday necessities to be always at hand by the shepherds and herdsmen of Hungary even in this century. Historical records are known from collecting flint for making fire in the last century, and shepherds of this century are known to prefer it for long to matches that were expensive and easy to run short of. In territories rich in flint resources, either primary or secondary ones, people used it almost exclusively in cases of emergency, like the period of the world wars and after them. J.HÁLA mentions some ritual aspects of the fire lit by the traditional way (HÁLA,J. 1986).

As for the procurement of fire-flint, they are known to be on sale at village fairs, by traders who had collected them mainly from secondary sites, quite often archeological localities. These sites are known under the name of "Tüzköves", "Kováshalom", "Kremenyák" etc., all denoting the flint (silex) found on them.

Our short survey in the Museum of Ethnography, Budapest, resulted in some statements in respect of fire-flint procurement. Most of the material is re-used: prehistorical chipped stone tools, and about the same amount, gun-flint was utilized for making fire. The source of the raw material is typically local, but the primary source can be quite distant. Pebbles, juvenile fragments of suitable material are seemingly rare as compared to worked implements. This preference was expressed by the Szentgál people as well; they told us, that flint "collected on the fields" were preferred to those of the hillside, being well-shaped, handy and not cracked. This means, that they preferred secondary archeological sources to flint outcrops. This statement is corroborated by the evidence of the museum material.

GUN-FLINT

Restricted certainly to a well defined and relatively short period of industrial (military) history, namely the period of the XVI-XIX. centuries in Hungary, gun-flint deserves some special attention because of the great quantity involved and the long distance import of flint used for them. The flints for guns are imported, mainly from France, though search for flint sources was encouraged by the Hapsburg sovereigns within Hungary as well (HÁLA,J. 1986). The gunflint most often found in Hungary is yellow, waxy with white spots, resembling very much the so-called Bánát flint of archeological prehistoric assemblages. Gun-flint from NW Europe is likely to represent the only lithic resource shared with the New World and Central Europe. Evidences of using gun-flint firearms as late as the first world-war are known (TEMESVÁRY,F. 1980), mainly the products of the Belgian workshops in the mid- and late XIXth century. The Oxford History of Technology Vol. 3. (1957) still mentions gun-flints knapped for supplying the African market at Brandon, Norfolk.

Another typical chipped stone function should be mentioned here, that is the treshing sledge. There is no evidence of its use in the Carpathian Basin, but they are frequent in the Balkans and Eastern Mediterranean region. The Museum of Ethnography at Budapest has some implements of this type from the collection of I.GYÖRFFY. Flint bladelets were inserted in a check-mate order into a wooden board, to be pulled over wheat to and fro, which resulted a high polish on the surface of the implement. Treshing sledge inlays are known from medieval context (KANCHEV,K. et al. 1986), as well as recent ethnographical material. Production of flint blades for the treshing sledge has been observed recently by J.WEINER in Turkey (WEINER,J. 1979). In the examples I had seen in Georgia, the flint teeth are being replaced, partly, by metal (iron) equivalents.

CONCLUSIONS

Archeological, historical and ethnographical data, relevant to the usage, access and procurement of the chipped stone implements were briefly summarized, in respect of the Carpathian Basin. We could follow the changes in function, quantity and relative importance, reflected in the qualitative requirements, provenance, ways and means of access from the Lower Palaeolithic up to our days. We can conclude, that the fluctuations in the access of the chipped stone lithic raw materials are geographically determined, by the actual cultural level and consequent needs, of the population and the geological/

geographical endowments of the area. For the Carpathian Basin, with diverse and identifyable raw material resources, as well as distinct, continuous steps in the development of the material culture, it is possible to elaborate a paleo-economical model, for which the study of lithic resources should form an integrated part.

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GEOMORPHOLOGICAL AND PALEO-ECOLOGICAL STUDIES

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Pleistocene environment in Hungary
Geographical Research Institute
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Budapest, 1987

RELATIONSHIP BETWEEN DOLINE TYPES AND GEOMORPHOLOGICAL SURFACES IN HUNGARY

L. JAKUCS - G. MEZÖSI

ABSTRACT

During their karst morphological investigations by authors in the Aggtelek Mountains, North-Hungary, it was assumed that conclusions can be drawn for the last date of exhumation of the particular morphogenetic units from their surficial features. The research focussed on karstic depressions in various lithological, tectonic or orographic positions. Authors succeeded in identifying doline types associated with the major morphogenetic units and their relative ages were estimated.

* * *

In recent years, a number of proposals have been put forward to typify the repeatedly buried and exhumed surfaces of the Hungarian Mountains and distinguish their geomorphological surfaces (PÉCSI,M. 1984; PÉCSI,M. and MEZÖSI,G. 1985, etc.). This paper presents a survey of our karst morphological investigations in the Aggtelek Mountains, with a view to clarifying the disputed questions of surface development in the Quaternary. We assume that conclusions can be drawn for the date of the final exhumation of the individual morphogenetic units from the complex system of forms that developed on their surfaces. The central feature of our studies was the karstic depressions in various lithologic, tectonic and orographic situations. Our analyses permitted the identification of the doline types belonging to the most important morphogenetic units and an estimation of their relative ages.

GEOMORPHOLOGICAL SURFACES OF THE MESOZOIC HORSTS OF THE NORTH-HUNGARIAN MOUNTAINS

From a structural-morphological aspect, the Rudabánya-Aggtelek Mountains comprise a folded-faulted (some authors consider it to be covered) horst planated in the Mesozoic. The paleokarstic erosional surface was repeatedly buried and exhumed during the Tertiary *(Fig. 1)*. In response to the Tertiary tectonic movements, it was dismembered into blocks undergoing independent development and eroding to various degrees. Because of their different geomorphic evolutions and positions, these mountains represent a relief subtype different from the previous ones. Orographically, they are now low mountains.

The course of their general evolution may be summarized as follows:

The early Mesozoic areas of syncline type were transformed into mainland from the Upper Triassic, and up to the Middle Cretaceous planation prevailed under tropical subhumid climatic conditions. At the end of the Mesozoic, the low, "karstic", tropical erosional surface was dismembered by major faults.

Although the climatic conditions would have permitted a further period of (regional) planation, extending to the entire Hungarian Mountains, active tectonism turned this region into a pediment zone of the higher, crystalline mountains to the north and south.

Geomorphologically, therefore, it may be assumed that peneplanation was followed by pediplanation in the Eocene.

Subsequently, during the Paleogene and particularly the Neogene, the surface was covered by sediments of varying thicknesses and kinds.As a result of these tectonic movements, which lasted from the end of the Miocene up to the Pleistocene and affected only certain zones, and also as a result of the oncoming erosional activity, this region was transformed into partially or completely exhumed low mountains with a horst-graben structure. Accordingly, the true horst surfaces lost their young Tertiary sediment mantles and underwent mountain margin pedimentation at the end of the Pliocene.

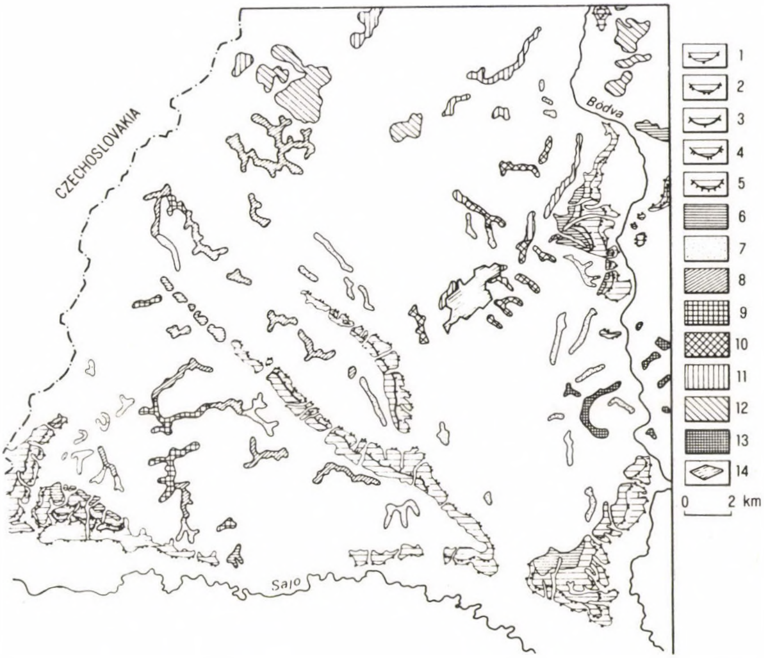

Fig. 1 Main geomorphological levels in the Aggtelek-Rudabánya Mountains and their environment.

1 = terrace II/a; 2 = terrace II/b; 3 = terrace III, travertine horizon; 4 = terrace IV, travertine horizon; 5 = terrace V; 6 = Upper Pliocene pediment (locally red clay formation); 7 = lower interfluvial ridges, derasional terrace steps, remnants of older pediment surfaces; 8 = higher hill-summit surfaces, or interfluvial ridges (initial phases of Quaternary valley formation); 9 = Neogene pediplain remnants; 10 = semi-exhumed planated horst surface transformed by pedimentation (covered by Paleogene sediments); 11 = moderately elevated planated horst surfaces (exhumed in Tertiary and Quaternary); 12 = bare planated horst surface in summit position, completely exhumed and intensely karstified; 13 = repeatedly buried and exhumed peneplain remnants built up from Paleozoic sediments; 14 = mine area

The investigations by LÁNG,S. (1973) and JAKUCS,L. (1964) indicated that neither the climatic nor the karst-hydrological conditions (the latter because of the high karst-water table) of the formerly assumed Pliocene karstic planation were present.

By taking into consideration the orography and the differences in evolution too, we distinguished the following horst types (sometimes in combination).

(a) Exhumed planated horsts in summit position: including the completely exhumed plateaux of the Aggtelek and Martony Mountains, which underwent intensive karstification during the Quaternary.

(b) Moderately elevated planated horsts: the central part of the Rudabánya Mountains (preserved with ore indications), from which the original Paleogene cover was totally degraded during the Late Tertiary and the Quaternary.

(c) Semi-exhumed planated horst transformed by pedimentation: these elevated horsts are covered by spots of Oligocene or Miocene sediments of various depths (e.g. the margin of the Rudabánya Mountains).

These relief subtypes frequently differ in orographic position, but this does not mean morphogenetic variation (i.e. a higher position does not necessarily mean an older geomorphological surface). Accordingly, it would have been a mistake to identify the horst levels with geomorphological surfaces merely on the basis of their present position.

DOLINE TYPES, TERRA ROSSA HORIZONS

In accordance with the individual relief subtypes, we carried out detailed morphometric and lithological studies of the karstic depressions and their fills (MEZÖSI,G. et al. 1978), *(Fig. 2, Table 1)*. These revealed unambiguous correlations with the evolution of the zones of the depressions. On this basis, three main groups may be distinguished:

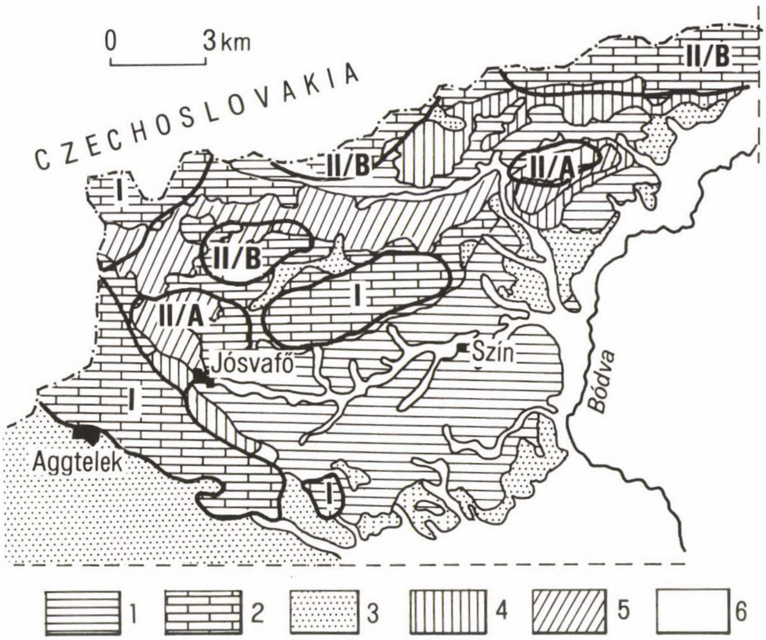

Fig. 2 Karst doline types in Aggtelek Mountains

1 = Lower Triassic (Campilian) limestone, shale; 2 = Lower Triassic (Gutenstein) limestone and dolomite; 3 = Wetterstein limestone; 4 = Wetterstein dolomite; 5 = Pliocene gravel, sandy gravel; 6 = extensive fluviatile sediment from Holocene; I = exhumed, intensely karstified karst; II/a = moderately elevated, weakly karstified, planated surface; II/b = bare planated exhumed horst surface in summit position

I. Dolines situated at a height of 310-350 m, with a diameter of 50-200 m and a depth of 15-40 m. Several large dolines frequently coalesced. Even disregarding the dolines, the terrain is strongly dismembered, with flat ridges of considerable extent where there are no, or only very few dolines, the peaks of these ridges even rise above 400 m. Most of the dolines are situated in rows and display N-S and W-E strikes.

A typical fill is dark-red terra rossa with a high iron oxide content (up to 14 %). This attains a layer thickness of 5-15 m on the doline bottoms. The doline sides and bottoms protected by the terra rossa exhibit definite tropical tower karst microforms. Such forms are absent from the ridges and doline sides not covered by terra rossa, probably as a result of secondary, normal surface karst denudation processes shaping the relief. In the doline bottoms covered by red clay (under several metres of terra rossa), the usual karren microforms are missing.

Table 1 Some results of morphometric studies of the dolines

	I	II/a	II/b
Doline density	11-13	32-36	7-9
Total area of dolines as percentage of karst surface	23	32	31
Average area of dolines per km^2	0.01	0.02	0.016
Relief ratio (depth/av. diameter)	0.08	0.14	0.12

II/a. Dolines situated at a height of 270-280 m, with a diameter of 5-30 m and a depth generally not more than 2-8 metre. The karstic terrain, rich in small dolines, has a fairly uniform height and a definite planation character. The material filling the depressions is yellowish-brown, and is primarily reminiscent of terra fusca, with a little terra rossa. The clay fill is 2-5 m thick, and is present not only on doline floors, but also on the ridges. The karstic limestone protrudes onto the surface at only a few sites, forming bare patches. The subsoil rock forms are primarily characterized by corrosional karren with the presence of fissure-karren.

