PROBLEMS OF THE NEOGENE AND QUATERNARY

IN THE CARPATHIAN BASIN

AKADÉMIAI KIADÓ · BUDAPEST

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(Studies in Geography
in Hungary, 19)

Edited by Miklós Kretzoi
and Márton Pécsi

The present volume is dedicated to the VIIIth Congress of the Regional Committee on Mediterranean Neogene Stratigraphy held in Budapest in September 1985, by INQUA Hungarian National Committee.

In the last decade a strong tendency has developed to extend the Quaternary in time. There are considerable differences even within individual countries concerning the criteria for defining the Neogene/Quaternary boundary and these differences reflect various interpretations of the stratigraphic and geochronological evidence.

In this respect the study of the rate of deposition of the several thousand metres of Neogene and Quaternary sediments in the Great Hungarian Plain and the denudation chronology of the geomorphological surfaces in the Hungarian mountains deserves special attention.

Along with the application of geological, sedimentological, stratigraphical, paleontological and geomorphological methods, various absolute dating techniques have been recently used. It is suggested that the Neogene/Quaternary sedimentation and surface evolution may serve as a model for other areas.

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GEOLOGICAL AND GEOMORPHOLOGICAL STUDIES

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Research Institute of Geography
Hungarian Academy of Sciences, Budapest

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Contribution to the VIIth Congress
of the Regional Committee
on Mediterranean Neogene Stratigraphy

Budapest, 1985

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PREFACE

The present volume is dedicated to the VIIIth Congress of the Regional Committee on Mediterranean Neogene Stratigraphy organized in Budapest, in September 1985, by the INQUA Hungarian National Committee. The problems of the Neogene/Quaternary boundary inevitably concern both committees, belong to their scope of activity and is part of their research. In the last decades a strong tendency is observed to extend the Quaternary in time; differences of opinion are considerable concerning the criteria of drawing this boundary. In fact, the Neogene/ /Quaternary boundary (0.7-0.9 or 1.8-2.4 or 3 MA B.P.) is defined in various ways even within a single country and the differences are not only stratigraphic but also geochronologic. Therefore, in order to exploit the opportunity for an international exchange of experience, the major results of research under way are published to serve the successful work of the congress of the RCMNS and to strengthen the interdisciplinary collaboration advantageous for both sides.

In this respect, it deserves special attention to study the rate of deposition of several thousand metres in the Great Hungarian Plain during the Neogene and the Quaternary and to investigate and correlate the denudation chronology of the geomorphological surfaces in the Hungarian Mountains. Along with the application of geological, sedimentological, stratigraphical, paleontological and geomorphological methods and the results achieved, some new absolute chronological methods have also been used recently. In the investigations by these latter methods, several specialists and teams abroad also joined in the work of Hungarian experts[1]; when it appeared that the Neogene-Quaternary sediments and surface evolution may serve as a model for other areas. Paleomagnetic investigations were underlined by their inclusion into research projects operated jointly by academies of sciences, universities and authorities (Hungarian Academy of Science - National Science Foundation, Hungarian Academy of Sciences - Academy of Sciences of the USSR, or Dalhousie University /Halifax, Canada/- Hungarian Geological Institute), and it undoubtedly accelerated the research which demands high costs. The continuous research resulted in new and wider opportunities of correlation.

The papers included in this collection present this research: first the situation of biochronologic divisions in Central Europe (M. KRETZOI), the N-Q sedimentation cycles in the Carpathian basin and their possible chronological divisions (A. RÓNAI), and a paper follows on the Neogene-Quaternary denudation chronology of geomorphological surfaces and on the N/Q boundary (M. PÉCSI - Gy. SCHEUER - F. SCHWEITZER - Gy. HAHN - M. A. PEVZNER); the geological and geomorphological position and origin of Neogene red clays and pediments in the Carpathian basin are analyzed using magnetostratigraphic data (M. PÉCSI; M. PÉCSI - P. MÁRTON - F. SCHWEITZER - Gy. HAHN).

The correlation of basaltic volcanics in the Transdanubian Mountains was primarily assisted by paleomagnetic analyses (E. MÁRTON).

It is a great pleasure for us that on the occasion of the VIIIth Neogene Congress the papers by outstanding authorities of the chronology of East European-Inner Asian vertebrates and magnetostratigraphy is issued in our volume (PEVZNER, M. A. - VANGENGEIM, E. A.); it is an instructive paper, although it contradicts our opinion. In the article the Pannonian (s.l.) ostracod and mollusc stratigraphies of the Carpathian basin and East Europe are compared.

Finally, acknowledgements are expressed to all those contributing to the volume (authors, translators and editors) and those who collaborated and helped in the publication of the volume, and, last but not least, to the Hungarian and foreign laboratories and experts who, by their analyses and advice promoted the work of authors.

Budapest, July 20th, 1985.

Miklós KRETZOI and Márton PÉCSI
Editors

[1] The participants include

1. Great Plain Department, Hungarian State Geological Institute (MÁFI) - led by A. RÓNAI;
2. Geomorphological Department, Geographical Research Institute Hung. Acad. Sci. (MTA FKI) - M. PÉCSI;
3. Geophysical Department, Eötvös Loránd University (ELTE) P. MÁRTON;
4. INQUA Hungarian National Committee - M. KRETZOI.

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1. Dalhousie University, Halifax, Canada - H. B. S. COOKE;
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M. Kretzoi-M. Pécsi (eds.)
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SKETCH OF THE BIOCHRONOLOGY OF THE LATE CENOZOIC IN CENTRAL EUROPE

M. KRETZOI

ABSTRACT

A short review is given on the succession of the epochs (3), subepochs (8) and ages (24) of the European - primarily Central European - terrestrial biostratigraphic system, as we understand it today, with a consequent nomenclatural revision. A time table following the text shows the supposed correlations of the adopted terrestrial time-taxons with the Mediterranean marine biochronology/biostratigraphy, the Eastern Paratethys chronological system and the North American terrestrial mammal ages.
The paper suggests to divide the Neogene of the classical stratigraphy in time units paralleled the terrestrial events of the history of the Earth, reflected by the historical evolution of the mammal fauna, meantime taking into account a more equilibrated duration of these time units, based on radiochronological experience. This is the main cause of the changes suggested for the terrestrial biochronology.

* * *

The aim of this short report is to synthetise the data and to explain the reasons for establishing an independent terrestrial biochronological system for the European "Neogene" and "Quaternary" based primarily on micro- and macromammal samples from the Western European "Miocene" and Central European "Pliocene" - "Quaternary" time intervals.

As we know, a more detailed Cenozoic chronology/stratigraphy soon followed the Lyellian chronological system. After initial sporadic attempts, POMEL (1853) and MAYER (1858) constructed the first chronological time-tables for the Cenozoic, the first based on terrestrial mammal faunae, the second on marine mollusc assemblages.

Because of its better accessibility for non-specialists, however, the marine based stratigraphy soon replaced the terrestrial chronological systems, and it is only with the increasing importance of the study of large-scale sedimentary basins in recent decades that a modern terrestrial stratigraphy has again come to the foreground. New biochronological and lithostratigraphical schemes have been published since 1940 not only in Europe but also in North America and South and East Asia. Russian and Soviet scientists have also attempted the construction of a combined marine/terrestrial scheme and only the most recent chronological time-tables are composed of sequences of mammal - "complexes".

The biochronological schemes of Hungarian students such as MÉHELY (1914), KORMOS - LAMBRECHT (1915), KORMOS (1937), ÉHIK (1921), KRETZOI (1927-1985), MOTTL (1938-1942), JÁNOSSY (1962-1979) and others can be synthetized to yield a nearly complete succession of mammal faunae for the Pliocene (s.l.) and Quaternary "epochs". Miocene mammalian biochronology, on the other hand, has been adapted from the well-known West European chronologies of POMEL, 1853; GAUDRY, 1873, 1878; DEPÉRET, 1887; CRUSAFONT PAIRÓ, 1950, 1965, 1974a,b; VAN DER VLERK and FLORSCHÜTZ 1950; THALER 1964, 1965; MEIN, 1971, 1975, 1979; CICHA et al. 1972; FAHLBUSH et al. 1976; FEJFAR - HEINRICH 1980 and others.

When compared with the North American terrestrial ages we can see that these latter are composed of a low number of 8 ages, which are equivalent to the 9 sub-epochs of the European terrestrial chronology. This lumping of possibly differentiable ages, established more than half a century ago is generally valid today, although further differentiation of some parts of the scale is now ripe for developing. The necessity of a more detailed biochronology for Europe relates to the more complex lithological and geohistorical situation of the European continent as well as to its more dissected nature. A possible "detronization" of the ages proposed to horizons and the fixing of the sub-epochs as ages would be a step backwards in the general progress of stratigraphy/biochronology and encourage the superficial stratigraphical practice of non-specialists in a period of urgent need for the refining of specialists' skill.

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The epochs, subepochs and ages (subages) adopted in this sketch are briefly characterised in the following pages, accompanied by a correlation table *(Fig. 1)* for the Mediterranean marine, the Tethydian marine/brackish and the North American terrestrial chronologies/stratigraphies.

(No epoch name is erected for the time span ending with the Agenian).

Agenium[1] (FAHLBUSCH et al. 1976) - Comprises: Paulhiacium (n), Gerandium (n) and Laugnacium (n). Contemporaneous with the Egerium of the Paratethys-stratigraphy, the Lower Aquitanium of the Mediterranean chronology (P 22 and N 4 micropaleontological zones, etc.).

Paulhiacium (n) - Contemporaneous with the P-22 Pelagic Plancton zone and representing zone No. 15 of the CRUSAFONT PAIRÓ/GOLPE POSSE chronology, zone No. 2 of the Munich Convention, and zone No. 1 of the MEIN chronology in the nomenclature. - Biochronotype: Paulhiac l.f. - Faunal characters (MEIN, 1975): First appearances: *Titanomys, Apeomys, Heteromyoxus, Diceratherium, Brachydiceratherium, Paraceratherium, Neoentelodon, Hyotherium*. Characteristic evolutionary forms: *Steneofiber eseri, Rhodanomys schlosseri, Melissiodon schröderi, Acera-therium paulhiacense*.

Gerandium (n) - Contemporaneous with zone No. 2a of the MEIN chronology. - Biochronotype: St. Gérand le Puy fauna. - Faunal characters (MEIN, 1975): First appearance: *Marcuinomys*. - Characteristic evolutionary forms: *Eucricedoton gerandianus, haslachensis, Melissiodon schlosseri, rocquesi*.

Laugnacium (n) - Contemporaneous with zone No. 2b of the MEIN zonation. - Biochronotype: Laugnac l.f. - Faunal characters (MEIN, 1975): First appearance: *Prolagus*. Characteristic evolutionary forms: *Eucricedoton aquitanicus, Ritteneria manca, Vasseuromys rugosus*.

Aragonicum (FAHLBUSCH et al. 1976). embraces the *Gomphotherium* and *Anchitherium* epoch and the Orléanium and Astaracium subepochs. It thus covers the time span of the classical Miocene.

Orléanium (FAHLBUSCH et al. 1976) - Comprises: Wintershofium (n), Tuchořiceum (n), Romievium (n) and Collongium (n).

Wintershofium (n)[2] - Equals zone No. 3a of the MEIN chronology. - Biochronotype: Wintershof-West l.f. - Characteristic faunal elements (MEIN, 1975): New appearance: *Galeotherium ("Ursavus"), Semigenetta, Miomephitis, Broiliana, Stromeriella, Anchitherium, Taucanamo, Palaeomeryx, Lagomeryx, Procervulus, Stephanocemas*.

Tuchořiceum (n)[2] - Represents zone No. 3b of the MEIN chronology. - Biochronotype: Tuchořice l.f. - Characteristic mammal forms (MEIN, 1975): *Blackia, Pentaglis, Ligerimys, Neocometes*.

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[1] The Latin ending (i)um is used for the technical names of stratotaxons instead of vernacular ones as -an, -en, -isch a.o.

[2] With O. Fejfar (Prague)

Romievium (n)[2] - Represents MEIN zone 4a. - Biochronotype: La Romieu l.f. - Faunal characters: First appearances are the cricetid *Democricetodon, Megacricetodon* and *Fahlbuschia,* the first Proboscideans in Europe: *Gomphotherium, Prodinotherium,* the rhinocerotid *Brachypotherium* and the first Bovid: *Eotragus.* The first apes: Pliopithecines.

Collongium (n)[2] - The name refers to the MEIN zone No. 4b. - Biochronotype: Vieux Collonges l.f. - Faunal characteristics (MEIN, 1975): First appearances: *Cricetodon, Lartetomys, Anomalomys,* sansanosmiline *Machairodonts, Micromeryx.*

- *Astaracium* (FAHLBUSCH et al. 1976) - The subepoch is subdivided into 3 or 4 ages: Pontilevium, Sansanium, Oeningium/Grivium and perhaps the Monacium (belonging sedimentologically and in geological event-history rather to the overlying Catalonium).

Pontilevium (n) - Represents MEIN zone No. 5 or Munich zone No. 6. It is accepted as be contemporaneous with the Karpatium (Upper Burdigalium in the Mediterranean chronology) age/stage of the Paratethys-stratigraphy. - Biochronotype: Pontlevoy-Thenay a.f. - Faunal characters: First appearances (MEIN, 1975): *Dicrocemas*[3], Giraffids.

Sansanium (GAUDRY, 1878) - Represents Munich zone No. 7 and MEIN zone No. 6 and probably covers the time span of the Central Parathetys Badenium. - Biochronotype: Sansan l.f. - Faunal characters: First appearances: *Crouzelia, Platybelodon, Conohyus, Listriodon, Heteroprox.*

Oeningium (HEER, 1859) - Grivium (GAUDRY, 1878) - Age or ages to be defined and demarcated in the upper boundary. This complex of the ages Oeningium-Grivium-Monacium is faunistically very confluent, and therefore needs faunal revision. Lithological-geohistorical arguments provide a good boundary between the Oeningian-Grivian and the Monacian, the time of the disappearance of the Western and desalination of the Central Paratethys. This boundary therefore also coincides with that of the Badenium-Sarmatium. The Oeningium-Grivium is best correlated provisionally with MEIN zones No. 7 and 8, the latter corresponding perhaps to the Monacium. - No biochronotype can be proposed until these three units are better understood. Faunal characters: First appearances: great apes of the *Dryopithecus* group, *Albanosmilus, Dinocyon, Euprox* a. o.

Catalonicum (FAHLBUSCH et al. 1976) - This marks the epoch of *Hipparion* faunae (with dominant invasion of this genus from North America) and of *Bunolophodon longirostris,* with rich rino-, gradually enriched antelope-fauna, together with giraffees, chalico-

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[3] n.n. for Dicrocerus Lartet 1837 (nec Rafinesque 1814 - Vermes)

theres, machairodonts and hyenas (varied Ictitheriines). In the micromammal fauna the cricetid variability decreases in taxonal number, but not in dominancy rates; later in the epoch Leporids and most importantly Murids enter the faunal picture. The gradual aridisation, ending in the dry-steppe conditions (LÓCZY, 1913) of the Bérbaltavárium ("Messinian salinity crisis") is the most characteristic bioclimatic feature of the epoch. - It is best divided in the two old-established subepochs Eppelsheimium and Baltavárium, which are distinctive in terms of both fauna and geological events.

Eppelsheimium (POMEL, 1853) - Based on the Eppelsheim l.f. in the Rhine "Dinotherium-Sand" area. - Vallesium (CRUSAFONT PAIRÓ, 1950) is the biochrono-strato-taxonal synonym for the terrestrial chronology. - The leading event during the subepoch is the *Hipparion*-invasion of the Eurasian (exactly North Asian to European) continental area from North America. Characteristic of the Eppelsheimian subepoch is the relatively rich Suid, Cervid fauna, and Lagomerycids, but poverty in Bovids, and survival of typical Aragonian carnivore forms (*Amphicyonids*, *Sansanosmilus*, small Agriotheriids and varied Mustelids). Hyenids, especially Ictitheriines are generally absent. Only *Palaeotragus* represents the Giraffids. *Tapirus* is present. Proboscideans are frequent. Dryopithecine and pliopithecid apes, the only Primates of the period, survive until the end of this humid/subtropical phase.

Monacium (KRETZOI, 1959a) - In terms of mammal fauna, this stage could belong to the top of the earlier epoch especially if arguments of faunal evolution are paramount in the decision. - Biochronotype: München, Flinzsand fm. l.f. - Being transitional between the Aragonian and the Catalonian, it contains the whole fauna of the latter, but lacks *Hipparions*. This fact can militate against a basic Catalonian position, but the leading geological event, the disappearance of Sarmatian marine-brackish conditions and the sharp change to the pannono-brackish (*Congeria*-faunae) regime of the Central Paratethys could suggest inclusion in the *Hipparion* faunal epoch.

Bodvaium (KRETZOI, 1975) - Biochrono- and stratotype: Rudabánya-2, fauna and profile. - The age is prominently characterised by the sudden invasion of the *Hipparion*-group of North American origin, arriving into E Europe through the Bering Strait and Siberia, and giving the "*Hipparion*-datum" of European biochronology. Otherwise, the bulk of the fauna is composed of the surviving forms of the Grivian/Oeningian/Monacian faunal complex. In submontane facies great apes and Suids are dominant.

Rhenohassium (KRETZOI, 1976) - Biochrono- and stratotype is the Eppelsheim l.f. and the relevant member of the Rhine sands. - The Rhenohassian (practically Eppelsheimian s. str.) is well distinguished from the Bodvaium by the lack of such "Miocene" survivals as *Sansanosmilus*, *Conohyus* and others and the arrival of a not insignificant number of newcomers from the Southwest, more explicitly Siwalian (Chinjian) immigrants. Forms of this type are primarily new Suids *("Microstonyx")*, and some Bovid types, Hyenids and Ictitheres.

Baltavárium (GAUDRY, 1878; KRETZOI, 1959a) - Terrestrial synonyms are: Pikermium (CRUSAFONT PAIRÓ, 1950), withdrawn, and Turolium (CRUSAFONT PAIRÓ, 1965). - Type is Baltavár l.f. (the type of age Baltavárium as Baltavárium s. str.). - This second subepoch of the Catalonian is best characterised by the dominant invasion of Murids, but Leporids, true Ochotonids are also new immigrants from the East. Modernized cricetid fauna and a general gradual disappearance of archaich elements is characteristic of the Late Catalonian. The climate and, therefore, vegetation was variable: a transitional, warm and dry type, being succeeded in turn by a northern cool type, and a very dry climate. The upper boundary of this period is disputed, because the dominance of the Hipparions abruptly ends at the top of the Bérbaltavarian dry period (Messinian in marine terms) of the Baltavárian subepoch, whilst the Pannonian brackish-lacustrine sedimentation ends on the bottom of the Bérbaltavárium.

Csákvárium (KRETZOI, 1959a) - Biochronotype: Esterházy Cave, Csákvár l.f. The fauna is imbedded in a phosphoritic clay interfingering with *Congeria ungulacaprae*-beds of the local malacological biochronological sequence of the "Upper Pannonian". - The Csákvárian faunae are *Hipparion* faunae lacking Miocene remnants of the Rhenohassian fauna such as *Korynochoerus*, *Tapirus*, and true Deinotheres, whilst Suids are represented only by *"Microstonyx"*, Tapirs by the dwarf *Tapiriscus*, accompanied by new dwarf "Cervids" *(Cervavitulus, Cervaviscus)*, new Hyenids *(Allohyaena)*, modernized Cricetide as *Neocricetodon* and as new invaders the Murids, Hystricids and Lagomorphs *(Alilepus, Ochotonids)*. The first great Agriotheriids appear here. Dominant in the fauna are *Hipparion* and *Cervavitus*, while Suids are frequent, and Lutrines are not rare, which contrasts with the infrequent occurrence of *Procapra* immigrants. These forms imply a wooded grassland as opposed to an open grassland environment. It is of interest to mention that the rarest "endemisms" of the Csákvár fauna, *Tapiriscus* and *Cervavitulus* are present in the Dorn-Dürkheim fauna, at the top of the Eppelsheim sand complex which not only extends the range of this faunal type, but also argues for the direct superposition of the Rhenohassium and Csákvárium.

Sümegium (KRETZOI, 1959a) - Biochronotype: Sümeg-Gerinc l.f., a vertical fissure locality in the Upper Cretaceous of the western outliers of the Bakony Mt. in W. Hungary. - The fauna is in sharp contrast with the Csákvár faunal type, comprising a characteristic southern assemblage with forms (or at least variants) typical of the contemporaneous fauna of Southern European areas (*Varanus*, gigantic *Testudo*, *Hyaenictis*, *Lycyaena*, and dwarf *Hipparion*), combined with African (*Graphiglis*) or Near Eastern (Ovines) immigrants, finally endemisms such as *Allospalax*. Small Ictitheres (*Protictitherium*), rodents and a lack of Late Baltavárium forms give a good transition with the earlier Csákvárium as also shown by the presence of more progressive forms of the Csákvár genera (like *Neocricetodon transdanubicus*, *Parapodemus cf. albae* etc. among rodents, and the ictitheriid *Protictitherium sümegense*, instead of *P. csákvárense* among carnivors).

Hatvanium (KRETZOI, 1959a) - Biochrono- and stratotype: Hatvan, Brickyard l.f. and in the sandy-clay sequence at the top of the coal-bearing clay member of the Petőfibánya coal mine, containing a rich warm-humid flora referred to as Sümegium. - Mammal fauna: characterised by North Chinese to Siberian forms instead of the South European warm-climate members of the Sümegian type. Most important is the presence of the cervid *Cervocerus* instead of *Cervavitus* of the earlier Pannonian faunae. The agriotheriids are also different: the rare *Agriarctos* comes in up the fauna, like the first Papionid baboon, *Mesopithecus*, representing the first non-Hominoid Primates since the disappearance of the apes at the end of the Eppelsheimium.

Bérbaltavárium (KRETZOI, 1976) - Biochrono- and stratotype: Baltavár-1 l.f. and freshwater-sediments with "*Unio wetzleri*" and *Tacheocamplyaea doderleini*. - Fauna: Entirely new *Hipparion*-fauna dominated by *Hipparion* and *Procapra ("Gazella")*, arguing for a dry steppe-vegetation in place of the former wooded-grassland of the earlier Baltavárian and containing a much higher proportion of Eppelsheimian assemblages. As indicators of the new ecological conditions, new forms appear in the fauna as the first true *Cricetus*, a new Hystricid (*Lamprodon*), the Schizoteriid *Ancilotherium* and from among the Carnivores, *Indarctos*, *Ictitherium* and *Adcrocuta*. The Helladotheres and the Tragocerines are the only representatives of these two families so abundant in the Baltavár s.str. fauna. Common Sümegian and Csákvárian taxons as *Neocricetodon*, *Galeotherium*, *Protictitherium*, *Allohyaena*, *Hyaenictis*, *Cervavitus*, *Lycyaena*, *Palaeotragus*, *Chalicotherium* a.o. are all lacking from the Baltavár fauna.

Europaeicum (n) - The need to answer to the world-wide consequences of the final disappearance of the Western and Middle Paratethys and its climatic, ecological and biogeographical results and to express the great revolution transforming the life in the post-*Hipparion* fauna during the ices-ages postulate the establishment of this period. At the same time it is proportional to the preceding two epochs, the Tethydian marine-controlled Astaracian and the terrestrial Catalonian, as a broad-dimensioned, "intercontinental" open land life period, representing the slow advancing and building up of the scenery today - greatly influenced by the glaciations.

Montpellierium (GAUDRY, 1878) - Biochronotype of this subepoch is typified by the Ruscinium, the Serrat d'en Vaquer l.f. as defined for the latter (KRETZOI, 1962). - Fauna: Two features characterise this faunal assemblage, the decline of the dominance of *Hipparion* and the transformation of the taxonal composition of the faunae from a steppe-*Hipparion*-fauna of European endemisms with North American type and Inner Asian immigrants to an entirely South-East Asiatic monsoon fauna. The above mentioned sharp decline of *Hipparions* is accompained by the disappearance of the bulk of other representatives of the *Hipparion* faunae which are replaced by types characteristic of the Southern flanks of the Himalayas or of the south Chinese mountainous regions, such as Helarctine bears (first appearance of true Ursids!), Ailurids, first true Viverrids, ancestral forms of the modern Hyenids, *Anancus*, possibly the first Elephantids to reach Europe, true Tapirs, Bovines and other macromammal types and an increasing number of Arvicolid sidebranches *(Baranomys, Trilophomys)* or true Arvicolids *(Promimomys)*, accompained by a rich Murid, Glirid and Petauristid fauna. This faunal composition contrasts strongly with the *Hipparion*-faunae and argues for a change to a humid-warm woodland- and woody-steppe environment after the Bérbaltavárian dry period(also called the Messinian desiccation).

Baltaium (BARBOT DE MARNY, 1869) - Biochrono- and stratotype: not fixed. - Fauna as published by WENJUKOV (1903) is a mixture of survivals from the Bérbaltavárian such as *Mammut borsoni* and the terminal forms *Deinotherium (Nikolovius n.) provaus*[4], but new forms as *Anancus, Propotamochoerus, Stephano-*

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4 Nikolovius n.sg. (type: Tapirus proavus Eichwald 1835) is distinguished from Deinotherium by thickened and abruptly backwards inclined symphyseal section of the mandible (Wenjukov 1903, T.6. figs. 1-3.), inflated premaxillary and exceeding dimensions. The type is limited to the time span beginning with the Baltavárian and ending with the Late Baltaian of E Europe

rhinus megarhinus, etc. are also present. New cervid elements and the virtual absence of Bovid forms characteristic for the *Hipparion*-faunae indicating the onset of new ecological conditions and a new fauna.

Ruscinium (KRETZOI, 1962) - Biochrono- and stratotype: Serrat d'en Vaquer (fixed KRETZOI, 1962). - Fauna: The broad extension of "South Asian" fauna and the virtual disappearance of nearly all members of the *Hipparion* fauna indicate this new faunal and time unit. *Dolichopithecus* among Primates, the helarctine *Protarctos*, the ailurid *Parailurus*, the first invasion of true Viverrids in Europe, the very primitively built Agriotheriid *Agriotherium*, the machairodontid *Megantereon*, the Hyaenids *"Euryboas"* and *Hyaena* s.l. representing the carnivores as well as the above mentioned *Anancus*, the new cervids *(Paracervulus, Metacervocerus, Narboniceros)*, and the first true Bovines *(Parabos)* are all new types of the European megafauna, accompanied by a rich variety of new micromammal types, as with a new variety of Murids *(Stephanomys, Anthracomys, Rhagapodemus* etc.*)*, the revival of *Neocricetodon ("Kowalskia")*, the first Arvicolids in the restricted sense *(Promimomys)* and others.

Csarnótanum (KRETZOI, 1959b) - Biochronotype: Csarnóta-2 l.f. in the kaolinitic red earth filling of the karst of the Villány Mts. - Fauna, primarily micromammal fauna is a continuation of the Ruscinian, but differs sharply from the latter by the dominance of the new Murid-Arvicolid forms (species of the genera *Apodemus, Rhagapodemus*, and new genera as *Micromys* and *Dolomys, Propliomys*, and *Cseria)* and the gradual disappearance of the ancestral genera *Trilophomys, Baranomys*, etc. Cricetids are restricted to *Cricetinus*, while rich Glirid fauna and Sciurids, Petauristids *(Pliopetaurista, Pliopetes)* complete the picture. Macromammal fauna cannot be delimited precisely as Csarnótan, which leaves open the question of the Plio/Pleistocene boundary. The most urgent task is to fix the chronological "datum" of the elephants *(Archidiskodon)* - which has remained open since the not-Siwalian immigration of this stratigraphically very important group was proven, which is suggestive of a Late Pliocene - Ruscinian to Csarnótan - arrival of this probably African Proboscidean in Europe.