II/b. Dolines situated at a height of around 500 m and higher, with a diameter of 50-200 m and a depth of 20-50 m. These dolines generally have steeper sides than the dolines at intermediate heights; this may well be connected with the fact that they contain little fill which favours the expression of the morphology of the original rock surface. The terra rossa is almost completely missing; the fill is rather black humous, rendzina forest soil. We have not yet encountered with justified tropical tower karst forms; both on the surface and under the generally thin soil layer, the microforms merely display the features of root and precipitation corrosion and of cryofraction. As far as their positions are concerned, the dolines are not aligned in definite rows; the terrain is a uniplanar plateau, generally presenting a picture only of a karstic erosional surface.

The relative ages of the various horsts as geomorphological surfaces can be given on the basis of the related doline types, in the following manner:

By the end of the Pannonian (Late Miocene), the surface had progressively lost its pediment position. Of the surface segments along the earlier tectonic lines, II/b was exhumed first, followed by II/a (currently in a basin position). In our view, the exhumation of unit I can be regarded complete; the remnants of the Pannonian gravel mantle are to be found in a number of sites. At the same time, the karstic valleys that appeared on its surface in the Pleistocene have exposed the older karstic form complex, additionally including dolina row formation, which meant the starting phase of intense karstification. Here, therefore, "old" and "young" karstic forms are found side by side in the same orographic situation.

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NATURE AND EXTENT OF RELIEF SCULPTURING IN THE HUNGARIAN MOUNTAINS DURING THE PLEISTOCENE

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ABSTRACT

As a result of the climatic cycles and intensive cyclic and differentiated tectonic movements of the Pleistocene, a new sculpturing of the relief of Hungary began to be effective in that period and characteristic features were produced. Although it was the shortest of the geomorphic stages, being the last and rather peculiar, it exerted a decisive influence on the present landforms.

Tectonic movements were long-lasting and only interrupted by short spells of tranquillity. Cyclicity was primarily manifest in the rates and speeds of movements. From the viewpoint of geomorphic evolution, four major climatic types are identified in Hungary in the Quaternary: arid and humid glacial (cool or cold) and humid and arid interglacial (warm or cool) types.

Denudation and accumulation, their rate and efficiency were controlled by the intensity and rate of uplift and subsidence. Denudation and the resulting features as well as the related (correlative) sediments are governed by the actual climatic conditions.

All these influences and changes varied with the relief units.

The longer interglacials were mainly characterized by valley cutting, dissection of mountains (linear erosion) in accordance with the rate of uplift and the nature of climate. On the contrary, during the periglacials sheet-wash (areal) erosion processes were significant (frost shattering, frost heaving, gelisolifluction, niveofluviation, derasion and cryoplanation). All over Hungary, geomorphic evolution was much more rapid in the periglacials with sparse vegetation cover (Fig. 1). The driving force was frost shattering. Cryoplanation was active in the medium-height mountains during the periglacials, heights were being reduced in elevation, while depressions were being filled with the eroded material (Fig. 2).

Periglacial planation went on at several levels simultaneously involving various mechanisms and having various intensity. Under periglacial climate relief asymmetry substantially increased; this eqully applies for valleys, ridges, river terraces and planation surfaces. Besides relief sculpturing periglacial microforms such as frost wedges, frost sacks and frost shattered stone barriers occur.

Derasion produced a series of features. The degree of periglacial sculpturing was highly dependent on the geological structure of mountains and, therefore, rock quality and bedding caused much variation.

The calculations carried out by the author for the alluvial fan of the Mátraalja suggest

that the height of the Eastern Mátra Mountains was reduced by cca 30 m during the Pleistocene, while the valleys widened several dozens of metres (from 50 m to 150 m). Consequently, the relief in our mountains was considerably resculptered in the Pleistocene: in the interglacials valley cutting and the dissection of the mountains and older surfaces was characteristic. In the periglacials sheet-wash produced further, lower-lying surfaces; planation was active on all levels.

* * *

INTRODUCTION

Most of the surficial geological formations and landforms of Hungary are constituted of Quaternary and particularly Pleistocene materials. This was recognized as early as the beginning of this century and, accordingly, the investigations of Pleistocene formations and landforms were equally prominent in geological and geomorphological research. Thus, over the last one hundred years, geologists and geomorphologists collected numerous valuable observations, data for the geomorphic evolution during the Pleistocene and mapping became more detailed on the basis of the more and more abundant evidence from boreholes. Early this century the geologist LÓCZY,L. and the geomorphologist CHOLNOKY,J. arrived at syntheses excellent in their time and these have been refined by their students, relying on accumulating borehole evidence from ever greater depths. In the forties and fifties, the geologist SÜMEGHY,J. and SHERF,E. and the geomorphologist BULLA,B. were very successful. Relying on vast amounts of data - mostly gathered in drilling projects - a completely new synthesis was achieved of the Hungarian Pleistocene, first of all, of geomorphic evolution during the Pleistocene. Since the sixties the still active generation produced another new synthesis through the application of contemporary methods, particularly in laboratory analyses (among the geologists, the names of ERDÉLYI,M., FRANYÓ,F., KRETZOI,M., KROLOPP,E., MOLNÁR,B. and RÓNAI,A., among the geomorphologists BORSY,Z. - research of the Great Hungarian Plain initiated by PÉCSI,M. - ÁDÁM,L., MAROSI,S. and SZILÁRD,J. - in hill regions - PINCZÉS,Z. and SZÉKELY,A. - in medium-height mountains - and SCHWEITZER,F. and SCHEUER, Gy. in the investigation of travertines should be mentioned).

On each of the three occasions, Pleistocene research started in the Great Hungarian Plain, since it is the largest in area, and subsequently the hill regions and finally the mountains were included, although in the latter landforms are most conspicuous and exposed.

DISCUSSION

As a result of the characteristic cyclic climatic alternations and the intensified rhythmic and differentiated tectonic movements, during Pleistocene geomorphic evolution fundamentally differed from the previous periods and the resulting forms were unique. Although it was the shortest period of surface evolution (cca 2 million years), it was the last and a unique one, which bears on the present landforms heavily. The most striking features are due to the periglacial stages, although they were much shorter than the interglacials.

Tectonic movements were lasting only interrupted by short spells of relative tranquillity. Rhythmicity was primarily present in the rate of movements. From the viewpoint of geomorphic evolution in Hungary, four main climatic types are identified in the Quaternary: arid and humid glacial climates (cool or cold) and the humid and arid interglacial climates (warm or cool - SZÉKELY,A. 1973a).

All these influences and changes were manifested in various ways - sometimes even in opposite directions - in the individual orographic units. First of all, there is a striking difference between the three orographic types of different altitude, dissection, lithology, age and character: plains, hill regions and medium-height mountains. The resulting sets of landforms reflect these differences (PÉCSI,M. 1963b; SZÉKELY,A. 1983).

Denudation and accumulation, their mechanisms and efficiency were determined by the intensity and rate of uplift or subsidence, while the resulting landforms and the character of the related correlative sediments were controlled by the actual climatic conditions (SZÉKELY,A. 1983). During the time the mountains were eroded, dissected by deep valleys lowering some tens of metres (SZÉKELY,A. 1977), the subsiding lowlands were infilling by several hundreds of metres of diverse sediment sequence. Their opposite evolution trends are apparent in their strongly different Pleistocene formations and landforms. In the present paper the geomorphic evolution of the mountains during the Pleistocene is demonstrated.

In Hungary mountains of medium height cover the smallest area (about 2 per cent of the country's area, 2000 km^2 above 400 m above sea level), but they are the highest (400 to 1000 metre), the most heavily dissected (with relative relief of 100 to 700 m), the most varied in structure and, thus, periglacial sculpturing was the most diverse and the most conspicuous here (SZÉKELY,A. 1983).

The main characteristic of the much longer interglacial stages was valley deepening, the dissection of mountains (linear erosion), as a function of the nature of climate (primarily corresponding to precipitation). In the humid spells of the interglacials, deciduous forests promoted chemical weathering and also protected the surface from the removal of weathered material. This explains the leading role of dissection (linear erosion) with the comparatively lesser significance of sheet wash (areal erosion). This resulted in considerable valley deepening and the formation of terrace series in the Hungarian Mountains. The largest valleys cut 100--150 m deep and 5--6 terraces were carved out. Some mountain streams also built 3--4 terraces. The steeper valley sides were further shaped by landslides.

In contrast, in the periglacial stages the areal processes of denudation - frost weathering, frost heaving and primarily gelisolifluction, niveofluviation, derasion and cryoplanation — were typical (PÉCSI,M. 1963b; SZÉKELY,A. 1965b). Relief evolution was much more rapid in the periglacial stages of sparse vegetation, not only in the medium-height mountains, but also all over the country (SZÉKELY,A. 1983, *Fig. 1*).

The primary periglacial agent was frost action. The extent

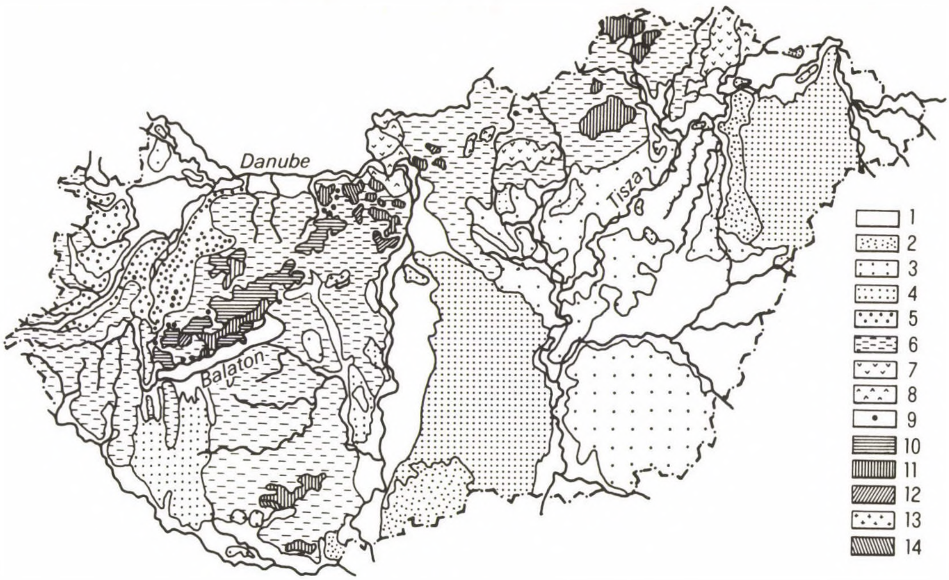

Fig. 1 Extent of relief sculpturing during the periglacials in Hungary (by SZÉKELY, A.)

1 = Recent fluvial floodplains (Holocene surfaces); 2 = areas covered with last periglacial subaerial loess (surfaces planated slightly further through loess accumulation (/eolian surfaces of microaccumulo-planation/); 3 = last periglacial wetland(flood-plain) loesses; 4 = sandy alluvial fans reshaped by wind action (higher lowland sand regions dissected and increased in relief in the periglacials, locally covered with sandy loess); 5 = Pleistocene gravel alluvial fans slightly planated in the periglacials by areal (gelisolifluction) processes with periglacial cryptoforms; 6 = areas of hills and mounds reshaped in periglacials overwhelmingly by gelisolifluction, generally further planated by loess or slope loess accumulation; 7 = Late Tertiary higher volcanic mountains primarily of andesite and agglomerate and tuff with relief substantially altered in the periglacials chiefly by intensive frost action; prevailing periglacial forms; 8 = Late Tertiary lower volcanic mountain remnants mainly of andesite or agglomerate and tuff with relief altered in the periglacials primarily by frost action; with ruins of periglacial forms and wide cryopediments; 9 = Late Pliocene-Early Quaternary cone and mantle remnants of basalt or agglomerate and tuff with slope walls considerably retreated in the periglacials due to frost action and periglacial forms; 10 = Triassic dolomite (locally limestone) horst with relief substantially altered by frost shattering; 11 = Mesozoic mountain mostly built up of limestone; plateaux and horsts slightly altered in the periglacials; with few periglacial forms; 12 = low Miocene limestone plateaux even less altered in the periglacials; 13 = low mountains of Paleozoic igneous and metamorphic rocks, slightly altered in the periglacials; 14 = sandstone mountains (Permian and Oligocene) with periglacial forms produced by frost shattering

of periglacial sculpturing depended, first of all, on this factor. The residual eluvium of felsenmeers of coarse blocks covers the plateaus of the mountains, maintaining the periglacial nature of the Hungarian mountains. Frost action also largely controlled geomorphic evolution. Decomposing the surficial rocks, it prepared them for erosion and the resulting felsenmeer of 4--5 m thickness protected the surface from further erosion (SZÉKELY,A. 1969). It is the primary source of the varied series of periglacial deposits of common origin, often to the finest deposits. The largest stone polygons in Hungary formed on felsenmeers and stretching out on slopes forming stone ridges (Streifenböden). On slopes steeper than 28--30° the comminuted felsenmeer blocks move downslope by gravity creep, further disintegrating and accumulating in talus slopes (screes) of 25--37° at the foot-slopes. Along gentler slopes transportation was promoted by gelisolifluction and the coarse debris mingled with finer material. The result is the mingled cover mantling the lower part of the slope. In contrast with the talus and mingled cover of areal nature, stoneflows are linear, for orographic or structural reasons.

On slopes of uneven surface, as a consequence of frost weathering, cryoplanation steps of some tens of metres width formed, locally 5--10 steps one above the other. Due to frost action, steep valley sides were gradually retreating and broader cryoplanation terraces formed with steep frost-riven scarps above. As a result of further comminution along vertical cracks the scarps were dissected into colonnades in many places. This way the valleys were gradually widening and infilling with coarse debris*, ridges narrowed down and subsequently worn down. Consequently, there was cryoplanation in the Hungarian mountains during the periglacials with the lowering of the elevations and the infilling of the depressions with the removed material *(Fig. 2)*.