(Pleistocene) - Note: The traditional nomenclature has resulted a historical hieararchy, in which the Quaternary received the same rank with at least 2,4 My, as the whole Tertiary of some 65 My. The same is the case with the Pleistocene and Holocene with 0,7 to 2,4 My and 0,01 My respectively. This disproportionality between the different epochs, ages/stages and other time units is a pressing argument for rearranging of the units used so

as to reflect more faithfully the various time intervals. But it is infinitely difficult to change a chronological hierarchy established for around 160 years - not to mention the difficulties of persuading scientists to accept to change. - Fauna: the sharpest change in the mammal fauna during the whole Neozoic occurred at the boundary of the Tertiary and, "Quaternary" and although many "Tertiary" types persist into the Lower Quaternary, the Villafranchian-Villányian, the Quaternary, to all intents and purposes, marks the emergence of the modern fauna. The genera of modern Soricids *(Sorex, Neomys, Crocidura), Erinaceus, Homo s.l., Sicista, Spalax, Cricetulus, Phodopus,* the explosive ramification and dominance of Arvicolids over the Holarctica that occurred in two phases, first the *Mimomys* stage, and the second, most effective, the *Microtus s.l.* evolutionary explosion, the arrival of *Vulpes, Canis,* the appearance and extension of *Ursus,* of the modern Mustelid genera *(Martes s.l., Mustela s.l., Putorius, Meles), Crocuta, Panthera, Leo* among other carnivores, dominant diffusion of Elephantids, *Equus s.l., Asinus, Sus,* the dispersion of camels, new cervids *(Capreolus, Rangifer, Dama, Cervus, Megaloceros, Alces),* and Bovids such as *Bison, Bos, Bubalus, Ovibos, Capra, Ovis* a.o. of the Ungulates. This invasion of predominantly North American forms *(Canis, Equus* a.o.) is connected with the large scale extinction of all the characteristic "Tertiary" remnants such as the Soricids *Blarinoides, Beremendia, Petényia, Petényiella, Asoriculus,* the "southern" Petaruristids *(Pliopetaurista, Pliopetes),* the archaic Glirids *(Dryomimys, Amphidyromys),* Cricetids *(Allocricetus),* Murids *(Parapodemus, Rhagapodemus, Beremendimys),* and Arvicolids *(Mimomys, Hintonia, Kislángia, Pliomys).* Even more spectacular, if that is possible, is the wave of stepwise extinctions of macromammals from the beginning of the Villafranchian to the end of the Peribaltian, and into modern times. The first boundary is to draw between the Villányian and Biharian, the second between the Peribaltian and the "Holocene" - and a new boundary of sharp changes in the composition of our fauna is just beginning with the total extinction of the macromammal fauna. On this basis the "Quaternary" can be subdivided in three ages. As reflected in the fauna, two global changes are responsible for the change in the faunal picture, i.e. the general aridisation after the humid-monsoonal Montpellierian and the rhythmic incidence of glacial conditions - 2-2 alternating polar and oreal glacial events, with numerous oscillations that fundemantally influenced the biosphere.

Perrierium (GAUDRY, 1878) - The subepoch is characteristically the time of the extinction of many "Tertiary" groups and the invasion of new, partly dominant elements from North America, changing the face of the fauna.

Villafranchium s.str. (PARETO, 1865) - Biochrono- and stratotype: Arondelli (Triversa) l.f. and profile. - The originally too broadly and only tentatively measured age confounded in the original definition elements of Ruscinian, Villafranchian, Villányian and in some respect Biharian elements and only the Italo-American excavations carried out in the last decade were able to fix the fauna and the sediment member what would represent the age to be called Villafranchian s.str. This restricted time range will be used below but it should be noted that the limited taxonal content of the stratotype fauna does not allow a very exact delimination. - Fauna (Triversa, Arondelli, Villafrancha d'Asti) not yet distinguished from Ruscinian/Csarnótan in macromammals. Micromammal fauna is easily separable from both Csarnótan and Villányian assemblages. The most important difference compared with earlier faunae is the dominant role of Arvicolids and nearly total absence of Murids compared with the dominance of Murids in the Csarnótan and the remarkable frequency of Petauristids in the Ruscinian to Csarnótan faunae. *Dolomys* and the primitive *Mimomys*-species *(méhelyi, stehlini* and *minor)* represent the Arvicolids in this faunal type which is not yet understood sufficiently.

Villányium (KRETZOI, 1941) - Biochronotype: Villány-2 l.f., a karstic fissure assemblage from the Villány Mts. in S Hungary. - Fauna: In sharp contrast to the humid monsoon climatic fauna of South Asiatic origin - or at least connections - the Villányian fauna shows in all respects the new invasion of North American forms via the Bering-Straits and Siberia that have mostly replaced the characteristic southern forms. This replacement is not only a zoogeographical one but is even more sharp emphatic in a climatic sense being connected with a very efficient drying out of a great area of Holarctica in sense of neozoology. The most characteristic feature of the change in climate is the essentially total disappearance of Murids, Glirids, Petauristids and other typical forest to forest/bush land forms and the coming into dominance of an Arvicolid-Cricetid assemblage coexisting with open land living burrowers such as Spalacids, *Urocitellus*, etc. In the macromammal fauna Papionids, *Canis*, *Vulpes*, true Ursids *("U".minimus, U.etruscus)*, the last Viverrids, as new arrivals *Panthera*, *Leo* and *"Acinonyx"*, in the Proboscidean assemblage the dominant role of *Archidiskodon* (with the parallel decrease in the number in *Anancus* and especially in *Mammut*), extinction of the tapirs as far north as the Alps, the dominant flood of new invaders of the *Equus* group *(Allohippus, Macrohippus,* and *Asinus*) from North America, the decrease of Suids (only *Sus* is present), new Cervids *(Croizetoceros, "Diglochis", Eucladoceros, Kosmelaphus, "Capreolus", Arvernoceros, Praemegaceros* and *Praealces),* mostly in the South, true Bovids such as *Leptobos* a.o. Simultaneously many archaic (some "Miocene" survival) forms become extinct by the end of the Villányian, like *Blarinoides, Petényia, Petényiella, Asoriculus,* some Chiropteres, *Petaurista, Baranomys,* most *Mimomys*-forms, *Anancus, Mammut, Tapirus* (north to the Alps), *Hipparion,* Suids except *Sus,* and all antelopes living during the Villányian. It is interesting to compare the decline of grassland macromammals with the micromammal fauna which is satisfied with a varied ecological mosaic.

<u>Tamisium</u> (n) - This is the subepoch of the arrival of the modern fauna and extinction of the last survivals of Tertiary elements. The exchange of fauna is also influenced by the fluctuating impact of the glaciations, beginning before the end of this time unit.

<u>Biharium</u> (KRETZOI, 1941) - Biochronotype: Betfia-2 l.f. from a karstic fissure filling in the Bihar Mts. - Fauna: The most important faunal feature is the effective arrival of all members (or at least the direct forerunner of all members) of our extant fauna, combined with the extinction of the last early groups. During this process only *Beremendia, Mimomys*) (one species), *Macaca, Xenocyon, Pachycrocuta, Epimachairodus, Archidiskodon* and *Stephanorhinus* reached in the Biharian. New arrivals are *Neomys,* some Chiropters, *Homo, Spalax, Lepus, Mammuthus, Coelodonta, Equus s.str., Capreolus, Cervus, Rangifer, Dama, Alces, Bison, Ovibos, Hemitragus* and some other small bovids. If we check this list of genera, we can see, that it was during the Biharian that the mammal fauna of the Holocene appeared here with the exception of the genera that became extinct at the end of the "Ice age", i.e. *Mammuthus, Coelodonta* and *Megaloceros,* and the retreat of others to the North *(Ovibos)* or South *(Crocuta, Hyaena, Panthera* and *Leo)* or East (Equines).

<u>Peribaltium</u> (KRETZOI, 1979) - Biostratotype: Gailenreuther Hyänenhöhle similarly as for the upper part of the age, the Toringium (FEJFAR - HEINRICH, 1980). - Fauna: The fauna of this time unit is primarily characterised by the very remarkable northward extension of certain Northern Hemisphere mammals in the first age (Steinheimium). *Hesperoloxodon* and *Stephanorhinus kirchbergensis* (the *"antiquus-mercki"*-elements) are typical macromammal forms that characterise the first half of this

age, whilst more arctic immigrants *(Mammuthus, Ovibos, Rangifer* etc.) characterise the second half (Toringium). The fluctation of the frontier of the Northern Ice Cap and of the Alpine ice margins with alternating cold-and-warm periods and associated arid to humid phases of very different duration produced a detailed stratigraphic series of alternating faunal composition, that enables the reconstruction of the dominant faunal changes, reflecting the fluctuating glacial processes in time and space. This detailed periodisation is less of earth historical than of glaciological and geomorphological importance and enables one to date the historical dynamics of the last steps of hominization.

"Holocene" - It is difficult to characterise a period still in statu nascendi on the basis of the first 10 thousand years of its history. It is the age of *Homo*-fauna, the definition of which must be postponed. - The fauna of the Holocene is difficult to characterise as it is still in the process of building after the collapse of the natural mammal fauna during the last glaciation. Moreover this process is hindered by the fact that man occupies all the former niches populated by mammals. Primarily macromammal forms were hindered in their return to areas occupied earlier, such as elephants, hippos, rhinos and the great carnivores. Extinction of the great mammals associated with "glacial" fauna and the overpopulation of areas by man has produced the Holocene "*Homo*-fauna" comprised of micro- and domesticated mammals.

*

The scheme for the biochronology of the last 12/13 My is based on the *Hipparion* fauna followed by assemblages of South Asian origin and ending with the so called Quaternary faunal assemblage whose full development has been interrupted by the impact of man. This sequence represent in absolute time three periods of 7, 5.2 and 3.2 My.
The geological events point to a sharper demarcation between the Baltavárian and Ruscinian, with the disappearance of the Paratethys (before cca 5.2 My) and the emergence of Europe as a continent as we know it today. Preference must be given this later event that brought together Southern and Northern Europe, an event that deserves the separate name Europaeicum.

In finishing this short sketch of the zoological history and stratigraphical relationships of the European, strictly-speaking Central European terrestrial Late Cenozoic, it is hoped that an independent terrestrial biostratigraphy will be of more use for the construction of a future universal holostratigraphy, than any premature attempts to correlate the marine and terrestrial chronologies. First we have to arrive at a well founded succession of areal and chronological chains for both the marine and continental systems before it is possible to synthetise a holostratigraphy from these growing number of merostratigraphies and -chronologies.

EXPLANATIONS TO THE CHRONOLOGICAL TABLE

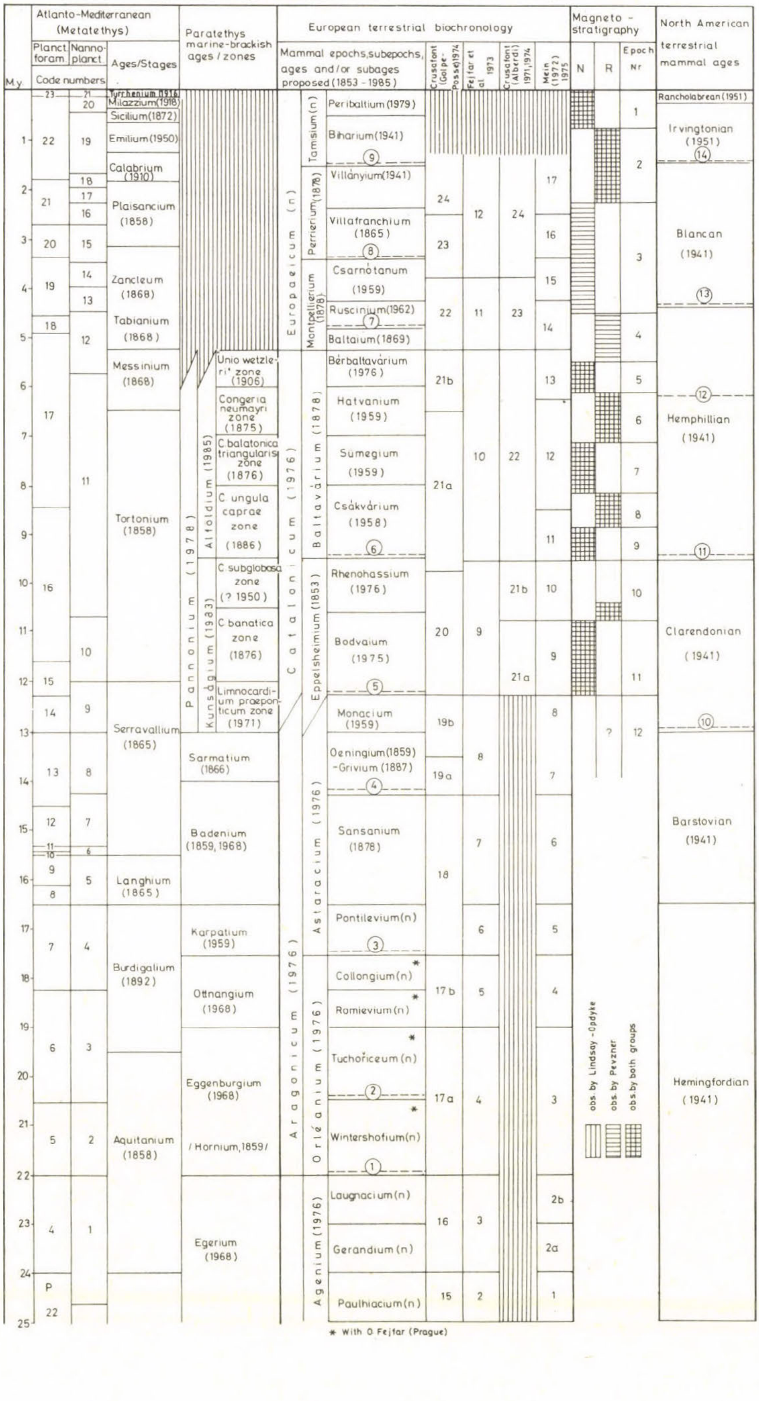
(Note: Coincidence of boundaries in time units does not indicate exact chronological correlation - it is more approximate, sometimes tentative.)

Horizontal numbered lines indicate in columns 8 and 16 approximative chronological date of major - intercontinental - immigrations, invasions of important, sometimes dominant taxonal units of faunal groups as:

1. appearance of *Anchitherium* in European faunae, immigrating from North America
2. European datum of immigration of Proboscideans from Africa
3. approximate datum of the arrival of *Pliopithecus* from Africa
4. third immigration from Africa, characterised at first by the Dryopithecine apes
5. European *Hipparion*-datum, indicated by the dominant invasion of the Hipparions in the Old World
6. appearance of Murids and Siwalik immigrants in the European faunae
7. (supposed) European immigration of the Elephantids *(Archidiskodon)*, arriving from Africa
8. earliest date of possible arrival of North American forms, primarily of the invasion of *Equus* s.str., accompanied by *Canis*, *Vulpes*, etc.
9. datum of the beginning of modern European fauna, practically of the extinction of nearly all genera of the Tertiary fauna and arrival of all genera and species (in many cases subspecies) of the extant fauna
10. datum of the dispersal of Mastodonts (arrived probably in Late Barstovian) in North America, invading from Asia
11. time level of the immigration of many forms of the European-Asian *Hipparion*-fauna to North America
12. second wawe of European immigrations of elements of the local *Hipparion*-faunae (as *Plesiogulo*, *Agriotherium*, etc.) in North America
13. indicates the dominant invasion of European forms as the first Arvicolids, first Cervids a.o.
14. datum of Elephantid *(Archidiskodon)* and dominant modern Arvicolid invasion to North America from the Holarctica

Table 1. European Late Cenozoic mammal biochronology with correlations

/Explanation of figures in columns No 8 and 16 see at the end of the text/



* With O Fejfar (Prague)

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LIMNIC AND TERRESTRIAL SEDIMENTATION AND THE N/Q BOUNDARY IN THE PANNONIAN BASIN

A. RÓNAI

ABSTRACT

The territory inside the Carpathian mountain arc was tectonically dismembered at the end of the Pliocene. Some parts have subsided at different rates and to different depths, while other parts have been lifted up. As a consequence the morphology of the surface changed profoundly during the Pleistocene and Holocene.