Periglacial cryoplanation took place simultaneously at va-

* There was much debris and little fluvial transport. In spite of their downcutting character, streams even now deepen their valleys mostly into periglacial debris. This is a legacy of the periglacial period.

rious levels differing in mechanism and intensity. The fundamental agent, however, was the same everywhere: frost-and-thaw alternations and the resulting strong frost weathering.

Fig. 2 A generalized section of periglacial sculpturing of relief in the volcanic mountains of Hungary (example of the Mátra Mountains).

1 = andesite and agglomerate; 2 = preperiglacial relief; 3 = present relief; 4 = frost-riven blocks and debris; Kr = cryoplanation terrace

Cryoplanation was most effective on the higher surfaces (generally 550--800 m) and even more so on the outstanding summits and peaks of 800--1000 m altitude. As a consequence, the outstanding heights were virtually decomposed and most of the summits and peaks were buried under their own debris. The large blocks moved, mainly by gravity, towards the neighbourhoods of the elevations, they were further disintegrating, and filled up the depressions. This process resulted in the remarkable planation of the higher surfaces (cryoplanation: applanation--equiplanation). After the initial strong frost action, however, the thickening felsenmeer or talus mantle itself (where it could not move downslope) protected the surface from further frost action and denudation. With advanced cryoplanation and inadequate slope, locally relative stability was achieved, an equilibrium state; the deep talus mantle prevented the surface from further lowering.

On lower and narrower middle levels (remnants of older piedmont steps or pediments) the sculpturing due to frost action was more restricted.

Another prominent relief type in the Hungarian mountains, the pediments, of Pliocene age encircling the mountains experienced further development, mainly in valley entrances, modified, slowly extended and lowered. These pediments formed by frost weathering during the periglacials are the cryopediments and their extensions over the looser deposits of the hill foreland of mountains are the cryoglacis (PÉCSI,M. 1963b, 1964, 1966; SZÉKELY,A. 1969, 1977; PINCZÉS,Z. 1977). In several places, adjusting to river terraces they often occur at several levels above one another. This is a good evidence of their adjustment to the actual base level and thus river terraces help determine their age. (The best examples are the cryopediments and cryoglacis in the Southern Börzsöny Mountains adjusted to the Danube, in the Mátra Mountains adjusted to the Zagyva and in the Tokaj Mountains adjusted to the terraces of the Hernád and Bodrog rivers).

The relatively rapid development and considerable extension of the Pleistocene pediments, compared to the relatively short duration of the periglacial stages, is explained by the circumstance that they are reshaped Upper Pliocene pediments. The pediments are mostly covered by slope deposits, slope loess of several m thickness.

Derasion processes produced a series of derasion features: narrow platforms, scarps, derasion terraces in valleys, the network of derasion valleys of various shape and size with broader or narrower interfluvial derasion ridges. They are often prevailing among the landforms of pediments and glacis (PÉCSI,M. 1964; SZÉKELY,A. 1960, 1969).

In addition, influenced by periglacial climate,relief asymmetry also largely increased (PÉCSI,M. 1963a): asymmetry was accentuated in the case of valleys, ridges, river terraces, and planated surfaces (SZÉKELY,A. 1969, 1977).

Relief sculpturing is also accompanied by a series of periglacial microforms: ice-wedges, ice-sacks, abandoned stone ridges and others (SZÉKELY,A. 1969).

In the Hungarian mountains of medium height, the intensity of periglacial frost weathering and the related processes was largely controlled by structure varying according lithology and bedding (PÉCSI,M. 1964, 1968; SZÉKELY,A. 1969, 1973a, 1973b, 1977).

Sculpturing, therefore, was most efficient in the mountains with stratovolcanoes built up of thin layers and on dolomite weathering easily and slowest on thick banked limestone. This explains why periglacial transformation was the strongest in the ruined stratovolcanoes of the Inner-Carpathian North Hungarian Mountain Range, which is several hundred metres higher than the horst series of the Transdanubian Mountains, where it was weakest. My calculations carried out on the alluvial fans of the Mátraalja foreland, well exposed in the open cast mine at Visonta (0.71 km^3 alluvium), the Pleistocene correlative sediments indicate cca 30 m lowering of surface during the Pleistocene for the Eastern Mátra Mountains, while valleys were broadening by dozens of metres (50-150 m) - primarily due to periglacial processes (SZÉKELY,A. 1977).

CONCLUSION

It can be concluded that the relief of Hungarian mountains was heavily reshaped during the Pleistocene: during the longer interglacial stages valleys were deepening and the mountains, older surfaces were being dissected considerably. During the periglacial stages aerial denudation produced new surfaces at lower levels and relief planation was characteristic on all levels.

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RELATIONSHIPS BETWEEN THE ORIENTATION OF DRAINAGE AND GEOLOGICAL STRUCTURE IN HUNGARY

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ABSTRACT

In order to reveal the relationships between major structural elements and the drainage, statistics of directions were analyzed and the results are presented here. The territory of Hungary is subdivided into 9 units and the cosmolineaments are compared with the 'strengthened out' drainage map and the neotectonic processes important in the evolution of water-courses, their distribution and regularities were determined. The peaks of the statistics of lineament directions are also maxima in the drainage and active to the immediate past; they are interpreted as neotectonic structures (not necessarily recent but possibly rejuvenated old elements) controlling the courses of streams. In contrast, the lineament peaks not manifested in the drainage may indicate ancient inactive structures. On this basis, author attempted to separate the two types of structural elements and their outlined presentation over the larger part of Hungary.

* * *

INTRODUCTION

The geomorphological significance of drainage has been obvious for a long time. Drainage patterns, density, orientation and other parameters have often been used in geomorphological and geological research as indicators of or evidence to certain phenomena. When interpreting aerial photographs for earth sciences purposes, drainage is among the most useful and informative elements in the interpretation. Nevertheless, in general it can be claimed that frequent use does not automatically mean regular application. The application is not yet regular, since the investigations of this kind have been incidental and isolated or have not reached beyond the stage of qualitative description of drainage parameters. Recently, a project has started in this topic to evaluate drainage parameters not only qualitatively but also quantitatively over most of the low mountains in Hungary and their forelands. Here some new achievements are presented concerning the relationships between the orientation of drainage and geological structure.

DISCUSSION

Disregarding some irregularities, the elements of drainage can be compared to geometrical forms. Orientation means correspondence between drainage and these simple linear elements (mostly straight and only seldom curved lines). Similarity may be of various degrees and can be expressed variously.

The evaluator can establish subjective, relative categories according to the degree of correspondence. The drainage of an area is assessed as oriented, poorly oriented or unoriented (irregular). With proper experience the number of qualitative classes can be raised, but the comparison with other areas or with the results of other evaluators will be difficult or even impossible.

The degree of correspondence between the system of geometrical elements (straight lines) and drainage pattern can be expressed numerically, too: the direction (azimuth relative to N) of 'straightened out' stream (or valley) sections taken from a drainage map are measured and the resulting angles and distances can be evaluated both in tables and in diagrams (EGYED, L. 1957).

The frequency of direction I_α belonging to the direction α of the linear system under study and the zone width $\Delta\alpha$

means the number of sections between the directions $\alpha-\frac{\Delta\alpha}{2}$ and $\alpha+\frac{\Delta\alpha}{2}$ while the frequency of direction of total length I'_{α} denotes the sum of unit sections of d_s aligned in the same direction. The tabulated measurement results are expedient to plot in a polar coordinate system. There are two ways to do it: I_{α} can be expressed in the percentage of ΣI_{α} or can be related to the maximum frequency province as $\frac{I_{\alpha}}{I_{\alpha}^{max}}$. The second is particularly efficient if the relationships of various factors within an area are to be revealed, while the first is applied, first of all, for regional comparisons and in the research of more general laws.

In the course of our investigations, at first, the value $\Delta\alpha$ was chosen 5° when drawing diagrams of frequency of direction. Some experiments, however, indicated that the calculation with provinces by 10° needs much less work and its exactitude in the orientation of the drainage of the area is still adequate. As a matter of course, the diagrams of direction and total frequency may differ for the same area and important conclusions can be drawn from the deviations *(Figs 2 and 3)*.

The surficial water-courses, the drainage elements, are very frequently associated with the geological structure and tectonic conditions of the region. The erosion of water-courses is more rapid and efficient along these lines and, thus, tectonic conditions predetermine drainage pattern. Since the explanation of the phenomenon is generally known and accepted, the only question is what the degree and the nature of the relationship is for the various areas. This is answered by the extent of structural control, which can be determined by the comparison of the diagram of frequency of direction for drainage with a tectonic diagram. Orientation is characteristic of several kinds of drainage pattern, but structural control is only manifest in some of them.

During the last 4--5 years, publications in this topic appeared one after the other in the international literature not reviewed here (AI,N.S.- SCHEIDEGGER,A.E. 1981; BANNISTER, E. 1980; FEZER,F.E. 1983; KOHLBECK,P. - SCHEIDEGGER,A.E. 1977; SCHEIDEGGER,A.E. 1979a,b, 1980; WATSON,G.S. 1970).

In the Hungarian State Geological Institute a so-called cosmolineament map of Hungary has been prepared through the interpretation of Landsat and Soyuz images and this map has also been analyzed for structural geological purposes too (SIKHEGYI,F. 1985). Contributing to this project, the statis-

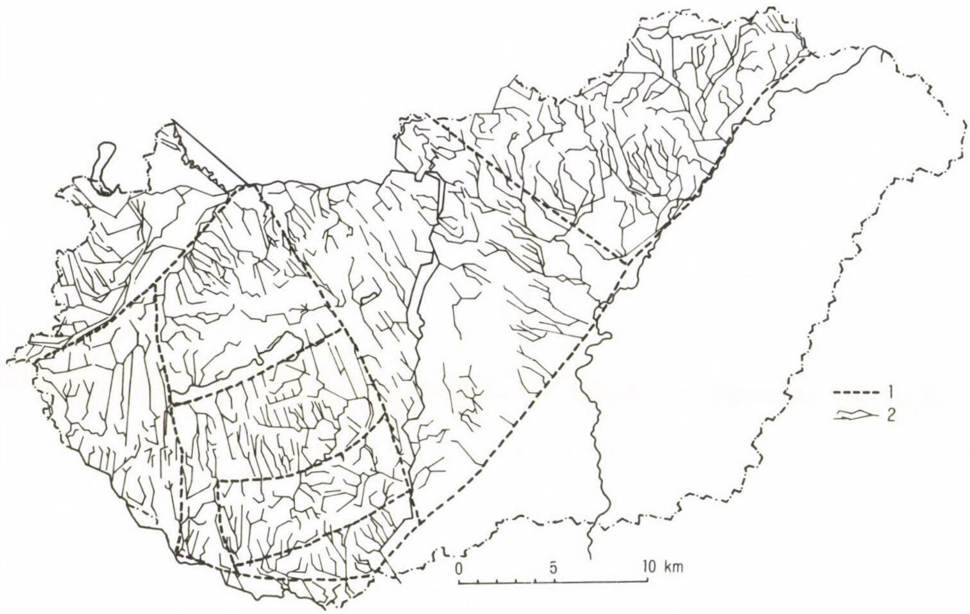

Fig. 1 'Straightened-out' version of the drainage of Hungary
1 = boundary of areal units; 2 = water-courses

tical investigation of the major water-courses of Hungary was completed in order to reveal the relationships between structure and drainage and to detect the neotectonic processes important in the development of drainage, their distribution and regularities in some regions of Hungary.

The 'straightened out' version of the drainage map of Hungary was drawn from a 1:500,000 scale base map *(Fig. 1)* and the system of lines represented on the map with different length, direction and density parameters was subdivided into areal units by structural geological, geomorphological and

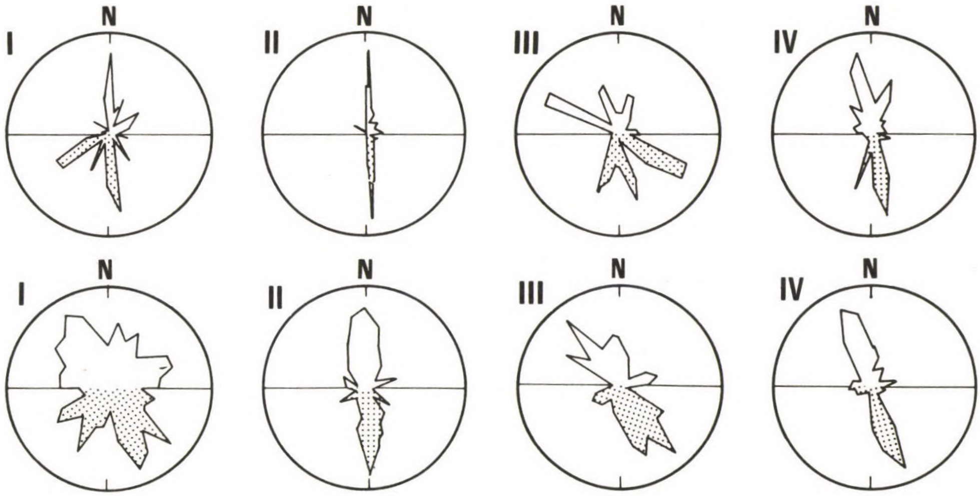

Fig. 2 Diagrams of direction for areal units I--IV. In the upper row the orientation of the lineaments is seen, while the lower presents the orientation of drainage. In the northern semicircle frequency is shown in both rows, while the southern semicircle indicates the distribution according to lengths

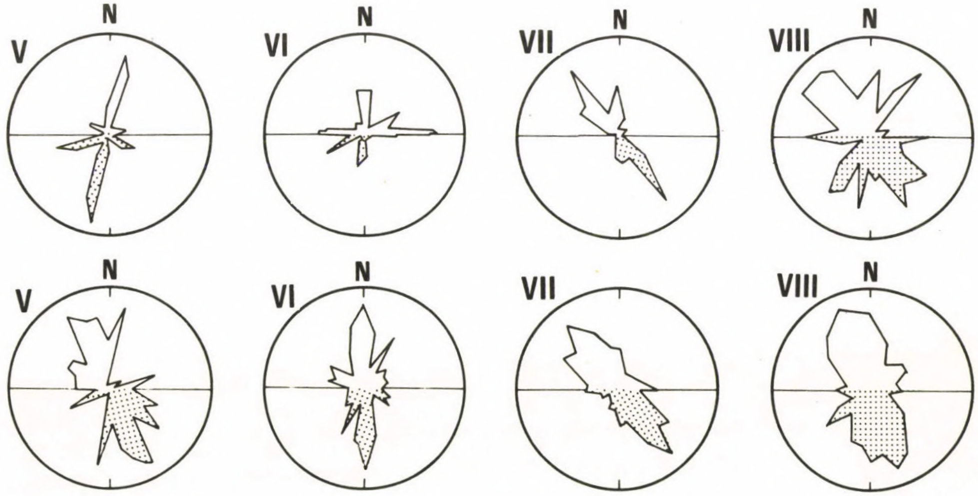

Fig. 3 Diagrams of direction for the areal units V--VIII. For explanations see Fig. 2

hydrographical viewpoints. Delineation on the lineament maps 'followed major lineaments which are often important and well-known structural lines in the macrostructure of Hungary' and they are typically 'of divisive nature and do not bear the traces of the main lineament systems of the individual blocks' (SIKHEGYI,F. 1985). It caused difficulties during the statistical calculations of frequencies of direction and in each case it had to be decided to which unit the boundary lines belong or whether they can be considered at all in the comparison with drainage.

Observing the above viewpoints, the area of Hungary was subdivided into 9 regional units. With the exception of the Trans-Tisza region, these units were subjected to statistical analyses of the frequencies of direction, both from the data of lineaments (SIKHEGYI,F. 1985) and of drainage (MÁRTA, E. 1985). (The processing was carried out at the Department of Physical Geography, Eötvös Loránd University; the computer programme was prepared by BAKÓ,T. 1984).

Regarding orientation, each unit is rather distinct, but correspondence between the lineaments and drainage varies with regions. The diagrams of frequency of direction are shown in *Figs 2--3*. The northern semicircle indicates frequency, while the southern presents distribution by lengths. Within the individual regions the comparisons suggest the following conclusions.

There are several maxima on the diagrams of both types for the Little Plain and the Subalpine region (area I). Among them, the main direction of 160--170° and the secondary direction of 50--60° coincide with the apex of drainage. Consequently, the correlation between the streams and tectonics is likely here. The role of N--S lineaments of high frequency (26.5 per cent) but small length cannot be proven for water-courses.

In the region of the Örség and Zala Hills (area II) the N--S direction is undoubtedly predominant in both systems. Although this maximum forms a broader belt on the diagram of water-courses and this indicates a less strict adjustment to faults, in a belt expanded by 10° 40 per cent of the rivers is included, while more than half of the lineaments points into this direction. It is characteristic for both the rivers and the structural lines that N--S sections are long and relatively few. There is a weak but still observable second coincidence at 120°.

In the Bakony Mountains and its northern foreland (area III) the three maxima of lineaments is matched by four peaks of the drainage, but only two of them corresponds in direction. The tectonic control of the water-courses in the main maximum of 160--170° and in the secondary maximum of 120° is obvious. At the same time, there is no counterpart in structure of the absolute frequency of direction peak of rivers at 140°! These sections are likely to be consequent valleys governed by the slope of the relief. Equally absent among the lineaments (0 per cent!) is the direction of 70°, present for streams. On the other hand, the maximum of direction at 10--20° in structure (15--17 per cent) is not found for water-courses. This may be explained by the older age of structural lines than assumed ('Pliocene structural graben' - SIKHEGYI,F. 1985) or their lack of influence on the present drainage.

In the Somogy and Tolna Hills (area IV) the statistics of directions show maxima of both the lineaments and the drainage in the direction of 160--170°: about 30 per cent of all lines and more than 35 per cent of all lengths fall in this direction. The investigation of the lineaments also found an expressed peak in the direction of 20° (12--16 per cent), but it is not manifest in drainage. Here too an older structural element is likely to appear and its presence does not exert an influence on the courses of rivers today.

In the region of the Mecsek Mountains and the Zselic Hills (area V) the almost N--S main direction (10° for 24--28 per cent of the lineaments and 0° for 14--18 per cent of drainage lines) gives evidence to the structural control of streams. The other peaks of the diagrams of direction, however, do not show correspondence. The major structural directions (80°

and 110°) do not coincide with the secondary maximum of water-courses (30°). Disregarding the N main direction, the two factors are not correlated at all.

In the small and narrow unit between the Mecsek Mts. and the Dráva river (area VI), along with the main direction of drainage (150--160°), several other directions are apparent (10°, 70°, 110°, 130°), but, with one exception, their percentage values remain below 10 per cent. There are, however, fundamental variations in the directions of lineaments, comparing both for the drainage of the unit and for the lineament system of other areas. The most striking feature is the 22--28 per cent share of the E--W direction and it is also different from other regions of Hungary. At the same time, this shear structure of arcuate transcurrent faults along the southwestern margin of the Pannonian Basin does not influence the courses of rivers at all. The weak peak at 10° (11 per cent) is met with a similar maximum of the drainage lines, thus, structural control is assumed in this case and in the direction of 60--70° too. Into the above mentioned main direction of the drainage (150--160°) 23--26 per cent of all rivers is aligned, while in the analysis of structural lines none was found. An explanation to this is expected from further detailed research.

The broad belt between the Mór trench and the Cserhát-Mátra-alja lineament including the Danube--Tisza Interfluve and the central members of the North Hungarian Mountain Range (area VII) is a single tectonical unit by its system of photolineaments, in spite of the major variations in geological structure. This seemingly heterogeneous region is so uniform that about 60 per cent of the lineaments lie in the two main directions (130--140°and 0°) and,together with the Zala Hills, the correlation between structure and drainage is the strongest here. In the northern part of different Mesozoic and Paleozoic structural units 'young' structural evolution is of uniform nature (ORAVECZ,J. 1981) and the southeastern continuity of lines allows the expansion of the area affected by homogeneous young (Cenozoic) structural evolution to the Tisza lineament. The young age of this evolution is also supported by the strong correlation with drainage.

The areas of the North Hungarian Mountain Range east from the Cserhát-Mátra-alja lineament and its foreland stretching to the Danube (area VIII) cannot be considered uniform by the investigations of direction. Further divisions would be useful in the area. The very broad main direction (or belt) of drainage falls between 130--200° and can cover several peaks of the lineaments (130°, 150° and 190°). The maximum of 40--50° important in structure is accompanied by the weaker peak of drainage at 50--60°. The E--W direction of 90° is of tertiary significance in the case of both elements, the adjustment, however, is good.

No phototectonic interpretation is available as yet for the Trans-Tisza region, therefore, the directions of water-courses cannot be compared to anything. The analysis of this area is a future task.

CONCLUSION

Analyzing the orientation of the drainage and lineaments in relationship, some general conclusions can be drawn.

1. According to the degree of correspondence, the areal units can be referred to three groups.

a. The relationship of the two factors is strong, the streams follow structurally controlled directions. The examples are the Zala Hills and area VII, where the correspondence is valid for almost all details. A general remark is made here and it is true for all the areas. Water-courses follow the lineaments less strictly as it is shown in the relative broadness of the maxima of drainage directions and in lower percentage values.

b. The diagrams for the two factors are almost completely different in the Baranya Hills (unit VI), where the independence of drainage from photolineaments can be assumed.

c. With one or two correspondence, the differences in maximum directions are striking; most areas belong into this transitional group.

2. The geological--geomorphological literature, based on observations and concrete statistical investigations of directions, agrees in the structural control of some of the water-courses. Going beyond this statement, the groups, 'b' and 'c' mentioned above deserve attention. The interpretation of independence and the survey of other factors important in the area in this respect require further research and does not belong to the topic of the present study. Much more important

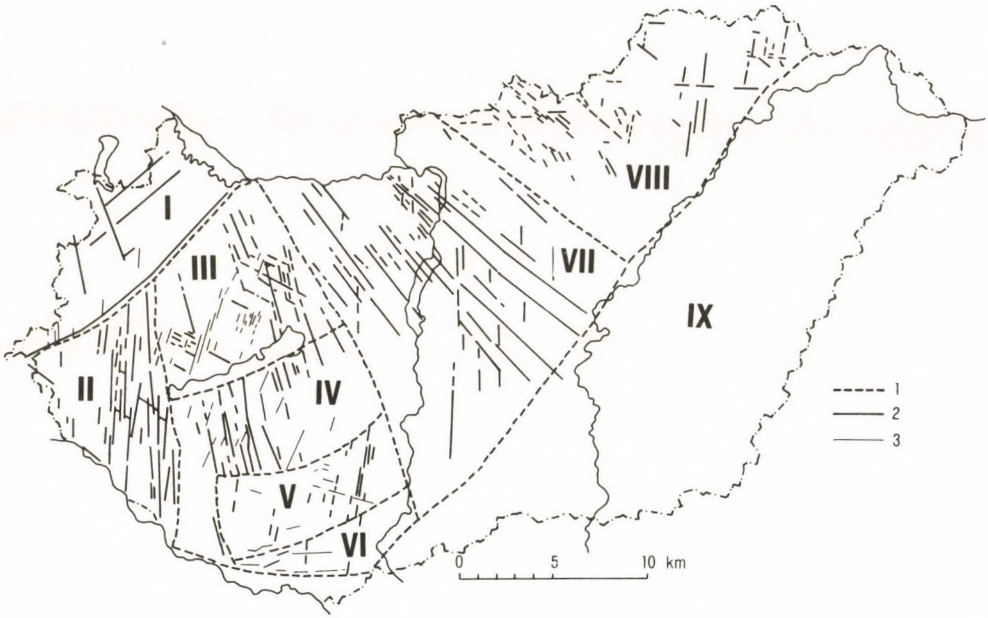

Fig. 4 Active and inactive structural lines in Hungary (from the map by SIKHEGYI,F. 1985) induced from the investigation of the orientation of drainage.
1 = boundary of areal units; 2 = neotectonic lines active in the control on drainage; 3 = old and inactive structural lines

is the neotectonic interpretation of the variation. In our opinion, the peaks shown by the statistical analysis of direction which are corresponded by maxima in drainage orientation can be interpreted as neotectonic structures still active and influential on the courses of streams. (They are not necessarily young elements, they may be rejuvenated old features). In contrast, the peaks of lineament orientation which have no counterparts in drainage are indicative of probably old and inactive structures. On this basis an experiment is made to divide the two types of structures over most of Hungary and to present them in outline *(Fig. 4)*.

The method chosen does not permit more precise dating. Young tectonic movements may equally be of Quaternary and Upper Tertiary age. Unfortunately, the analysis could not as yet cover the areas of sedimentation in the Great Hungarian Plain, which are suitable for the detection of the youngest processes.

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CONTRIBUTIONS TO THE PLEISTOCENE LEGACY IN MICROREGIONAL ECOLOGICAL VARIATION IN HUNGARY

S. MAROSI

ABSTRACT

Author presents examples to the mechanism how the changes of groundwater table depth (controlled by surface slope) result in the formation of hydromorphous soil type and a complex ecological transformation within some metres distance (Fig.1). He also demonstrates the origin of a zonal, in the given case, brown forest soil induced by the appearance of spots or zones of 1 m thick loess on a surface of dolomite with lithomorphous (rendzina) soil (Fig.2).
Detailed investigations also attest that the difference in precipitation in the Late Pleistocene within 15--20 km zonally has been preserved to our days. In its influence, the complex ecological differences remained to be significant manifested in the temporal sequence of soils and in their genetic types as well as in the different conditions of sedimentation and erosion resulted from the 100 mm variation in precipitation and the related contrast in vegetation (lessivage in more humid soil and its absence on relatively higher terrain; remaining woods in the Boreal stage on more humid soils and the occurrence of steppe and deflation in places with drier ecology - Figs.3 and 4).

* * *

INTRODUCTION

The totality of physical ecological factors is well reflected in the genetic types, dynamics and physico-chemical properties of soils. It often happens that natural vegetation and the related soil type are adjusted to microtopography and the depth of groundwater table.

MICROECOLOGICAL VARIATIONS INDUCED BY HYDROMORPHOUS OR LITHOMORPHOUS INFLUENCES

In exposures the surficial soils are typically different within some dozen metre distance. Mainly in the quarries of sedimentary rocks (loess, sand and gravel) it is observed that the depth (erodedness) of zonal soils is adjusted to the microtopography along the quarry wall or if the cross section of a (recent or fossil) dell is exposed, on its bottom the zonal soils of the slope change into hydromorphous (recent or fossil) soils *(Fig.1)*.

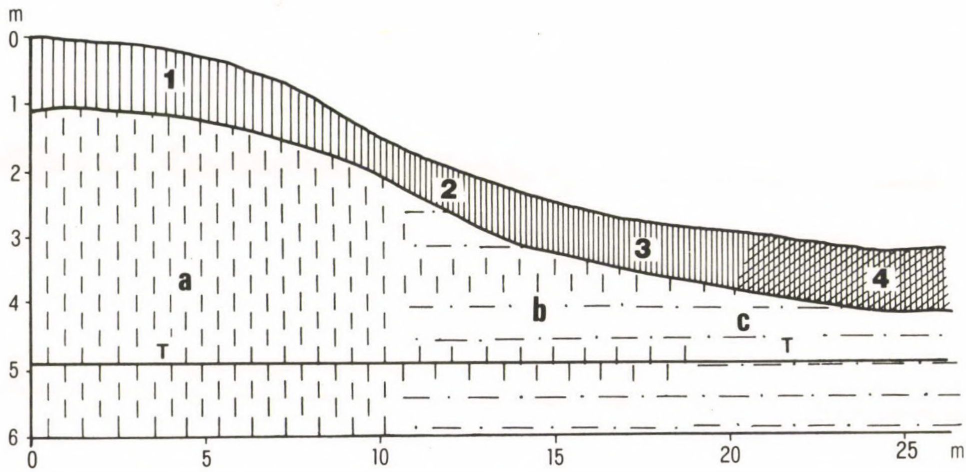

Fig. 1 Genetic soil types influenced by microtopography and the groundwater table adjusted to it.
1 = zonal Ramann's brown forest soil, complete profile in summit position; 2 = the same on slope, eroded; 3 = semihydromorphous chernozem meadow soil; 4 = hydromorphous meadow soil; T = groundwater table; a = loess; b = sand with loess silt; c = silty sand

A similar local microecological or topological variation is induced by, for instance, minimum lithological change. Along the marginal zone of an extended dolomite area, the lithomorphous rendzina soil on the dolomite is immediately replaced by the zonal brown forest soil if the dolomite is covered by

1 m of loessy or slope deposits, which functions as parent material *(Fig. 2)*.