Due to general uplift throughout the whole area, the Pannonian Lake regressed from the basin bottom and the territory became dry land, producing the largest geological change during the 5 mill. years of development of the area.

This is why Hungarian geological literature regards the change from limnic to terrestrial sedimentation as marking the Neogene-Quaternary stratigraphic boundary, an event roughly synchronous with Matuyama-Gauss paleomagnetic reversal (-2.4 mill. y.).

The tectonic movements produced depressions 400-700 m in depth inside the Basin and uplift of 300-400 m in the mountain regions. The limnic-terrestrial stratigraphic boundary is easy to trace in the mountain territories, where fluvial terrace-sediments lie upon Pannonian limnic clays. It is more difficult to demonstrate the boundary in the deep basins, where the change from limnic to terrestrial sediments was repeated several times, due to the oscillation of the water level. Regional morphological uneveness of the surface also produced temporal variations in the start of fluvial sedimentation.

Characteristic are some regions where the transition from limnic to fluvial sedimentation lasted for hundreds of thousands of years. The resulting sediments are variegated clays and silts rich in fossil soil zones and marshy soils. The degree of stratigraphic uncertainty increases in these sections because of the faunal sterility of sediments of 300-400 m thickness.

Paleomagnetic measurements made on cores from two boreholes in the Körös-basin have helped with the determination of suitable chronostratigraphic events on which to attach the stratigraphic divisions of the Quaternary.

GENESIS OF THE SEDIMENTS

The Pannonian basin, which had been inundated during the Miocene by the Pannonian Sea and later in the Pliocene by the Pannonian

Table 1. Lithology and stratigraphy of three representative boreholes

Stratigraphic division		Dévaványa				Vésztő				Jászladány			
		Thickness m	Sand	Silt %	Clay	Thickness m	Sand	Silt %	Clay	Thickness m	Sand	Silt %	Clay
Quaternary		0-420	16	24	60	0-480	20	16	64	0-430	17	26	57
Upper Pliocene		420-680	19	23	58	480-760	18	22	60	430-600	18	20	62
Middle Pl	Upper Pannonian	680-900	16	32	52	760-1010	16	32	52	600-730	34	31	35
Lower Pl		900-1116	15	23	62	1010-1200	11	10	79	730-950	43	23	34

fresh water Lake, became dry land at the end of the Pliocene due to general uplift of the whole Carpathian region. There are regions where the sedimentation has been continuous from the Miocene till the present time and where one can study the unbroken sequence of marine (Miocene), limnic (Pliocene) and fluvial and eolian (Quaternary) deposits.

The change from Pannonian lacustrine to fluvial sedimentation is recognised as marking the Plio-Pleistocene boundary in the geological development of the Pannonian Basin. Nevertheless this change was not everywhere abrupt and there are many sequences hundreds of metres in thickness of half limnic and half terrestrial character. These transitional formations which cause confusion in the stratigraphy, are usually variegated clays divided by many fossil soil horizons and peaty-marshy layers.

There are characteristic differences in the granulometric structure between limnic, fluvial, eolian and solified or eluvial sediments. We can ascribe as eluvial formations the variegated clay beds because they are characterized by solificated deposits and the dense occurrence of fossil soils in the sequence. Granulometric differences help us to detect environmental changes during the sedimentary process and to assess the real stratigraphic boundaries (*Table 1*).

Fluvial sedimentation is characterised by the gradual cyclical variation of the granulometry. The coarse material in the beds becomes gradually finer as one moves through the sequence before coarsering again. Above gravel or coarse sand layers there are fine sands and silts on the top of which fine clays occur. The processes then reversed, the granulometry coarsening in the sediment sequence as the fine clays change through

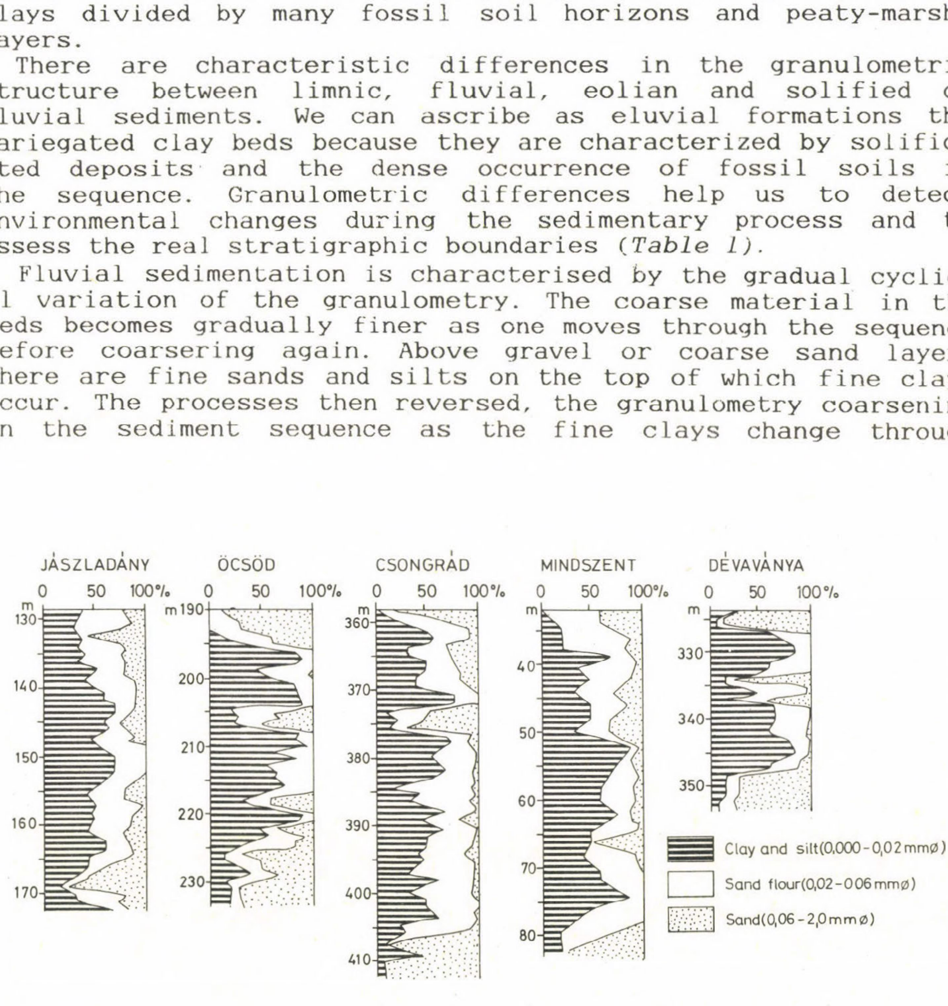

Fig. 1 Examples of fluvial sedimentary cycles

silts and fine sands to coarse sands or gravel. This curve represents a fluvial cycle. The cyclic sedimentation can be explained by the steplike sinking of the basin bottom and by the gradual succession of wet and dry climatic periods *(Fig. 1)*.

The granulometric structure of the limnic sedimentary seqquences is different. Fine grained clays alternate abruptly with coarse sand or gravel separated by sharp boundaries and vice-versa. There are no transitional beds of gradually coarsening or vice-versa *(Fig. 2)*.

Again different is the granulometric composition of the variegated clay beds. They have a mixed granulometry over long sections, with equal proportions of clay, silt and sand fractions. This is characteristic especially of the Upper Pliocene sediments *(Fig. 3)*.

It should be mentioned that there are loess-like sediments not only in the Quaternary but also in the Pliocene. These beds are dominated by sand-flour particle size fraction and

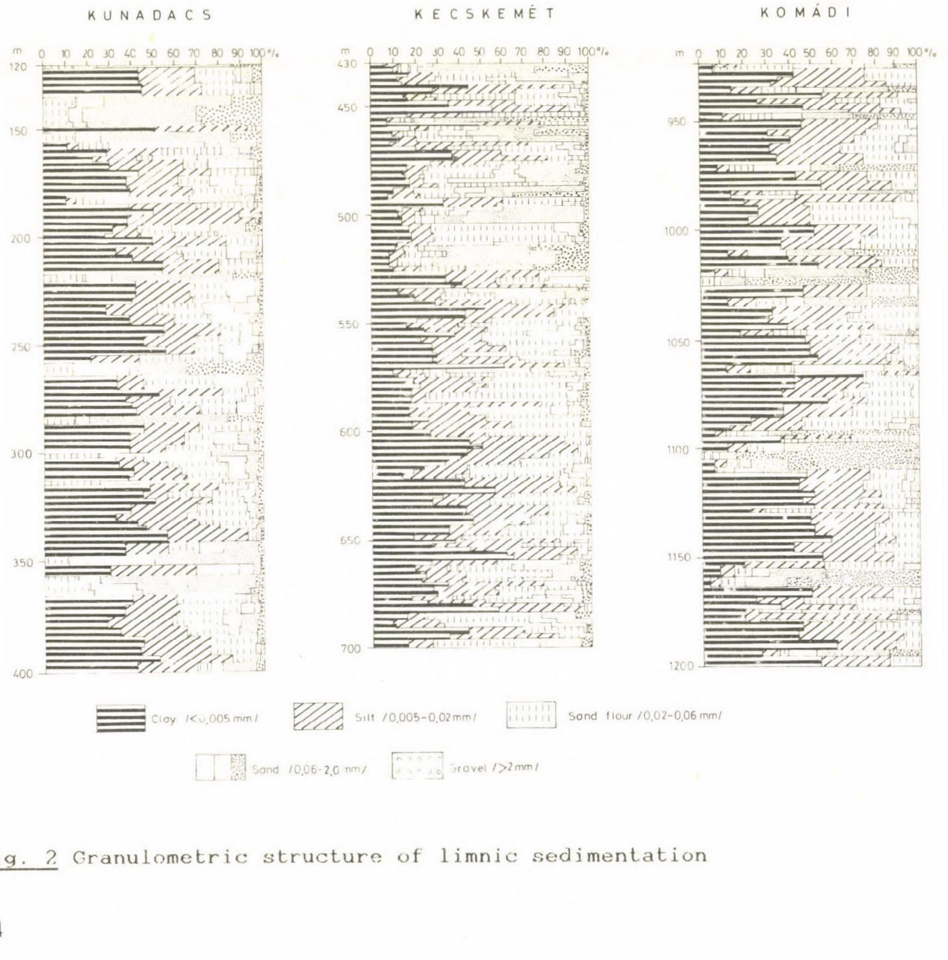

Fig. 2 Granulometric structure of limnic sedimentation

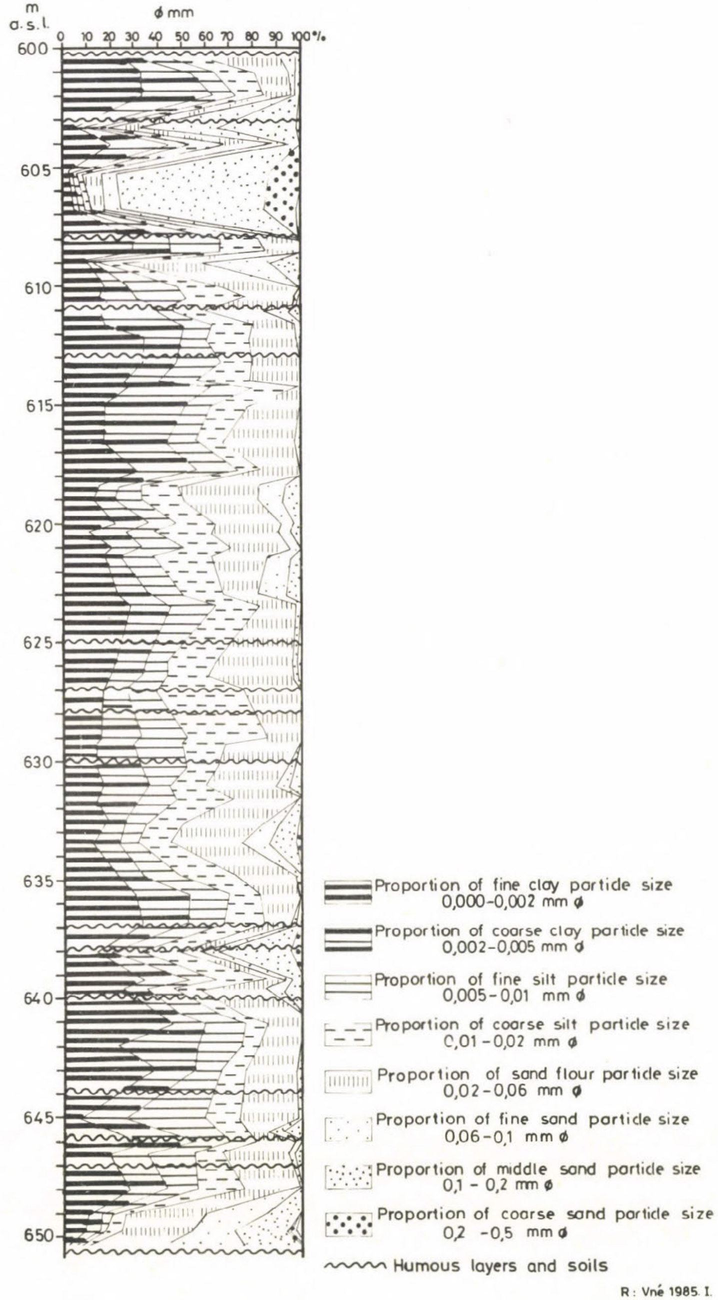

Fig. 3 Characteristically unsorted granulometry of Upper Pliocene terrestrial sediments - Dévaványa borehole