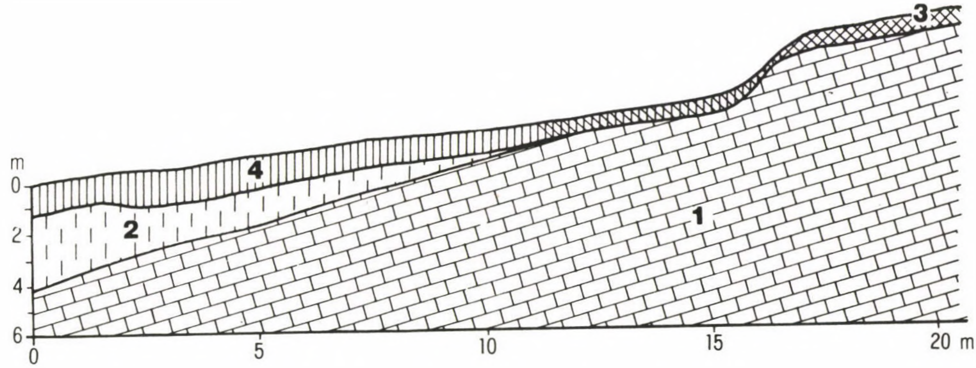

Fig. 2 Occurrence of zonal soil in a dolomite region with lithomorphous soil
1 = dolomite; 2 = loessy slope deposit; 3 = rendzina; 4 = Ramann's brown forest soil

INHERITENCE OF SPATIAL VARIATION IN TIME

It is instructive when, in areas of similar lithology (sand), climate, 100 mm difference in precipitation, induces variation in microecology through chain reactions. This spatial variation is maintained for a long time and inherited from the Pleistocene to our days.

The surface of the Carpathian Basin belonged to the periglacial belt during the Late Pleistocene and, thus, was enriched by various minor periglacial phenomena as frost wedges, frost sacks, periglacial felsenmeers and others (PÉCSI,M.1961, 1963). Alternating climates resulted in different processes and forms in other periglacial areas (DYLIK,J. 1963; PÉWÉ,T.L. 1954; POPOV,A.I. 1959; TROLL,C. 1944). The detailed analyses of Quaternary sediments and the typical Pleistocene periglacial polygonal tundra phenomena, cryoturbation and the multistoried soil profiles founded the reconstruction of the paleoclimatic conditions of Transdanubia.

In some parts of the Inner Somogy alluvial fan mantled by blown sand, S of Lake Balaton, two or three forest soils overlying each other are often observed. The parent material(sand) attests to sedimentation interrupted with climatic phases favourable for forest soil formation. During the latter the sand body was affected by soil formation. In extreme cases the C horizon with $CaCO_3$ of several dozen cm thickness interbedded between forest soil profiles without $CaCO_3$ unambigously indicates the cyclicity of deep soil formation.Along with the rust brown forest soil with 'kovárvány'(striped B horizon - KÁDÁR,L. 1957; MAROSI,S. 1966, 1969), reaching down into the deep cryogenic involutions, they explain the soil complexes of often 4--5 m thickness and at the same time they reveal that the surface is essentially (regarding macroforms) fossil and preserved Late Pleistocene relict surface.

The geomorphology was not changed in the drier stage (Subboreal) of the Holocene either, since geographical location allowed sufficient precipitation for the forests and the area did not become a dry steppe, at a maximum it turned into a forested steppe.

The relatively humid climate made lessivage the predominant process of soil formation. The parent material of prevailing fine sand and microstratification promoted the development of B horizons with 'kovárvány' (iron-rich bending) during soil formation.

The mosaical distribution of soils over a small area is illustrated by three examples: a. The initial situation is characterized by the 1 to 1.5 m soil profile with the underlying 1 to 2 m of parent material, indicating relatively undisturbed sedimentation, and below that the next, older soil profile is present. b. Often 3 m thick brown forest soil profile reaching deep and showing the distinct stripes of 'kovárvány' *(Fig. 3)*; below there is a thin sediment layer unaffected by soil formation separating the young and old soil profiles.

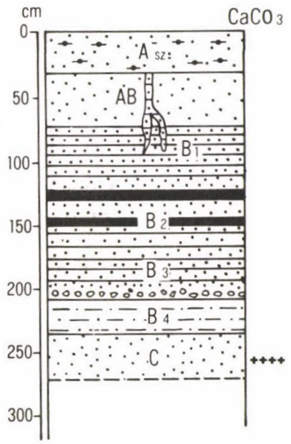

Fig. 3 Profile of lessivated brown forest soil with 'kovárvány' at depth, on sand, Öreglak, Inner-Somogy. - Genetic horizons with depth indicated: $\underline{A}_{sz}$ (ploughed) 0--30 cm = 10 YR 4/3, loamy sand. Loose grains, micaceous. $CaCO_3$ Ø. AB 30--75 cm = 10 YR 5/6 sand. Loose, feels wet, without structure. In a vertical krotovina reddish brown clayey sand fill from B horizon. $CaCO_3$ Ø. $\underline{B}_1$ 75--120 cm = 7.5 YR 4/4, clayey sand. Clay film is 5 YR 3/4. Large crumbs. Variegated krotovinas, iron speckled. Intensive earthworm activity. $CaCO_3$ Ø. $\underline{B}_2$ 120--180 cm = horizon with 'kovárvány', 10 YR 5/6 base colour, variegated, clayey sand. Thick 'kovárvány' stripes. Fall in clay downwards, 'kovárvány' stripes thinning out. Root and erathworm traces. $CaCO_3$ Ø. $\underline{B}_3$ 180--220 cm = olive greenish grey, loose, grainy sand. Thin 'kovárvány' stripes. Iron rust.Oxidation-reduction spots. At 220 cm quartz pebble stripe (0.5 to 1 cm Ø). $CaCO_3$ Ø. $\underline{B}_4$ 220--240 cm = 2.5 Y 5/4, loose silty sand. Rusty-gleyed, micaceous. Lower limit of roots. $CaCO_3$ Ø. $\underline{C}$ 240--275 cm = mouse grey sand with $CaCO_3$ accumulation. Gleyed spots in upper part

c. Erosion or poor deposition is indicated by the phenomenon of two or more soil profiles directly overlying each other producing a soil complex of 4--5 m total thickness *(Fig. 4)*. There are combinations of the cases b and c too.

Within a small area the examples supporting variation in temporal overstratification show the preservation of pheno-

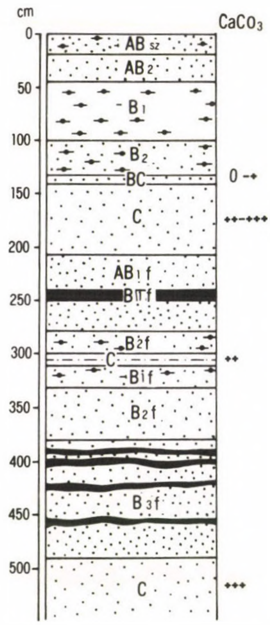

Fig. 4 Multistoried fossil rust-brown forest soil series partly with 'kovárvány' and partly lessivated. Genetic horizons with depth indicated. - 1. $\underline{AB}_{sz}$ (ploughed) 0--20 cm = 10 YR 3/3 - 7.5 YR 4/3, heavily eroded humus horizon (mixed by ploughing with B horizon material), loamy sand. Loose, without structure. $CaCO_3$ 0. $\underline{AB}_2$ 20--40 cm = lighter than the above, slightly humous (0.1--0.2 per cent) sand. Loose, without structure. $CaCO_3$ 0. $\underline{B}_1$ 40--100 cm = brick red, cohesive, lessivated loam. Loose prismatic or large crumb structure. $CaCO_3$ 0. $\underline{B}_2$ 100--130 cm = reddish yellowish brown, slightly cohesive sandy loam. Looser than the above. $CaCO_3$ 0. $\underline{BC}$ 130--140 = brownish--yellowish loose sand. $CaCO_3$ 0- +. $\underline{C}$ 140--210 cm = Olive loose sand. $CaCO_3$ ++ -- +++. 2. $\underline{AB}_{1f}$ (f = fossil) 210--240 cm = beige loose sand. Eluviation horizon. $CaCO_3$ 0. $\underline{B}_{1f}$ 240--250 cm = rust-brown (7.5 YR 4/4) 'kovárvány' stripe of sand. $CaCO_3$ 0.250--280 cm = beige loose sand. Eluviation horizon. $CaCO_3$ 0. $\underline{B}_{2f}$ 280--300 cm = rust-brown, slightly cohesive sandy loam. $CaCO_3$ 0. $\underline{C}$ 300--310 cm = olive grey, cohesive silty sand. $CaCO_3$ ++. 3. $\underline{B}_{1f}$ 310--330 cm = dark reddish brown (5 YR 3/4) sandy loam. Loose prismatic, large crumb. Eroded horizon. $CaCO_3$ 0. $\underline{B}_{2f}$ 330--380 cm = Light brown slightly cohesive sand getting lighter with depth. Iron oxide cement, weak lessivage. $CaCO_3$ 0. $\underline{B}_{3f}$ 380--490 cm = loose sand of 'kovárvány' (iron oxide) stripes, scarser downwards, of 1--3 cm thickness. 'Kovárvány' stripes are 7.5 YR 4/6, interbedded sand 10 YR 5/6. $\underline{C}$ 490-(510) cm = olive, loose, medium grained sand. $CaCO_3$ +++.

mena to our days in paleoclimatological, paleopedological and paleogeomorphological features which are absent in 15--20 km to the E. To the E (in the environs of Látrány), however, only 100--150 cm deep rust-brown forest soils are typical on sand surfaces of the same level. This is explained by the present climatic conditions as well as in the paleoecological situation. Today precipitation is 100 mm higher in the more westerly area. The difference also existed earlier. It was in the Subboreal stage that in the eastern area the amount of precipitation fell below a threshold value of aridization and, as a result, forest was replaced by poorer vegetation mantle. Thus, in the more eastern area deflation attacked the Late Pleistocene blown sand surface, and, as a consequence, the soils and features possibly formed under periglacial climate were destroyed. It seems probable, however, that the latter could not develop, at least, not to the extent observed in the area more to the W with higher precipitation. The difference in precipitation and the related ecological factors between the two areas is clearly manifested in the lack of lessivage in recent soils, while in the western area this soil type is predominant (GÓCZÁN,L. - MAROSI,S. - SZILÁRD,J. 1974; STEFANOVITS,P. 1971).

CONCLUSION

The above do not only illustrate the relationships between temporal processes (sedimentation and soil formation and geomorphic evolution) and geofactors in time, but are suitable to measure the local influences of ecological factors and their intensity. They provide evidence to the fact that a relatively minor variation in a single geofactor (here precipitation) may cause important differences through the chain of the other ecological factors and also underlines that the same relative difference has been preserved over a long time span (from the Late Pleistocene to our days) and remained ecologically predominant. In other words, the Pleistocene microregional ecological difference was inherited to the present.

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ENGINEERING GEOLOGICAL, EXPERIMENTAL AND METHODICAL STUDIES

M. Pécsi (ed.)
Pleistocene environment in Hungary
Geographical Research Institute
Hungarian Academy of Sciences
Budapest, 1987

ENGINEERING GEOLOGICAL CHARACTERISTICS OF THE QUATERNARY IN THE LAKE BALATON REGION

J. BOROS - T. CSERNY

ABSTRACT

The largest recreational and touristic area in Hungary is the Lake Balaton Region, that's why this country was the first larger area to be mapped engineering geologically. In the course of mapping 2469 shallow boreholes (5-15 m) were drilled with a total metrage of 30,000 m. Samples from the boreholes and other exposures and excavations were investigated and analyzed geologically for soil mechanics, rock physics and water quality. The Quaternary in the Lake Balaton Region has been subdivided into Early and Late Pleistocene and Holocene. The formations involved widely vary in genetic, petrographic and physical-mechanical characteristics. The Pleistocene includes fluviatile, eluvial, proluvial debris-cones, eolian-deluvial and deluvial formations, the Holocene is represented by lacustrine, colluvial, deluvial, proluvial and fluviatile ones. The petrographic types like dusty clay, clayey silt, silt, sandy silt, dusty sand and sand were investigated in laboratory. The laboratory parameters of the Quaternary deposits were analyzed statistically. The results of calculation of natural moisture content (W), void factors (e), specific weight (ϱ), density (γ), flow limit (W_f), plasticity index (I_p) and consistency index (I_K) and their evaluation are tabulated.
Housing and engineering projects glow from year to year in the Lake Balaton region. Designers and executors are confronted with Quaternary deposits in most of the cases so that unlimited possibilities for the use of the above parameters are offered.

* * *

The largest recreational and touristic area in Hungary is the Lake Balaton Region the scheduled development and regional planning of which was commenced in the early 1960's. Thus it is not by accident that in this country the Balaton

Recreational District was the first larger area tc be mapped engineering geologically *(Fig. 1.;* Irányelvek .....1971; Magyarázó.....1980).

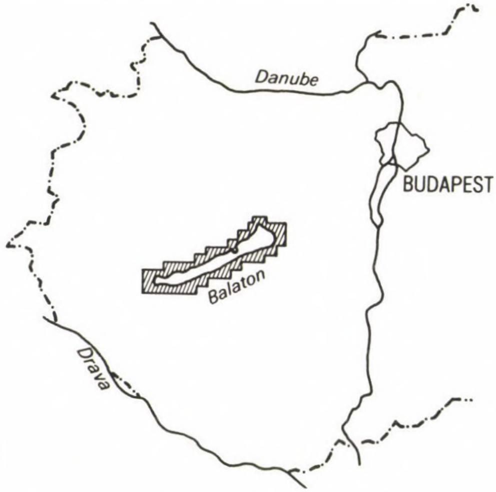

Fig. 1 The area of engineering geological mapping

The size of the mapped area is 779 km². Under the auspices of the mapping project completed in 1980 a series of engineering geological maps on a scale of 1:20,000, including 15 map-variants, was prepared for the 4 to 6 km wide lakeshore belt.