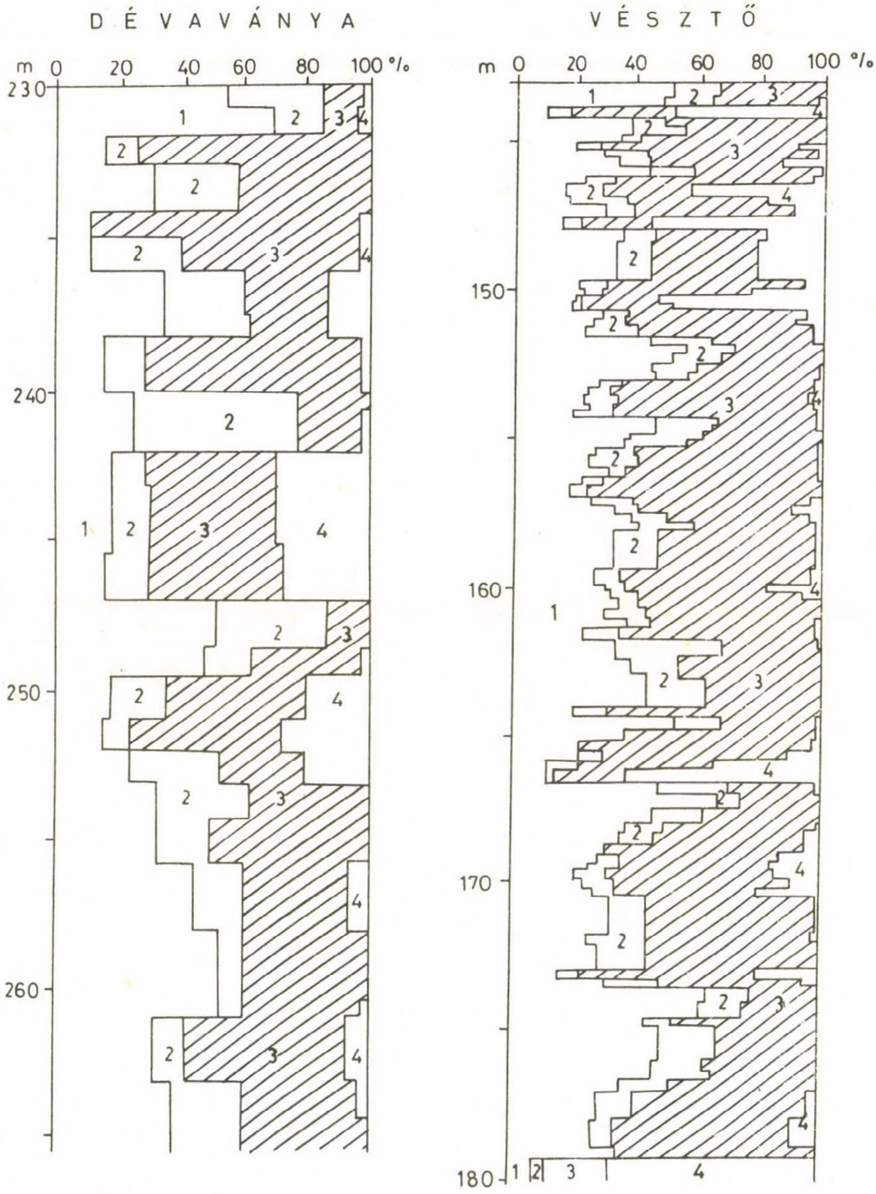

Fig. 4 Loess-like deposits at depth
1 = clay particle size fraction (< 0,005 mm ø)
2 = silt fraction (0,005-0,01 mm ø)
3 = sand flour graines (0,1-0,1 mm ø)
4 = sand fraction (> 0,1 mm ø)

the granulometric frequency curves usually are of symmetrical shape. Loess-like horizons within the Upper Pliocene strata are proof of the dry climate at the top of the Pliocene *(Fig. 4)*.

SEDIMENTATION AND CLIMATIC HISTORY

Ten major Quaternary sedimentary cycles are acknowledged to have occurred in the fluvial sequences of the Hungarian Great Plain where sedimentation was continuous. Although these cycles do not correspond precisely to climatic periods, they can be used for stratigraphic delimitation.

The main dividing zone between the Pliocene and Pleistocene is the dry climatic period occurring during the Uppermost Pliocene in the Pannonian Basin, which corresponds to a faunally sterile section in the borehole cores. The Quaternary set in with a humid period after the dry climate of the top of the Pliocene. The growth of humidity was the big change in the climate and not the drastic lowering of temperature. Such a large change never again occurred in the climate although changes were frequent during the Quaternary *(Fig. 5-6)*.

Abundant pollen finds produced from the core samples of a few boreholes help us to reconstruct the Quaternary climatic history of the Pannonian Basin and 25 distinct climatic periods have been established, the length of which have been calculated on the basis of paleomagnetic measurements *(Fig. 7)*.

In the stratigraphical arrangement of variegated clay sequences the major difficulty is their total sterility in fauna, probably due to numerous environmental changes during sedimentation. The sedimentary load of the rivers, which had very small gradients, was deposited over the huge alluvial plains in shallow water. The flood-plains were desiccated several times and dry and wet surfaces alternated over periods of hundreds to thousands of years, because of the meandering of the river channels over the huge flat surface. During dry periods wind activity also helped in the redeposition of the surface materials. Solification also occurred in dry periods and the uppermost layers have been transformed physically, chemically and biologically. Thereafter the lowlands again became inundated and started a new sedimentary cycle. In some regions the alternation of wet and dry surfaces continued for a million years. The sterility of the variegated clays in fauna can be explained by these circumstances. They also explain the several fossil soil horizons and the different colouration of the solified layers. Redeposition also caused the mixed granulometry of these layers which is their most characteristic mark.

The granulometry and mineralogy of the cores as well as their faunal and palynological content have been analysed in the Hungarian Geological Institute. The Plio-Pleistocene boundary has been found to lie at the top of the section sterile in fauna where the greatest climatic change is also observed. It corresponds to the Matuyama-Gauss paleomagnetic polarity boundary 2.4 million years B.P.

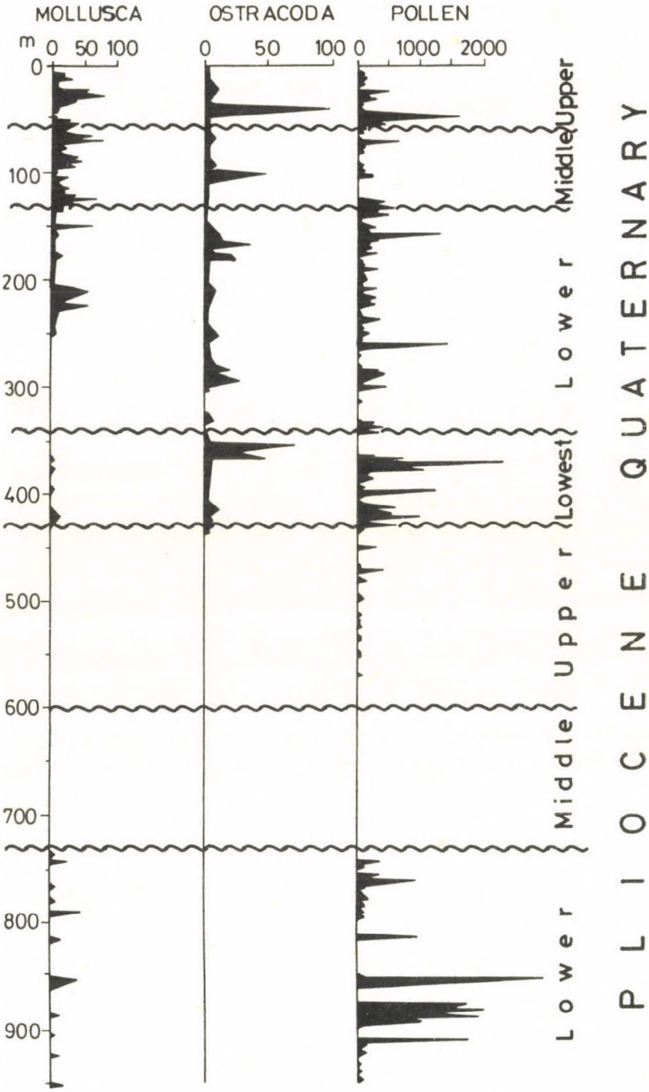

Fig. 5 Number and distribution of paleontologic finds from the borehole at Jászladány (Hungary)

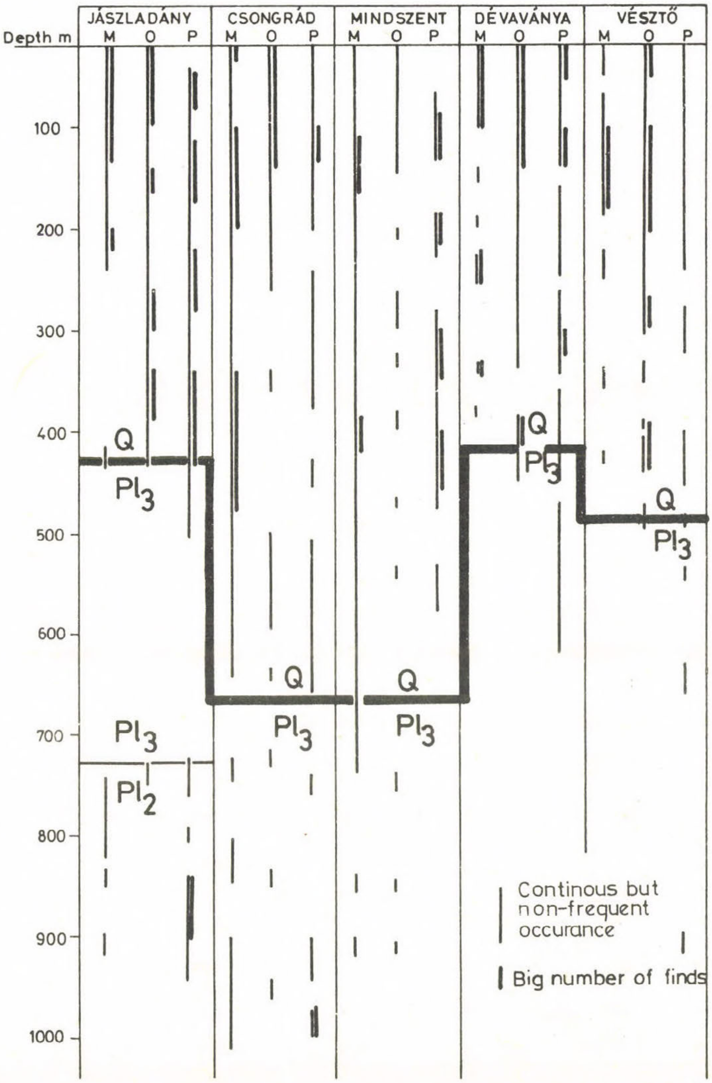

Fig. 6 Frequency of paleontological finds in key-boreholes, Hungary
M = Mollusca; O = Ostracoda; P = Pollen

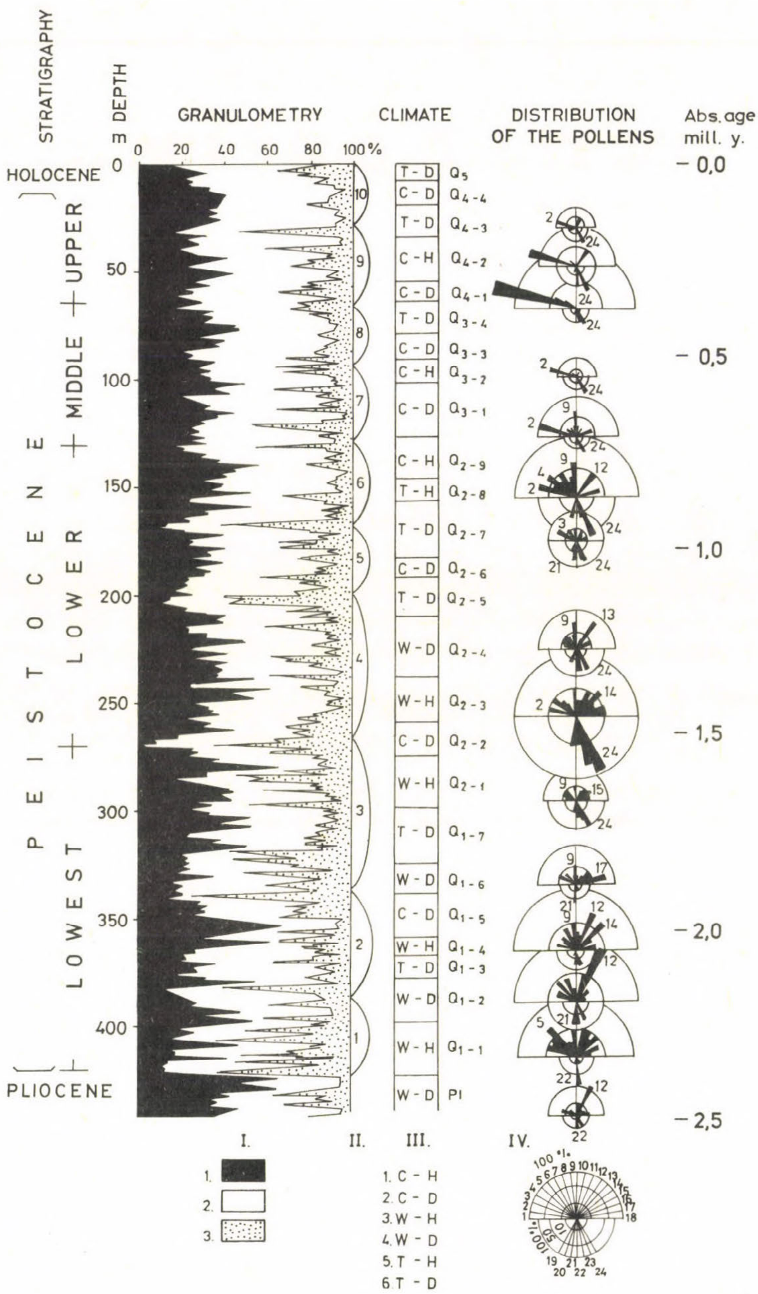

Fig. 7 Quaternary climate and sedimentation in the Hungarian Great Plain. Based upon the Jászladány borehole (A. RÓNAI, 1982)

The most reliable support for establishing the stratigraphic sequence is obtained from paleomagnetic investigations of the sediments. The core samples of two boreholes, each 1200 m in depth have been analysed to assess their paleomagnetic polarity in Halifax, Canada. The laboratory of Dalhousie University with the assistance of Professor H. B. COOKE and J. M. HALL investigated the core samples sent by air mail from Budapest. The samples were generally taken at one metre intervals, although in some sections this was reduced to every 20 cm. The paleomagnetic records that have been produced demonstrate all the polarity changes known from the international paleomagnetic time-scale. The distance between paleomagnetic events, that is the thickness of sediment deposited between two consecutive reversals is regarded as proportionate to the time elapsed between the corresponding two events. It proved that sedimentation was continuous and no significant breaks were observed. The paleomagnetic records of the two boreholes correspond with each other precisely confirming the reliability of the observations. The holes were drilled in 1976 and 1978 at the villages of Dévaványa and Vésztő located 25 km from each other in the Körös depressions in the eastern part of the Hungarian Plain *(Fig. 8, Table 2)*.

The paleomagnetic records produced from these cores have changed considerably the stratigraphic picture of the Pannonian Basin. The polarity changes have been calibrated in terms of absolute age, and have furnished data on the duration of sedimentation and the rate of subsidence. Before these results were known the stratigraphic model of the Pannonian Basin comprised four units: the Lower Pannonian, the Upper Pannonian, the topmost Pliocene or Levantine and the Quaternary. The duration of the Pannonian was estimated at 10-12 million years and was regarded as being of Pliocene age. No reliable data were available about the duration of the inner stratigraphic members of the Quaternary. The paleomagnetic records have shown that Pannonian sedimentation had already started in the Upper Miocene and continued through to the end of the

Fig. 7

I. Granulometry: 1 = Clay silt (<0,01 mm ø); 2 = Sand dust; 3 = Sand (0,1 < mm ø)

II. Sedimentary cycles; III. Climate: 1 = Cold--Humid; 2 = Cold-Dry; 3 = Warm--Humid; 4 = Warm--Dry; 5 = Temperate--Humid; 6 = Temperate--Dry

IV. Pollens: 1 = Pinus cembra; 2 = Pinus silvestris; 3 = Larix; 4 = Picea; 5 = Abies, Tsuga; 6 = Salix, Betula; 7 = Fagus; 8 = Acer; 9 = Quercus; 10 = Carpinus, Tilia, Fraxinus; 11 = Ulmus; 12 = Alnus; 13 = Taxodiaceae, Cupressaceae, 14 = Carya, Pterocarya, Nyssa; 15 = Gingko, Zelkova, Engelhardtia; 16 = Castaneae; 17 = Corylus, Rhus, Ilex; 18 = Cedrus, Palma, Pinus haplax; 19 = Micophyta; 20 = Bryophyta; 21 = Pterydophyta; 22 = Potamogalonaceae, Cyperaceae, Nympheaceae, Typhaceae, Azolla; 23 = Gramineae; 24 = Varia

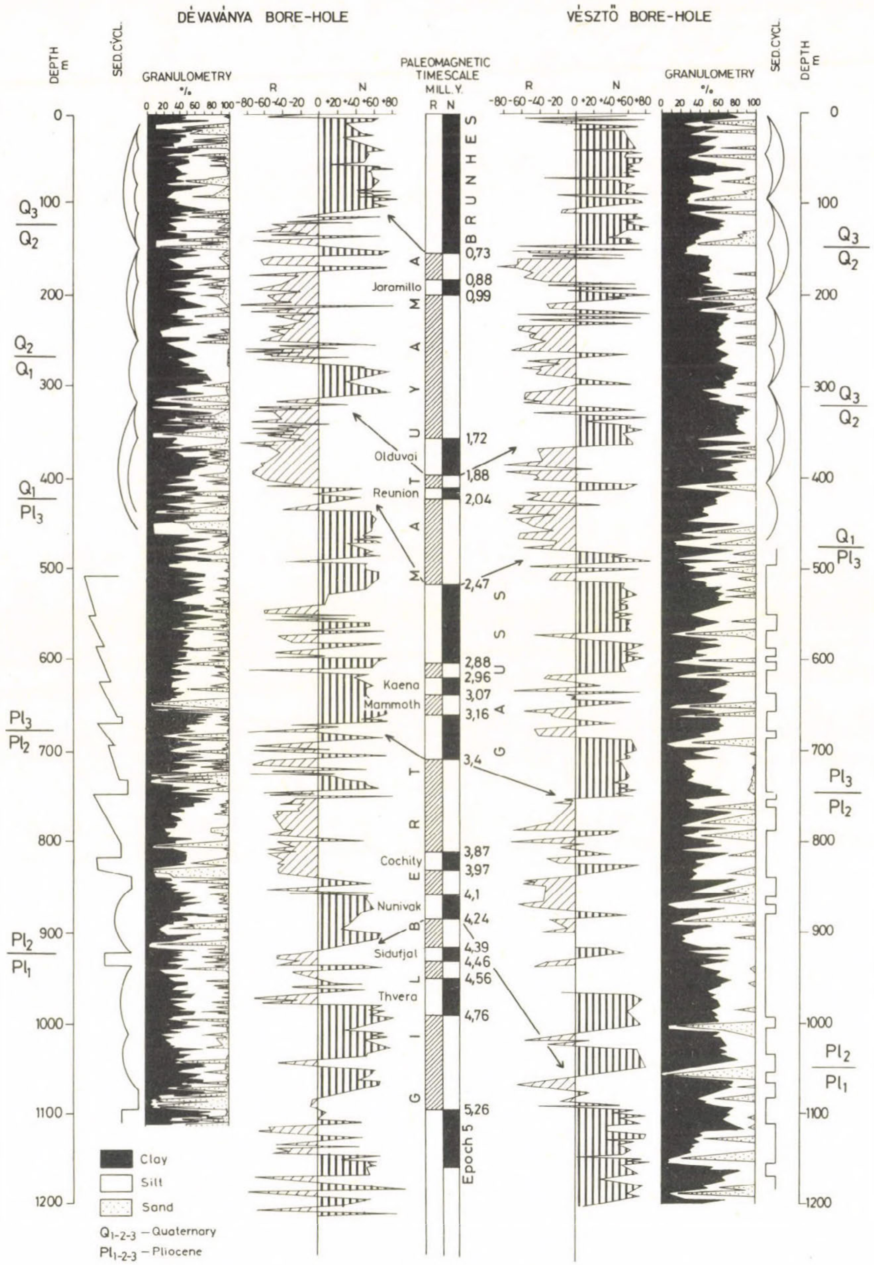

Fig. 8 Quaternary and Pliocene stratigraphy based on paleomagnetic records in Hungary (A. RÓNAI 1984).

Source of paleomagnetic data: H. B. S. COOKE - J. M. HALL - A. RÓNAI: Paleomagnetic Sedimentary, and Climatic Records. Acta Geol. Hung. 1979. Tom. 22. pp. 89-109.

Table 2. Quaternary and Pliocene stratigraphy of the representative boreholes

Name	Age mill.y.	Paleomagnetic event	Dévaványa m	Vésztő m	Jászladány m
Upper Pleistocene cca	0,3	Brunhes upper part	80	100	80
Middle Pleistocene	0,7	Brunhes lower part	120	140	130
Lower Pleistocene	1,7	End of Olduvai event	270	320	270
Lowest Pleistocene	2,4	Matuyama-Gauss bound.	420	480	430
Upper Pliocene	3,4	Gauss normal epoch	680	760	600
Middle Pliocene	4,2	Cochity-Nunivak event	900	1010	730
Lower Pliocene	5,3	Gilbert-Epoch 5. bound.	.	.	.

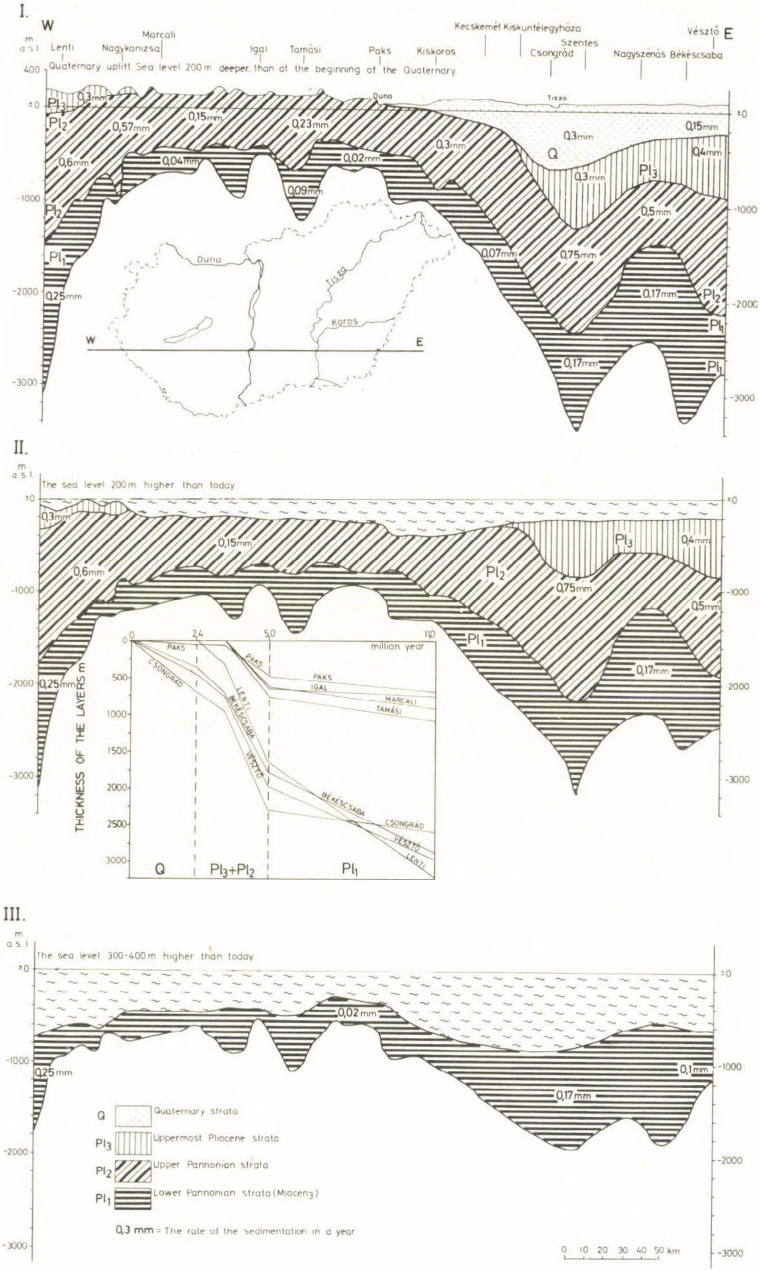

Fig. 9 The development of the Pannonian Basin (A. RÓNAI 1984)

I. The last period of the development. The Quaternary (-2.4 m.y. to present)

II. Development during the Pliocene (-5.3 to -2.4 m.y.)

III. Development during the Lower Pannonian (Miocene) (-11 to -5.3 m.y.)

Pliocene. The duration of the Quaternary has been quantified; the Levantine and Upper Pannonian sediments have been incorporated in the Pliocene, and the Lower Pannonian has been placed in the Miocene.

Modern division and designation			Former division and designation	
Q	Quaternary	0-2.4 mill. y.	Quaternary	Q
Pl_3	Upper Pliocene	2.4-3.4 mill. y.	Levantine	Pl_3
Pl_2	Middle Pliocene	3.4-4.2 mill. y.	Upper Pannonian	Pl_2
Pl_1	Lower Pliocene	4.2-5.3 mill. y.		
M_3	Upper Miocene	5.3-11.0 mill. y.	Lower Pannonian	Pl_1

The annexed *Figure 9.* shows the development of the Pannonian Basin as reflected in the Hungarian literature. The section runs from W to E in the lower part of the Pannonian Basin. The upper section shows the present situation, the second section refers to the beginning of the Pliocene, while the third section shows sedimentation during the Lower Pannonian, which is now placed in the Miocene.

The greatest depths are found east of the Tisza valley, where the Lower Pannonian horizons are conglomerates, sandstones marls and clays, the Upper Pannonian strata densely alternating sands and clays, and the Quaternary sequences fluvial and eolian clays, silts, sands, and occasionally gravels.

THE NEW STRATIGRAPHY

Based on the paleomagnetic records supported by faunal, palynologial and climatic factors, the stratigraphic division of the cores taken from the Dévaványa and Vésztő boreholes is presented in *Table 1.* Beside the two boreholes investigated paleomagnetically the table contains data from the borehole at Jászladány, which was extraordinarily rich in pollen finds.

The Upper Pliocene (Levantine) substage corresponds to the Gauss paleomagnetic epoch (2.4-3.4 mill.y.) with normal polarity. The Middle Pliocene includes the upper part of the Gilbert reversed paleomagnetic epoch up to the Cochity-Nunivak events (3.9-4.2 mill.y). The Lower Pliocene represents the lower part of the Gilbert paleomagnetic epoch with reversed polarity as far as the Gilbert Epoch 5. paleomagnetic boundary (5.3 mill.y.).

The Upper and Middle Pliocene periods correspond in many boreholes to the sections sterile in fauna, and also to the variegated clay sequences, though there are exceptions, e.g. in the Körös Basin where the variegated clays already appearing in the Quaternary and occur as far back as the beginning of the Miocene.

Paleomagnetic records have also been used for determining the internal stratigraphic boundaries of the Quaternary. The international literature has also recently used paleomagnetic events for dating the Quaternary sequence. The stratigraphic divisions based on the most important boreholes is to be found in *Table 2*.

The Pliocene which is estimated to have lasted for 2 mill.y. can be divided into two parts. From 2.4 to 3.4 mill.y. during the Gauss normal paleomagnetic epoch, it was marked by the deposition of clays with a few, thin sand intercalations. This is the poorest sedimentary sequence in water. The first half of the Pliocene (3.4 - 4.4 mill.y.) shows a fluctuating sedimentation which was of cyclic character in some places.

The main stratigraphic bodies show a good correlation with the mineral composition of the fluvial and lacustrine sandy horizons. The Neogene-Quaternary boundary is easy to find in the mineralogical records. The stratigraphic division is also reflected in the climatic changes and the tectonic movements that occurred. The block-like uplift of the mountain areas, which was intensive during the Quaternary, modified the catchment area of the rivers, whose load also changed as a consequence as different rocks were eroded *(Figs. 10-11.)*.

More homogeneous are the mineralogical spectra of the limnic sediments. Between the fluvial and limnic layers, the half limnic and half fluvial or terrestrial sediments show a rather uniform mineralogical character. In these sections the transformation, metamorphism, meteorisation, and erosion of the minerals play a large role.