In the course of mapping 2,469 shallow boreholes (5--15 m) were drilled with a total metrage of 30,000 m. Samples from the boreholes and other exposures and excavations were investigated and analyzed geologically for soil mechanics, rock physics and water quality. Geophysical measurements played an important role, too. The Quaternary in the Lake Balaton Region has been subdivided into Early and Late Pleistocene and Holocene, respectively. The formations involved vary largely in genetic, petrographic and physical-mechanical characteristics *(Table 1)*.

1. EARLY PLEISTOCENE FORMATIONS (LOWER PLEISTOCENE STAGE)

The oldest Pleistocene deposits in the study area are fluviatile formations represented primarily by gravelly sands. Their rich vertebrate and mollusc fauna (determination by M.

KRETZOI and E.KROLOPP) has verified the Early Pleistocene age of the gravelly sand.

Another representative of the Early Pleistocene is eluvial (in situ, weathered) argillaceous silt which was also described as "red and variegated clay". Its thickness is 3-5 m.

The spatial extension of the Early Pleistocene formations is small. On account on this, relatively few samples could be collected and studied. The materials show good physical-mechanical parameters, their moisture content is low, their bulk density being low, too (about 2.6 g/cm^3). They are compact, very plastic, but hard, being assignable, in terms of unidirectional compression strength, to the category of rigid to extremely rigid soils (σ_u= 0.12-0.65 N/mm^2).

2. LATE PLEISTOCENE FORMATIONS (UPPER PLEISTOCENE STAGE)

In Late Pleistocene time, prior to the large-scale deposition of airfall dust and simultaneously with it, fluvial activities were also taking place. The rivers involved had already lower energy than it was the case with their older forerunners. This fact is proved by a reduction in the amount of coarse clastics and the accumulation of organic matter, peat, in the marshy areas of the flood plains. The thickness of fluviatile beds is considerable, attaining a maximum of 20 m.

On the northern lakeshore the proluvial debris-cones in the forelands of the mountains and in the valley-heads form deposits of very diversified grain size and lithologic composition. Their thickness is as a rule 1--5 m.

Because of sampling difficulties, the physical-mechanical properties of the fluviatile and proluvial deposits are poorly known, the samples tested in laboratories having been few in number. Because of their genetic circumstances their physical parameters are very diversified.

The most important formation of the Upper Pleistocene is eolian-deluvial loess covering a sizable portion of the study area (mainly the southern shore). The major feature of the loess sequence is its being heavily sandy, typical loess being

Table 1 Petrophysical parameters of the Quaternary sediments

			W%	e%	ϱ g/cm³	γ g/cm³	W_L %	I_p%	I_k	φ° pressure	φ° shear	c N/mm² pressure	c N/mm² shear
Holocene lacustrine sediments	clayey silt	$\bar{x}$	30	0.72	2.66	1.97	49	22	0.90				
		n	110	60	125	47	110	110	110				
	silt	$\bar{x}$	27	0.63	2.67	1.99	36	17	0.89	18	9	0.039	0.036
		n	72	31	102	23	34	34	34	42	50	42	50
	sandy silt	$\bar{x}$	24	0.56	2.63	2.01	43	17	1.00				
		n	35	7	100	7	18	18	18				
Upper Pleistocene wind-blown sediments (loess)	clayey silt	$\bar{x}$	19	0.59	2.65	2.02	39	19	1.20				
		n	150	105	219	82	93	93	93				
	silt	$\bar{x}$	17	0.62	2.68	1.95	31	11	0.90	20	19	0.040	0.044
		n	299	178	604	171	123	123	123	100	220	100	220
	sandy silt	$\bar{x}$	13	0.53	2.67	2.01	29	9	1.00				
		n	107	65	328	63	34	34	34				
Quaternary fluviatile sediments	clayey silt	$\bar{x}$	21	0.69	2.65	1.97	37	20	1.00				
		n	42	25	28	25	62	62	62				
	silt	$\bar{x}$	20	0.60	2.67	1.98	33	13	1.06				
		n	70	27	32	23	73	73	73				
	sandy silt	$\bar{x}$	21	0.71	2.66	1.90	39	15	1.00				
		n	25	6	5	4	22	22	22				
Quaternary deluvial sediments	clayey silt	$\bar{x}$	19	0.59	2.69	2.00	37	21	1.20				
		n	195	89	175	82	170	170	170				
	silt	$\bar{x}$	18	0.54	2.68	2.04	34	13	1.07	19	17	0.044	0.054
		n	129	56	131	45	71	71	71	78	68	78	68
	sandy silt	$\bar{x}$	15	0.56	2.63	1.99	32	11	1.10				
		n	101	32	112	21	53	53	53				

quite rare. The loess sequence often contains fossil soil horizons. Its thickness varies from a few m up to 30 m.

The physical-mechanical properties of the loess sequence are very well known, as the loess is wide-spread, considerably thick, having been studied in greatest detail after the Upper Pannonian deposits. Its moisture content is variable (3-38%), being usually low to fair, because it seldom lies below the groundwater table. Its void factor varies between 0.37 and 0.88, being most frequently about 0.6. Generally not macroporous, the rock under consideration is not liable to collapse. Its specific weight varies between 2.65 and 2.70 g/cm^3, only in the fossil soil horizons are there lower values (2.50 g/cm^3). Its bulk density is more variable: 1.72-2.20 g/cm^3 values being known in a very irregular distribution. The rock is generally not plastic, except for the fossil soil horizons that are plastic owing their clay and organic matter content. This may be responsible for the occurrence of higher values in statistical data processing (I_p = 4-32%). On the basis of its consistency index, the rock is half-hard in the majority of the cases, being less frequently twistable and just incidentally soft. The internal angle of friction varies between 7 and 40°, the cohesion during testing for unidirectional compression fell between 0.010 and 0.072 N/mm^2, whereas in case of rapid shear the same figure was 0.026-0.095 N/mm^2. An extremely high value was obtained for its unidirectional compression strength as well, values below 0.1 N/mm^2 having been observed very seldom. Thus the loess is to be regarded as hard and very rigid (σ_u = 0.035-0.950 N/mm^2), feature that is supposed to be due to its high lime content.

Next to follow in importance and extension after loess are deluvial formations. Showing a very diversified petrographic composition, they have resulted primarily from deposition of Upper Pannonian loess and sandy-silty formations, but in the northern areas they got heavily mixed up with clastics of basement origin. This variability is reflected in the physical-mechanical characteristics as well. All in all, the physical-mechanical parameters are similar to those of loess, the only difference being the much greater scatter of the values.

3. HOLOCENE FORMATIONS (HOLOCENE SEQUENCE)

The Holocene deposits cover vast areas in a very low thickness. Along with lacustrine deposits that are most wide-spread, the Holocene is represented by alluvial, proluvial and deluvial deposits.

The denudation processes that began in the Pleistocene continued in the Holocene. As a result of gravitation and erosion, rocks of different age (Lower Paleozoic--Upper Pleistocene) and composition (solid rocks and unconsolidated sediments) were redeposited, now covering the slopes of the valley floors in form of a deluvial deposit of 2-3 m thickness. At the base of the "basalt organs of the mesabuttes" and at the base of high shores the accumulations of falling rock and slumpings may attain even 20 m in thickness.

Proluvial debris-cones are found mainly on the N shore. These are characterized by a low thickness (1-2 m), a poor extension and finer grain size as compared to the Pleistocene debris-cones.

In the case of the deposits of the Zala river, emptying into Lake Balaton, and the Sió Canal that drains the former, fluviatile and lacustrine formations are inseparable, so, in this case, fluvio-lacustrine deposits can be spoken of. In the vicinity of the effluence of the Sió Canal the fluvio-lacustrine deposits are much more heterogeneous.

The major Holocene deposits are of lacustrine origin, being represented by so-called beach-barrier materials (sands, gravelly sands), silts deposited in a less agitated water and lime-mud and peat are associated with the lagoons of the lake. The thickness of the beach-barrier is 5-6 m. The lime-mud of the lagoons attains an average of 0.5 m in thickness. In terms of grain composition, it ought to be called silt, but its name expresses its chemical composition (its carbonate content: 40-85%) and genesis. Peats are also associated with the lagoons, occurring in two horizons: at the surface and at the depth of 6-10 m.

An examination of the physico-mechanical properties of Holocene deposits is handicapped by the unconsolidated nature of the sediment which implies limitations to sampling. Having generally a high moisture content (saturated), they are situated below the water table. An exception to the rule is represented by the deluvial and proluvial materials (clastics, sands and silts). Their void factor is much higher than that of the Pleistocene materials ($e = 0.58-1.03$). Their specific weight varies within wide limits with a heavy scatter (ρ = 2.47-2.76 g/cm^3), the low values being due to the abundance of organic matter. Their bulk density is characterized by lower values (γ = 1.52-2.14 g/cm^3). Their plasticity index is rather variable, but the correlation between clay content and plasticity index is direct, a feature manifested quite characteristically. Their consistency index is quite variable (0.21-1.91). The laboratory results, however, do not truly reflect the reality, for the samples have been taken from parts of better preservation state. As could be observed, however, lacustrine materials tend to be softer, deluvial ones being harder and fluviatile ones representing quasi a transition between the two. Because of selective sampling their mechanical characteristics do not fully reflect the reality. Their internal angle of friction is 3--35º, their cohesion varies between 0.01 and 0.07 N/mm^2.

4. CONCLUSIONS, EVALUATION OF THE RESULTS

Thousands of laboratory analyses and tests were made on disturbed and undisturbed samples recovered from boreholes put down in the course of engineering geological mapping on a scale of 1:10,000. The laboratory parameters of the Quaternary deposits were analyzed statistically. The results of calculation and their evaluation are given in *Table 1*.

<u>Natural moisture content</u> (W). The highest moisture values belong to the lacustrine and fluviatile deposits (W = 20-31%). At the same time, the eolian deposits contain only 13-19% water, the former being situated mainly below the water table, the latter above it.

The void factors (e) of the Quaternary deposits show a decrease that is directly proportional with the clay content. The lower porosity of the eolian and deluvial deposits as compared to the water-deposited ones stems from their older age. Silts of eolian age gave a little higher average value that is due to the occasional macroporosity of the loess.

Specific weight (ρ). The Quaternary deposits derive from deposition of the Pannonian deposits. For this reason, sediments of different origin have practically the same specific weight. Independently of the lithology, the more argillaceous varieties have a specific weight that is by a few per cent higher.

Bulk density (γ). Older deposits (of eolian and deluvian origin) have, on the average, higher bulk density compared to younger ones (limnic, fluviatile).

Flow limit (W_f), plasticity index (I_p) and consistency index (I_k). The character of the relationship between flow limit values and clay content is similar between eolian and deluvial deposits on the one hand and limnic and fluvial ones on the other. Naturally, the plasticity index decreases with the clay content, but it tends to become higher than would be justified by the clay content. It is in these formations that the disturbing effect of the "dust" fraction (0.002-0.05 mm) is manifested.

Housing and engineering projects increase in number from year to year in the Lake Balaton region. Designers and executors are confronted with Quaternary deposits in most of the cases, so that an almost unlimited possibility for the use of the above parameters is offered.

Along with map-atlases compiled during mapping, a qualitative characterization of the formations may be important for both specialists dealing with urban planning and regional planning and for engineers drawing up implementation plans for concrete projects.

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DISINTEGRATION OF ROCKS DUE TO FROST ACTION (EXPERIMENTS IN FREEZING CHAMBERS)

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ABSTRACT

The paper presents the results of freezing experiments on 13 volcanic and sedimentary rock types of different strength. During the 180 days of experiment, the temperature of the frost chamber was +10°C during the day and at night -5°C for 22 days, -20°C for two weeks and, finally, for the rest of time -10°C. The changes in rocks were checked and recorded every day during the experiment. After 180 days the matter was dried and the grain size composition of the flaked particles was determined. Analyzing grain size distribution, three types of rock were identified. The first is constituted by hard rocks, where the ratio of flakes particles did not amount to 0.5 % of total weight of the rock studied. Each flaked particles were found to be of 2 mm size or smaller. The second class includes rocks half of which remained in a single block after freezing. The disintegrated part had grain sizes below 20 mm. The rocks in the third category disintegrated completely, into all grain size classes, due to frost action. The experiment shows that rocks of different origin and similar physical properties (compactness and hardness) disintegrate into grains of similar size.

* * *

INTRODUCTION

Due to frost-and-thaw alternations considerable amounts of rock fragments have been produced recently in the subnival belts which were the periglacial zones in the Pleistocene. In spite of the fact that this material occurs in major part of the Earth either in recent or in fossil form, very little has been dealt with the frost mechanism and with the resistance of rocks to frost. At the beginning, research into frost served the practical life and was carried out by engineers on building materials, bricks in relation with their use (THOMAS,W.N. 1938; STULL,R.T.-JOHNSON,P.V. 1940). KESSLER,D.W. (1940) initiated the investigation of natural building stones (granite) in freezing chamber. Although the first study of geomorphological aspect was carried out in the last century (HÖGBOM,A.G. 1899), the fifties of our century saw the freezing chamber experiments that studied the resistance of rocks to frost. The investigations of TRICART,J. (1956) and MASSEPORT,J. (1959) concerned mainly the limestones of France. WIMAN,S. (1963) in Scandinavia, MARTINI,A. (1967) in the Western Sudetes and POTTS,A.S. (1970) in the region of Central Wales collected different crystalline rocks, e.g. gneisses, granites, schists, as well as conglomerates and volcanics to study them under experimental conditions. These researches provided exact data on the frost susceptibility of certain rock types.

Among the laboratory experiments perhaps the work carried out in the Caen University at the "Centre de Géomorphologie du CNRS" in the last 15 years seems to be most significant in the concept of experiments. By means of freezing different rock types, the team aimed at the simulation of field conditions and to get data to discover the characteristics of periglacial sediments and to make clear the climatic conditions necessary to the development of the forms in question (LAUTRIDOU,J.P.-OZOUF,J.C. 1982).

The freezing of rocks is a complicated physical and physicochemical process. Its most characteristic feature is that at 0°C or below the water transits from liquid state into solid state. In the crystalline, metamorphic and other compact rocks the freezing itself does not cause remarkable structural change. In the loose and soft rocks this process is much more complicated due to the migration of water. In the rock, in addition to the free water (gravitation water, that freezes at 0°C or directly below) and to the vapour, bound water is also present. This is adsorbed directly by the particles and is affected by the surface potential of the grains, thus it is of distorted structure (those in the surface of the particles are most strongly bound being thus distorted to the greatest extent) and its features differ from those of the free water (ANANYAN,A.A. 1959). Its freezing point is lower. Consequently, in the rock the different types of water are frozen at different times, and thus there is always liquid water in the frozen rock. The quantity of this unfrozen water determines the peculiarities of the rock as well as the physico-chemical processes occurring during freezing, further the mechanical stresses evolved in the rock and the deformation of the material (SUMGIN,M.I. 1929; TSYTOVICH,N.A. 1945; FEDOSOV,A.E. 1935; ANANYAN,A.A. 1959).

RESULTS OF LABORATORY EXPERIMENTS

The frost resistance of rocks is determined by their interaction with water controlled by the conditions of development (microtectonics, megatectonics) and by the petrologic features (porosity, pore size distribution, compression strength, fissure and cleavage systems, and capillary conditions). On this basis the rocks can be assigned to three groups: rocks without frost danger, rocks with frost danger and rocks disintegrating due to frost action can be distinguished.

To study the afore-mentioned interactions rocks were gathered from different areas. Having carried out the experiment in freezing chamber we wanted to answer the questions: what is the rate of disintegration of different rocks and how this is affected by the change of temperature and humidity. In the freezing chamber temperatures around 10°C prevailed under daily conditions (8 hours duration), under night conditions freezing was carried out initially at -5°C (during 22 days), then the temperature was changed, i.e. the investigation was carried out at -20°C during two weeks and later on at -10°C. The total duration of freezing was 180 days.

The collected rock samples (2 of each) were dried, measured then impregnated by water. In the meantime the weight of rock was controlled every day up to reaching maximum water capacity. Based on the two data and by means of the well-known formula the porosity given in air-dry weight percent could be determined.

In the course of freezing rocks were controlled every day, the dates of development of cracks and of disintegration of the sample were recorded. At the end of the experiment the sample was dried and the grain size composition of the disintegrated parts was determined.

13 volcanic and sedimentary rocks were used with different strength in the experiments. The frost action was observed first in case of the Bába-valley (Ond) china-clay. After freezing at -5°C during three days one of the samples was divided into two parts and small fragments were also found. The other sample completely disintegrated during 14 days. After freezing of 55 days the disintegrated detritus consisted mainly of grit and sand. Thus, the china-clay is less resistant to frost and becomes disintegrated at -5°C within a few days *(Fig. 1)*.

<u>Fig. 1</u> Disintegrated china clay (Bába-valley, Mád) after 180 days' freezing

It is to be noted that in case of several samples no change could be observed after freezing at -5°C during three weeks, but under -20°C the disintegration of the rock begun after 5 days. E.g. the hydrohematitic siliceous kaolin (Mád) disintegrated into several parts after freezing of 28 days (including 5 days at -20°C), then after 55 days only grit and sand remained. The Bekecs potash-tuff showed interesting behavior. Similarly to the hydrohematitic siliceous kaolin, it was disintegrated into several pieces after 28 day freezing, but subsequently the process of disintegration became slower. After 55 days the sample retained considerable amounts of pebble grain size in addition to the predominance of sand grains, moreover having finished the experiment we found more than one-third pebble-grains in the sample *(Fig. 2)*.

Fig. 2 Disintegrated potash-tuff of Bekecs after 180 days' freezing

Other tuffs proved to be more resistant to frost. The millstone quartzite of Sárospatak, the siliceous kaolin of Bonboly (Mád) as well as the alunite-bearing pumices and rhyolite tuffs (Mád) showed negligible disintegration after 180 days freezing (the proportion of the disintegrated parts was 0.5%) and showed essentially the same behaviour as did the pyroxene dacite of Tokaj, the grey limestone of Cserépfalu and the metamorphized diabase of Lillafüred.

The mordenitic pumice-bearing rhyolite tuff of Bodrogkeresztur showed observable disintegration (although this is an important building stone). The disintegration of this followed practically only at -20°C, since the major part of the disintegrated matter was formed after 55 days freezing and no remarkable change followed due to further freezing (at about -10°C).

Perlite displayed a peculiar behaviour to frost action. The rock remained in block for a relatively long time and did not disintegrated at -20°C either. It shattered only at the end of freezing due to the effect of the temperature -10°C. It seems probable that the devastation of about one-third of the sample is a consequence of rock-fatigue followed due to the long-lasting frost-and-thaw alternations.

The compact rocks of sedimentary and volcanic origin (limestone, crystalline schist, pyroxene-dacite) are most resistant. Practically no foliation or cracking have been observed after 180 days, the Buda Marl, on the contrary, became foliated after 5 days freezing at -20°C.

Investigating the grain size distribution, three types of the rocks can be distinguished *(Table 1)*. The first type involves the solid hard rocks that hardly changed due to freezing: volcanic lavas, silicified tuffs, the Lillafüred metamorphized diabase and the Cserépfalu grey limestone. In case of these rocks the proportion of the disintegrated parts does not exceed 0.5 %.

The second group includes the rocks, the roughly half of which remained in one piece after freezing, the other half, however, disintegrated into small fragments. Perlite and potash-tuff belong to this type. The third group involves the samples that completely disintegrated due to frost action (hydrohematitic siliceous kaolin, china clay, Buda Marl).

The proportion of the detached parts displays an interesting picture concerning each grain-size category *(Table 1)*. In the first group no coarse-grained material was formed. All the disintegrated grains were of 2 mm or less. The rock being either andesite or limestone disintegrated to this grain size. In case of the second group grain-size categories of less than 20 mm were formed as a result of disintegration while in the case of the third group a detritus of heterogeneous composition formed where all the grain-size categories were represented. It is obvious on the basis of the results obtained that the process of disintegration is peculiar in the case of compact hard rocks. Nature showed that due to frost action the solid rocks produce large blocks (stone-flows, detrital aggregates). Parallel to this process particles of sand grain size detach from the rock surface. Besides the coarse blocks the sand category becomes more abundant, the intermediate categories are missing. It is to be noted that this is valid only for the hard, compact rocks.

It has been demonstrated also, that due to frost action the grains accumulate in certain grain size categories. When taking weight-percentage proportion of the material in each grain size category, some regularities can be determined.

- Rocks of different origin disintegrate to the same grain size if these are of the same physical properties (e.g. compactness, hardness).

- The grain size distribution of the parallel samples show the same tendency in the same grain size category (in both cases the weight-percentage proportion is higher or lower, respectively, in the same category).

- In the subsequent grain size categories the measure of weight percentage proportion is very different. In the category sequence the high and low percentages show nearly regular alternation.

- In certain grain sizes accumulation tendency can be determined. High values were found in the case of rocks belonging to the second group in the categories 5-3.15 and 2-1 mm, respectively. This trend is stronger in the third group in

Table 1 Disintegration products of different rocks after 180 days freezing (in weight percentage)

Grain size (mm) Locality	> 35	35-25	25-20	20-10	10-6.3	6.3-5	5-3.15	3.15-2	2-1	1-0.63	0.63-0.32	0.32-0.2	< 0.2	Porosity value
Pyroxene dacite (Tokaj)	99.85 99.81	- -	- -	- -	- -	- -	- -	- -	- 0.02	- 0.03	0.01 0.03	0.01 0.03	0.12 0.11	1.60 1.37
Millstone quartzite (quartz-sandy hydroquartzite; Sárospatak)	99.82 99.86	- -	- -	- -	- -	- -	- -	- -	0.03 0.005	0.01 0.005	0.005 0.005	0.005 0.005	0.12 0.11	0.92 1.18
Siliceous kaolin (Mád, Bonboly)	99.88 99.61	- -	- -	- -	- -	- -	- 0.06	- 0.02	0.02 0.05	0.01 0.03	0.01 0.04	0.01 0.04	0.07 0.16	1.27 1.39
Alunite-and pumice-bearing rhyolite tuff (Mád, Király-hegy)	99.79 99.12	- -	- -	- -	- -	- -	- -	- -	- 0.06	0.01 0.09	0.02 0.14	0.05 0.20	0.13 0.39	12.07 12.9
Metamorphized diabase (Lillafüred)	99.54 99.82	- -	- -	- -	- -	- -	- -	- 0.02	0.04 0.02	0.03 0.02	0.06 0.02	0.16 0.04	0.16 0.06	1.54 1.47
Grey limestone (Cserépfalu, Perpác)	99.7 98.3	- -	- -	- 0.49	- 0.47	- 0.17	- 0.08	- 0.04	0.05 0.08	0.02 0.03	0.03 0.04	0.08 0.03	0.09 0.28	0.30 0.20
Hydrohematitic siliceous kaolin (Mád, Királyhegy)	- -	- -	- -	- -	2.5 -	3.1 0.6	15.2 8.0	6.2 6.5	29.9 31.6	13.7 20.3	11.8 18.9	5.8 7.4	11.7 6.8	32.87 33.66
Mordenitic pumice-bearing rhyolite tuff (Bodrogkeresztur)	87.3 62.1	- -	- -	0.2 4.8	1.9 9.3	1.4 5.0	2.7 7.9	0.7 1.4	1.5 3.5	0.6 1.4	0.8 1.2	0.7 0.9	2.0 2.5	19.02 25.02
Perlite (Pálháza)	62.1 8o.2	- -	- -	5.1 3.5	3.8 2.4	2.6 1.3	6.6 2.7	2.1 1.1	6.3 2.8	3.6 1.9	3.9 2.1	1.6 0.9	2.1 1.1	6.1 4.06
China clay (Ond, Bába-valley)	- -	- -	- -	- 10.2	0.5 3.7	2.5 2.9	18.3 13.2	11.3 10.0	34.5 29.1	11.8 10.5	8.8 8.0	5.0 4.7	7.4 7.7	33.05 31.45
Potash-tuff (Bekecs, Kis-hegy	38.5 52.0	9.0 -	- -	9.6 10.2	12.9 11.2	6.4 5.8	10.5 8.9	1.9 1.6	5.5 4.4	1.9 1.7	1.7 1.7	0.7 0.8	1.2 1.8	21.2 20.59
Buda Marl	16.8 53.9	17.0 6.2	6.9 6.1	17.4 9.8	10.8 6.4	5.4 2.5	9.3 6.2	1.7 1.0	7.6 4.2	3.3 1.5	2.2 1.2	0.8 0.4	0.8 0.5	4.5 3.9

the grain size categories of 20-10, and 10-6.3 mm grain size, respectively.

The experiment in freezing chamber supported the view that

- the intensity of disintegration is determined by the number of freezing-thawing cycles, in addition to the physical properties of rocks,
- the intensity of freezing bears only secondary significance,
- the alternation of freezing at different temperatures (-5°C, -20°C and -10°C) accelerates the disintegration of rocks.

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INVESTIGATION OF QUATERNARY SPORADIC FINDS (VERTEBRATA) BY DTA, DTG, TG, QMS-EGA METHOD

Gy. SZÖÖR - S. BOHÁTKA - L. KORDOS

ABSTRACT

Authors report on the further elaboration of dating based on the previously developed thermoanalytical method. The thermoanalytical Derivatograph (MOM) applied so far was coupled with a quadrupole mass spectrometer (QMS-ATOMKI) and, thus, thermal gas analysis (QMS-EGA) can also be performed as well as the analyses of thermoanalytical curves (DTA, DTG and TG).
The comparative analysis of two Ophidia vertebral segments of different age collected from the cave deposit demonstrates that fossilization altered the organic and inorganic composition of the bone in a characteristically different way.
The results suggest that the new analytical technique is more successful in dating, strata identification and facial analysis, particularly in cases when the matrix deposits contain vertebrate finds difficult or impossible to evaluate.

* * *

A new geochronological method has been developed by one of the authors (SZÖÖR,Gy. 1982a). The evaluation of the simultaneous thermoanalytical curves (DTA, DTG, TG) of Quaternary vertebrate fossil materials from Hungary's karstic areas produced characteristic parameters closely related to geological age. Using this statement as a means for dating authors carried out a chronostratigraphic evaluation of the major fossil localities (SZÖÖR,Gy. 1982b; SZÖÖR,GY.-KORDOS,L. 1981).

A home-made quadrupole mass spectrometer (QMS-ATOMKI) has been coupled to a thermoanalytical instrument (Derivatograph-

MOM). The QMS makes it possible to carry out complex and sensitive evolved gas analysis (EGA), simultaneously with the DTA, DTG, TG analysis (BERECZ,I. et al., 1983).

In this paper we demonstrate the combined method which provided the required information to explain the difference in the composition of fossil bones by measuring the gases evolved during the thermoanalytical process.

In the course of our work this chronologically well-defined sample material was evaluated. We performed comparative studies on two vertebral segments of Ophidia indeterminata.

The first sporadic find was collected from the Balla-cave, Répáshuta, Hungary. Upper Pleistocene, "Würm glacial stage", "Magdalenian II", (VÉRTES,L. 1965; JÁNOSSY,D. 1979). ^{14}C date = 20.100 yr(Groningen) (in KROLOPP,E. 1977). Derivatographic date is 20 040 yr (in SZÖÖR,Gy. 1982a).

The other one was excavated from Kököz-2 karstic fissure, Felsötárkány, Hungary. Upper Pleistocene, "Riss-Würm interglacial stage", Derivatographic date is 100 000 yr. (in SZÖÖR, Gy. 1982a).

Samples were heated with a rate of 10°C/min up to 1000°C in platina crucibles. A continuous He flow (0.6 ml/s) washed the evolved gases into the QMS (response time: 50 ms). Mass range of the quadrupole: 1-300 μ. The oil diffusion pump system was able to produce 10^{-8} mbar in the QMS without baking.

Figs 1 and *2* show the results of DTA, DTG, TG, QMS-EGA examinations of vertebral segments. Water as basic constituent was released up to 220°C from the organic, and inorganic structures (A process). In this range CO_2 relates to the beginning of the decomposition of organic content (fossile collagen). The main process (B) takes place between 220 and 600°C.