In order to reconstruct the environmental conditions during sedimentation it is both interesting and instructive to investigate the $CaCO_3$ content of the various horizons. The fluvial and eolian deposits of Quaternary age are generally rich in lime content and the same holds for the Pannonian lake sediments. Pliocene terrestrial sediments, by contrast, especially the variegated clays, are in most cases poor in $CaCO_3$. The lime content of the cores from the interfluvial region of the Danube and Tisza is strikingly different from those coming from the Trans-Tisza region, the former being very rich and the latter very poor in lime content. The denudated rocks to the west of the Pannonian Basin are mostly limestones, whereas the rocks of Transylvania to the east of the Basin are of volcanic and metamorphic origin *(Figs. 12 - 13)*. Nevertheless, what small lime content there is, diminishes strikingly in the Upper Pliocene sequences of the Trans-Tisza region.

Paleomagnetic measurements and data on absolute age enable us to evaluate the speed of subsidence in the basin and the sedimentation *(Fig. 14)*. The sedimentation rate varies throughout the basin. The rate found in the Dévaványa and Vésztő boreholes is characteristic of those parts infilled with fine

Fig. 10 Distribution of minerals in the bore-cores

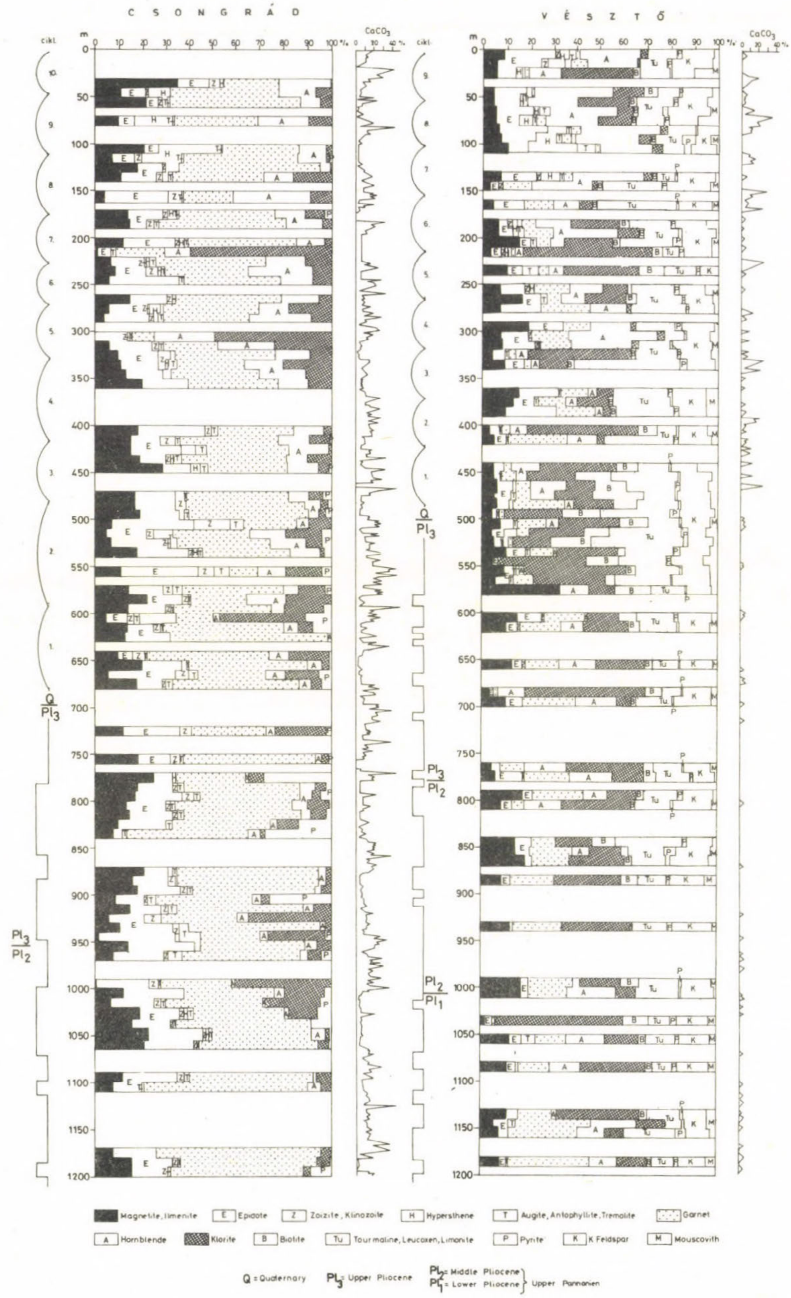

Fig. 11 Distribution of minerals in the bore-cores

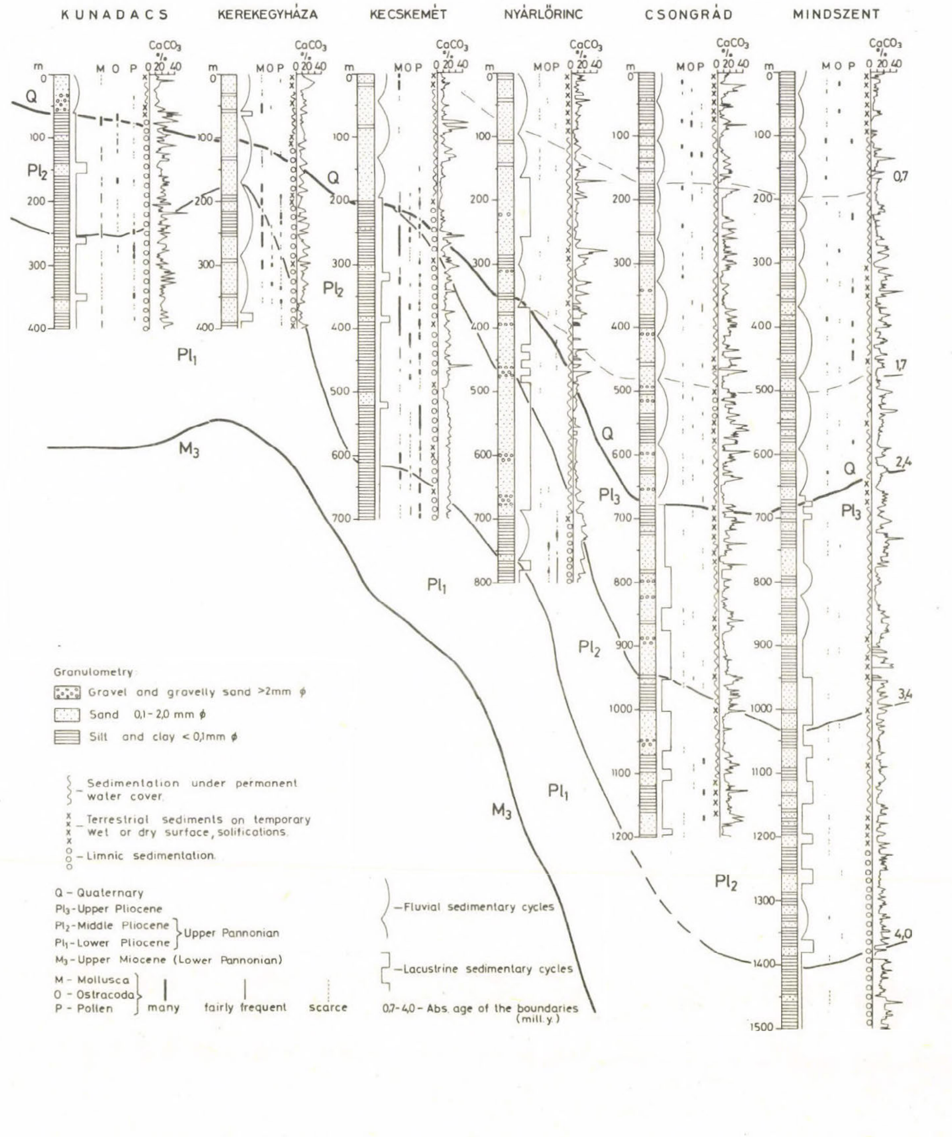

Fig. 12 Geological drilling profiles between the Danube and Tisza rivers, Hungary (A. RÓNAI 1985)

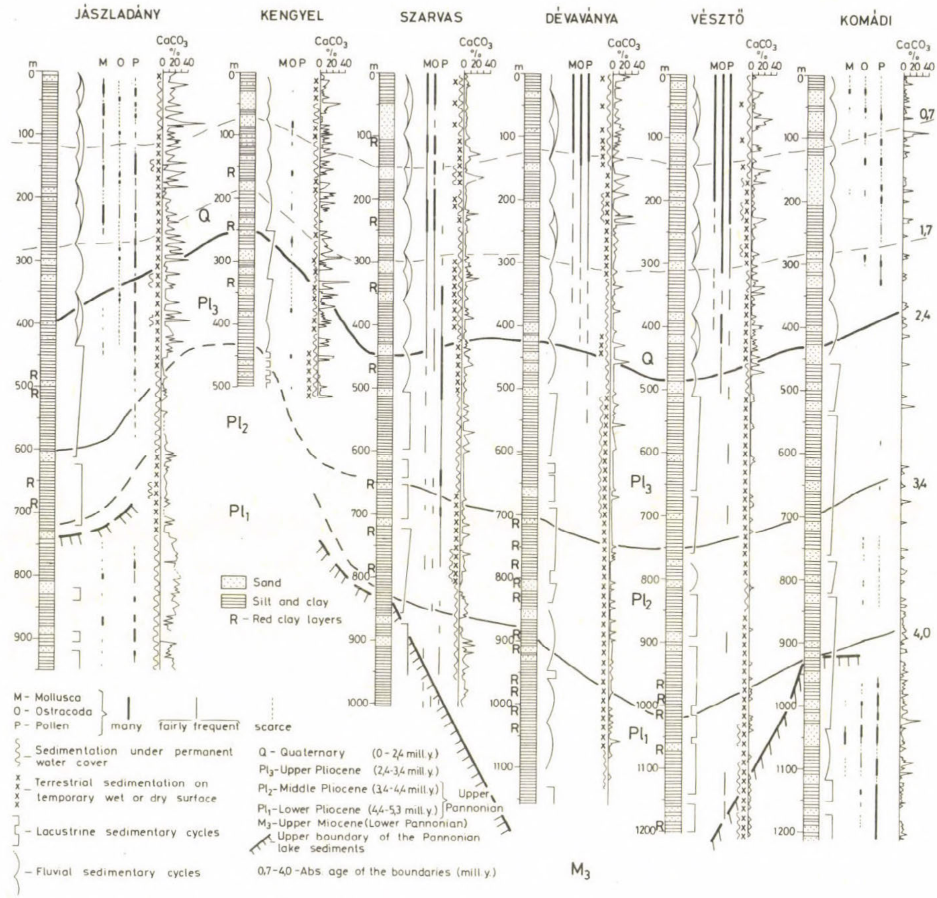

Fig. 13 Comparative profiles of the bore-holes in local depressions filled with fine grained sediments (Comp. by A. RÓNAI 1985)

grained sediments. In local basins where sediments are coarse grained the sedimentation rate was higher. In calculating the speed of subsidence we have to be aware, that the sinking process was not continuous in all parts of the Basin. It was continuous in the Körös Basin in the eastern part, in the Jászság in the northern part and in the southern section of the Tisza river. The first two local basins were filled with fine grained clays and silts, whereas the third basin was mostly filled with coarse sand and gravel *(Fig. 15)*.

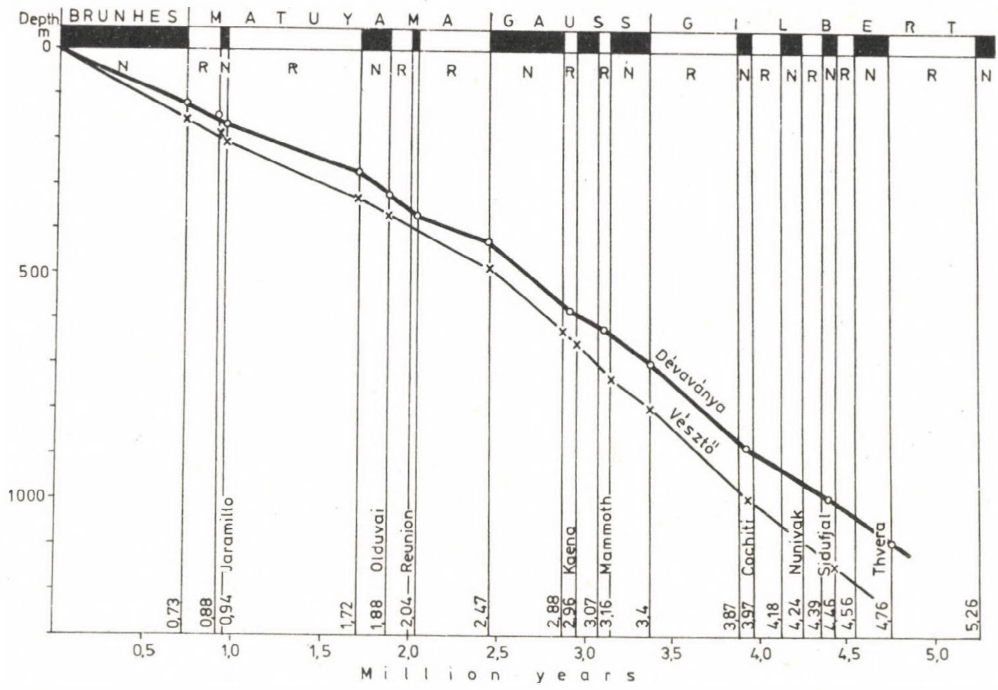

Fig. 14 The rate of sedimentation in the Körös Basin, Hungary (A. RÓNAI 1980)

A general view of the magnitude of the Quaternary movement and as a consequence of the thickness of Quaternary deposition is given in *Figure 16.* It shows that Quaternary subsidence was patchy with deep kettles developing in the subsiding basin bottom *(Fig. 16).*

Analysing the granulometry and the genesis of the sediments, one can find among the clearly lacustrine, fluvial, and eolian horizons others of genetically uncertain origin. These are mostly associated with the cores in those depth-sections where the Plio-Pleistocene boundary was to be waited. These genetically transitional sediments consisting mostly of clays and silts are of considerable thickness in the middle part of the Great Plain. Thin sand layers are included within them. They are densely stratified and divided by many fossil soil strata, and have a very mixed - unsorted - granulometry. The colour of the layers is grey with brown and red spots, or yellow with dark red-brown, red, purplish-red and dark grey or black, marshy fossil soils.