The quantity and MS pattern of organic gas components are different in samples of different ages.

The carbonate of carbonate-hydroxyapatite and calciumcarbonate secondarily built into the apatite structure dissociate in the range of 600-1000°C (C process).

The evolved CO_2 is partially reduced by carbon residues of the sample and CO is also produced in the inert atmosphere.

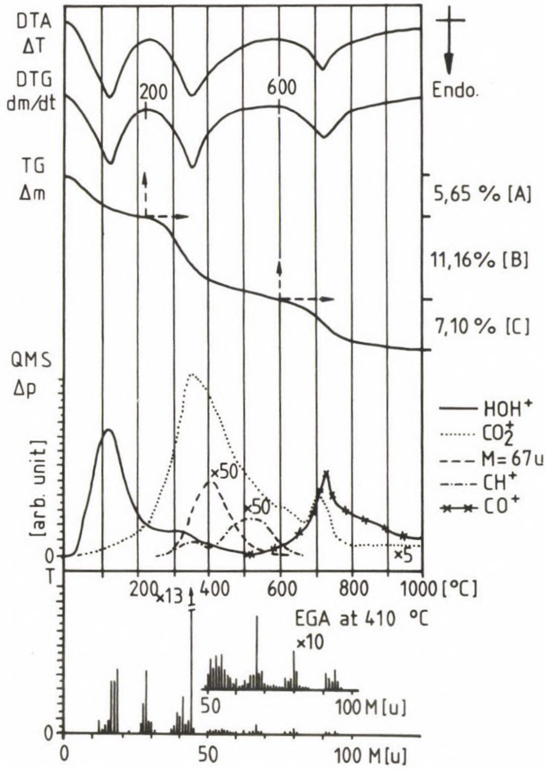

Fig. 1 DTA, DTG, TG, QMS-EGA analyses of the 20 100-year-old vertebra segment from the Balla-cave, Hungary

Comparing with the former method, essentially more and detailed information can be obtained by this one about the organic and inorganic composition of fossil bones.

In the immediate future, the serial investigation of the samples of most important localities will be completed to reveal the regularities of collagen destruction dependent on geological age and facies.

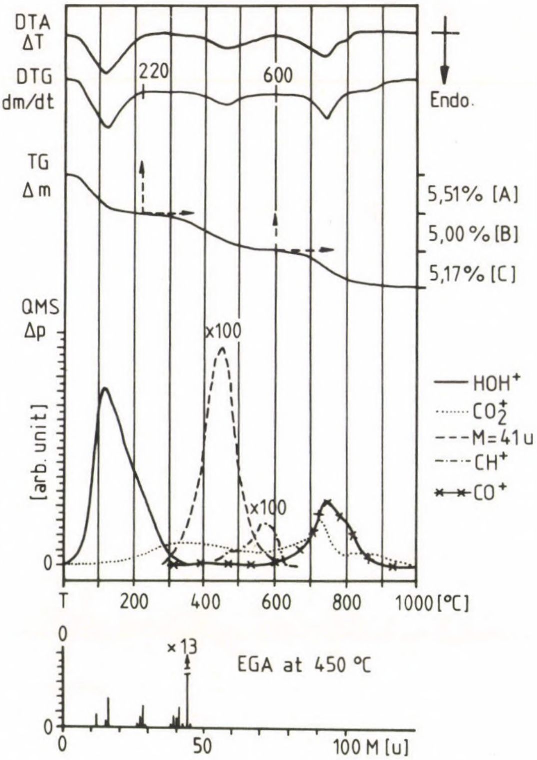

Fig. 2 DTA, DTG, TG, QMS-EGA analysis of the 100.000-year-old vertebra segment from Kököz-2 karstic fissure, Hungary

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MINERALOGICAL TRACING OF THE TELETHERMAL ACTIVITY IN A FLUVIAL GRAVEL DEPOSIT AT UZSA, HUNGARY

Gy. SZÖÖR - M. KOZÁK - J. FÉLSZERFALVI - S. BOHÁTKA

ABSTRACT

In the Keszthely Mountains, Hungary, impregnated marcasite and pirite occur in several places in Pannonian sediments. Authors described marcasite impregnation cementing the material of frost sacks in Pleistocene fluviatile gravel at Uzsa. Very rare secondary mineral paragenesis (copiapite and rhomboclase) were found as weathering products of the sulphide mineral.

The cementation by sulphidic and sulphatic minerals gives evidence to the ascending telethermal activity during the Quaternary.

* * *

The fluvial gravel complex at Uzsa, NE part of Keszthely Mts., Transdanubian Mountain Range *(Fig. 1.)* is cemented by marcasite deposited by low temperature hydrothermal activity *(Fig. 2.)*. In this locality the vivid yellow incrustations on the weathered rock surfaces proved to be a mixture of the minerals copiapite and rhomboclase.

This is the first known occurrence of rhomboclase and the second one of copiapite for the present-day territory of Hungary, although both minerals had been described earlier by classical Hungarian authors (e.g. first description of rhomboclase by KRENNER,J. 1891).

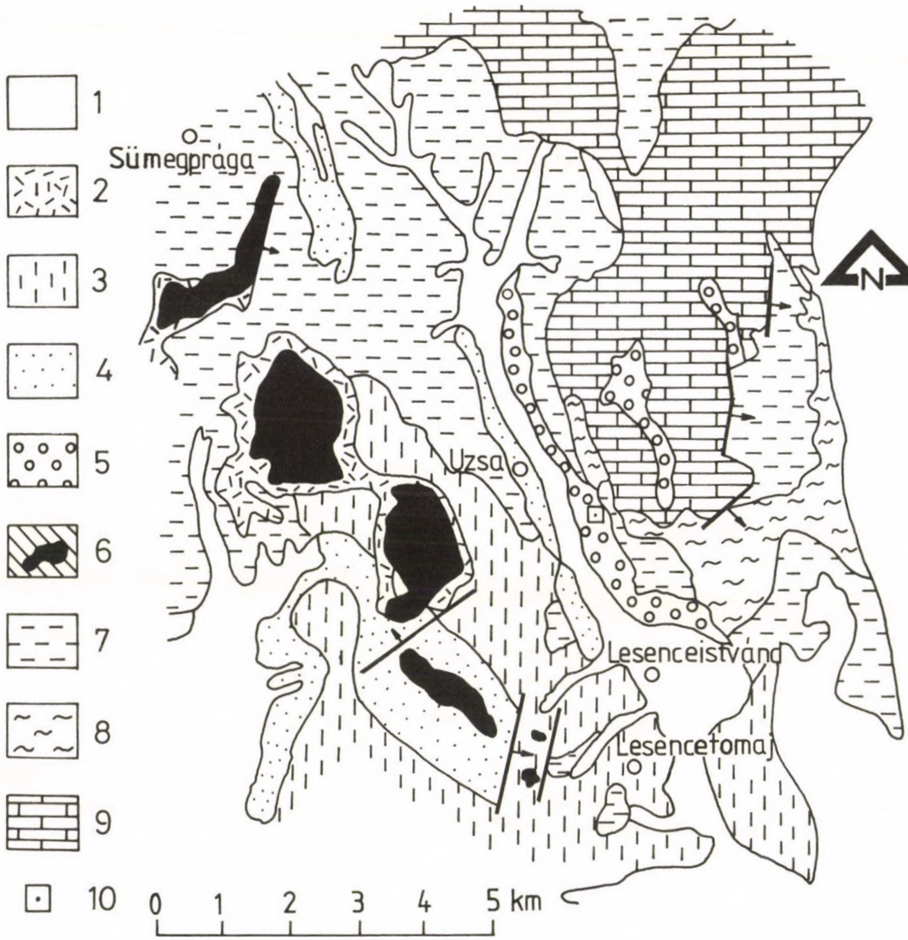

Fig. 1 Geological sketch of the surrounding area of Uzsa Village (by F.SZENTES et al. 1972; J.BOROS, 1978)

Holocene: 1 = flood-plain sediments; Pleistocene: 2 = piedmont deposits; 3 = loess, sandy loess; 4 = river-sand; 5 = detrital cone of river-gravel; Upper Pannonian: 6 = basalt, basaltic tuff; 7 = arenaceous and argillaceous sediments with lignite layers; Badenian: 8 = sandy and coaly clay, rhyolitic tuff, conglomerate; Upper Triassic: 9 = dolomite; 10 = gravel pit

The morphology of the minerals was studied by scanning electron microscope (KOZÁK,M. - SZÖÖR,Gy. - FÉLSZERFALVI,J. 1983). Copiapite occurs in nest-like aggregates, bands and rosettes, rhomboclase shows tabular lamellae with good cleavage *(Fig. 3.)*.

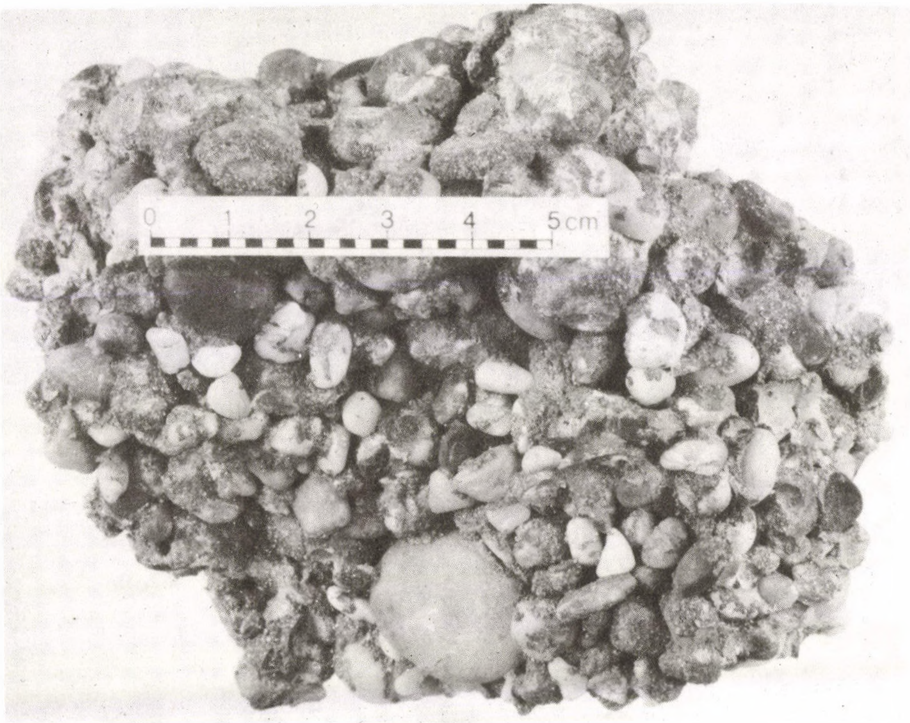

Fig. 2 Pleistocene fluviatile gravel cemented by marcasite

The hydrous iron sulphate minerals copiapite and rhomboclase were identified by X-ray diffraction (VICZIÁN, I. - KOZÁK, M. - SZÖÖR, Gy. 1986), using standard data of the JCPDS cards No. 20-659 and 27-245, respectively.

The thermoanalytical investigation was carried out by a combination of the DTA, DTG, TG, EGA methods (SZÖÖR,Gy. - BOHÁTKA,S. 1985). The estimated weight proportion of H_2O to SO_3 corresponds to a value which is expected for a mixture of copiapite and rhomboclase.

The Lower Pannonian gravel complex (JÁMBOR,Á. 1980) deposited on Upper Triassic dolomite was reaccumulated several times. Since the gravels of a large polygon are cemented by sulphide ore (BORSY,Z. 1983, personal communication), the telethermal activity most probable took place in the Quaternary Period.

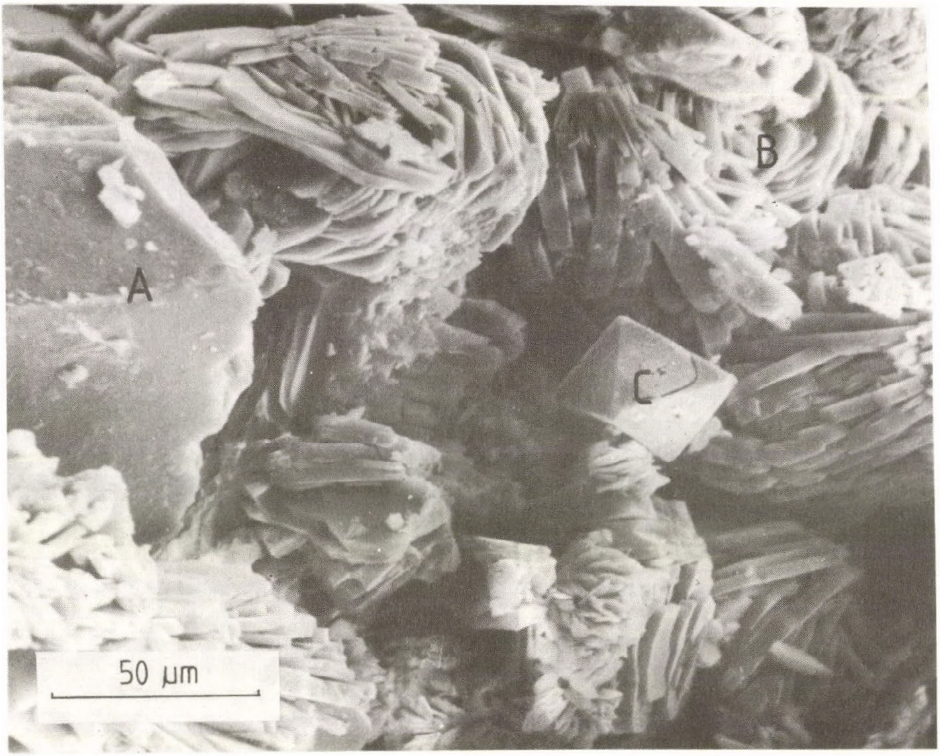

Fig. 3 A = Well cleavable rhomboclase crystal with tabular habit begins to foliate at its sides. The tabular face is (001); B = Flat tabular crystals of copiapite build up rosaces; C = On their surfaces, there are crystals of marcasite begin to weather away

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