It is from this colouration that the name "variegated clay" originates *(Fig. 17).*

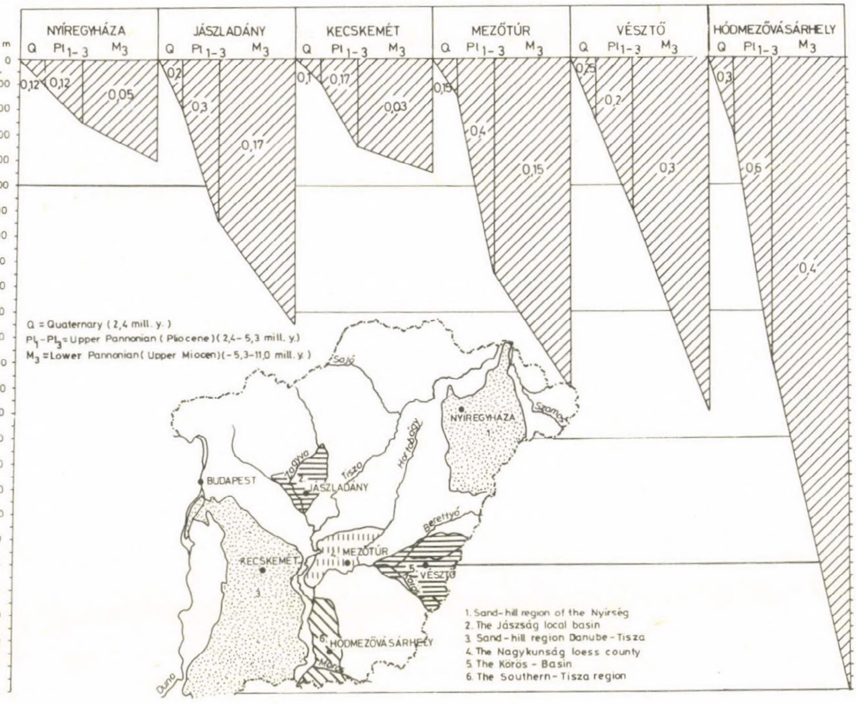

Fig. 15 Degree of Quaternary--Pliocene--Miocene subsidence in the Hungarian Great Plain

Fig. 16 Thickness of Quaternary deposits (m) (A. RÓNAI 1982)

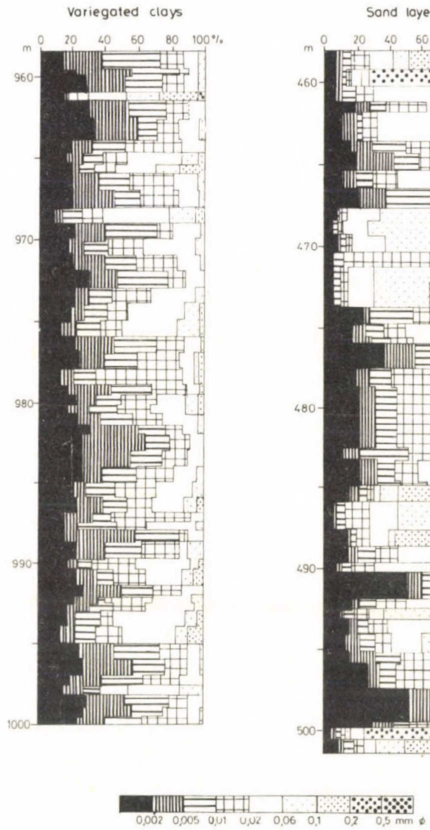

Fig. 17 Characteristic unsorted granulometry of Upper Pliocene terrestrial sediments (Dévaványa)

A DETAILED W-E GEOLOGICAL SECTION ACROSS THE GREAT PLAIN

It is worth studying the particular conditions of sedimentation along a W-E geological section, starting at the Danube, crossing the Danube-Tisza interfluve traverses the Trans-Tisza region, and ending at the Roumanian border close to the Transylvanian mountains. Between Komádi and Vésztő lies a characteristic

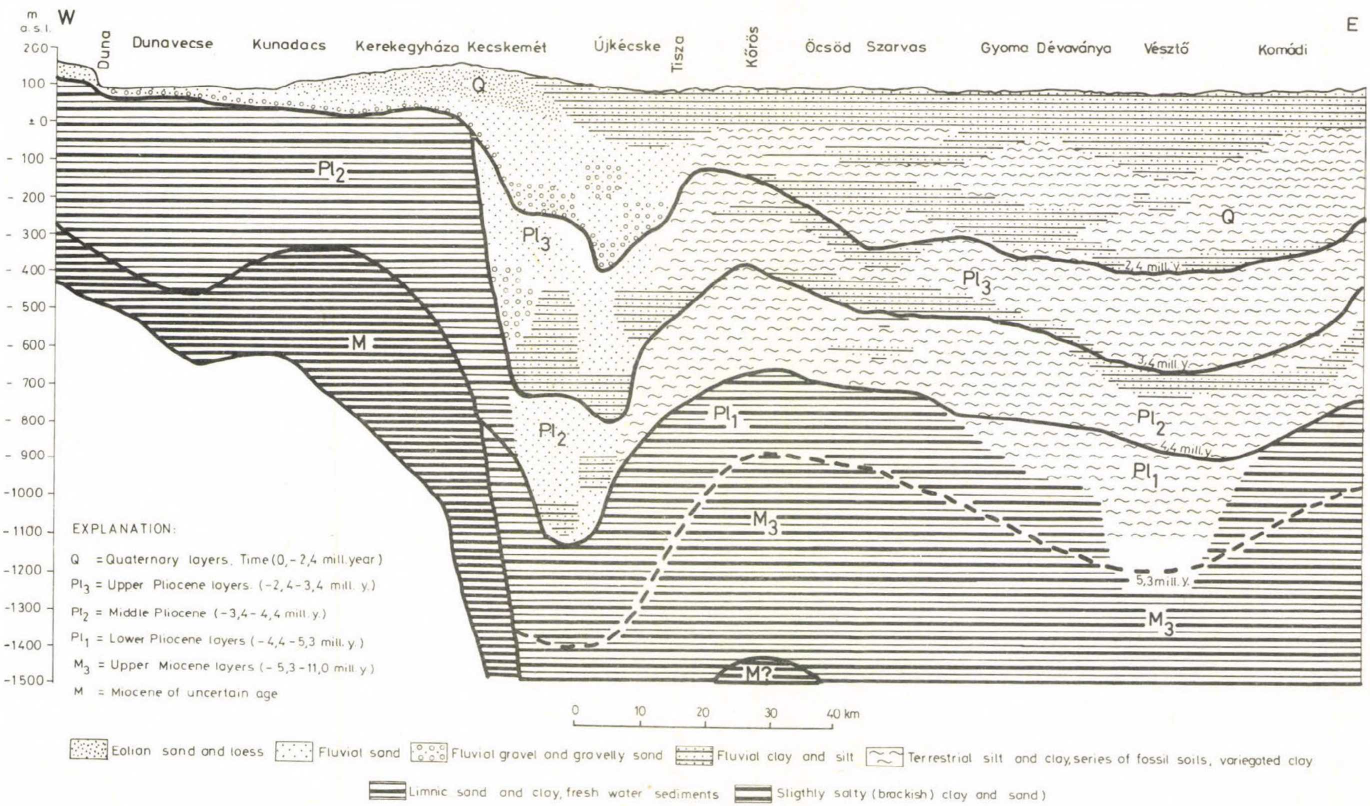

Fig. 18 Stratigraphical and lithological section across the Hungarian Great Plain

New stratigraphy (A. RÓNAI 1985)

"foredeep" to the west of the Transylvanian mountains. The section demonstrates the important tectonic line along which the eastern part of the Great Plain subsided. The Miocene, Pliocene and Quaternary stratigraphy is rather clear and simple in the western part of the section; and the problem with the limnic, fluviatile, eolian and eluvial sedimentation occurs in the eastern part of the depression.

Along this tectonic line the ancient Danube cut a deep corridor into lacustrine Pannonian (Pliocene) deposits. The corridor was filled mostly with fluvial sands and gravel during the Upper Pliocene and Quaternary. Some detrital material accumulated during the Upper Pannonian (Middle Pliocene Pl_2) at the foot of the lacustrine sedimentary wall. Eastward from the Tisza valley the lacustrine sequence of clays and sands has an uneven surface. The deepest trough developed - as a circular foredeep - in the region of Vésztő, which is still active (*Fig. 18*).

Subsidence proceeded over the plain at a generally uniform rate. Fluvial sediments were alternatively deposited into shallow alluvial lakes, as well as on dry land. In the later case solification started on the surface and several series of soil horizons developed. Genetically these are eluvial sediments because of physical, chemical, biological and structural changes brought about by the solification processes. Under shallow water conditions marshes, peats and marshy soils developed. Wet and dry conditions alternated over large and short periods even seasonally.

CONCLUSION

Based upon scientific geological borehole data and the utilization of artesian water and oil exploration findings, we are able to reconstruct the geological history of the Pannonian basin. Most interesting is the sedimentological development of the great Hungarian Plain in the Pliocene and Quaternary. This extensive Basin is filled with Miocene, Pliocene and Quaternary consolidated sediments. Faunal and palynological evidence is usually insufficient for stratigraphic division and the reconstruction of its geological development is faced with several obstacles. There are extensive areas of the Great Hungarian Plain where the Tertiary lacustrine and Quaternary fluviatile sediments cannot be easily separated from each other. There are many hundreds of metres of transitional sediments deposited under alternating water and dry conditions. Moreover the environment has been transformed continuously due to climatic and tectonic changes. All of these plus the effect of repeated solification processes have produced a characteristic sediment formation many hundreds of metres in thickness which are genetically described as eluvial formations.

Recent investigations show that Pliocene limnic sediments are present on the actual surface in many parts of the Pannonian Basin, while Pliocene fluviatile sediments are present on the periphery and sporadically in some of the deeper parts of the Basin. Pliocene and Quaternary eluvial and transitional sediments reach a thickness of 300–1000 m in the middle of the Great Plain, where in Pliocene limnic sediments are only reached at depths of more than one thousand m.

The Quaternary is represented by fluviatile, eolian and eluvial sediments, which achieve a thickness of 50-70 m in the mountain areas, 100-300 m in the Little Plain and 100-700 m in the Great Plain. The Quaternary stratigraphy has been elucidated with the use of paleomagnetic measurements.

The subsidence of the Pliocene and Quaternary depressions and the rate of the accumulation varied throughout the Pannonian Basin. There were regions, where the subsidence was continuous achieving an average rate of 0.2-0.3 mm per year during the Pliocene and the Quaternary. Nevertheless a slight deceleration in the rate of subsidence and in the accumulation of the sediments can be observed from the beginning of the Pannonian. It is also characteristic that in some of the depressions of the Great Plain, subsidence displayed a pulsating movement during the Pliocene and the Quaternary.

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NEOGENE-QUATERNARY GEOMORPHOLOGICAL SURFACES* IN THE HUNGARIAN MOUNTAINS

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ABSTRACT

The Neogene-Quaternary geomorphological surfaces in the Hungarian Mountains represent the various stages of relief evolution. The paper comprises the achievements of research into the chronological sequence of the particular surfaces which is summarized in Tables 1, 2. For the dating of the geomorphological surfaces, besides classic methods, the techniques of absolute chronology are applied on ever wider scale. The research project has been carried out in the cooperation of Hungarian and foreign experts during the last two decades. The Neogene/Quatenary boundary is placed between the river terraces Nos VI and VII.

* * *

On the occasion of the VIIIth Neogene Congress not accidentally organized in Hungary it is appropriate to discuss the recent results achieved in the denudation chronology of geomorphological surfaces.

As is widely appreciated, in the reconstruction of relief evolution the analysis and identification of geomorphological surfaces is an important tool. One is also aware of the differences of opinion both in the Hungarian and international literature concerning the age of the boundary between the Tertiary and the Quaternary. There is much variation in the criteria used for this delimination. A recent tendency has been observed to establish this boundary at some absolute chronological date such as the boundary of a paleomagnetic epoch or event, although this only seems appropriate if no other geological change can be detected. At any rate, it is a fact that different authors give widely varying age in absolute terms to the Tertiary/Quaternary boundary (0.7-0.9; 1.8-2.4 or 3 MA),

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* peneplain, erosional surface, pediment, raised beaches (marine terraces), river terraces

in spite of the proposals of some international commissions to fix this date between 1.6 and 1.8 MA. As a matter of course, a geologist attempts to correlate the N/Q boundary with some change in Earth history and paleogeography and, for the purpose of global correlation, seeks absolute chronological dates to support this chronological interpretation.

GEOMORPHOLOGICAL SURFACES AND DENUDATION CHRONOLOGY

In our approach to search for N/Q boundary we have applied a wide range of methods in denudation chronology in an attempt to determine which geomorphological surfaces in Hungary should be referred to the Neogene and which to the Quaternary.
However, the highest geomorphological surfaces were noted necessarily the oldest in each geological period. Along the margins of some mountains or along some valley sides previously formed surfaces of fluvial or marine origin (e.g. old terraces) were subsequently displaced by tectonic movements and even locally buried in areas subject to intermittent or permanent subsidence. It is also common that some surfaces buried before and during the Neogene have subsequently been partly or totally exhumed.

Table 1. Geomorphological surfaces in the Hungarian Mountains (PÉCSI, M. 1985)

I. REMNANTS OF OLD EROSION SURFACES
1. Remnants of Mesozoic peneplains with tower karst
   - buried under Eocene limestone (at Gánt in the Vértes Mountains; at Nyirád in the Bakony Mountains)
   - buried under Oligocene sandstone (on Hárshegy, in the Buda Mountains)
   - remnants of an exhumed peneplain in summit position (in the Keszthely Mountains; at Tés in the Bakony Mountains)
2. Remnants of Paleogene (and mostly Mesozoic) peneplains resculptured by Oligo-Miocene pedimentation
   - with a thick Miocene gravel in summit position (at Farkasgyepü in the Bakony Mountains)
   - with patches of Miocene gravel in a summit position (on Öregkovács and Peskő in the Gerecse Mountains)

II. REMNANTS OF NEOGENE EROSION SURFACES
1. Miocene raised beaches
   - Surface with Karpatian conglomerate (along the northern foreland of the Bakony Mountains)
   - Surface with Badenian littoral sandy-gravelly limestone (in the Visegrád and Börzsöny Mountains)
   - Sarmatian raised beach (in the Buda Mountains and Balaton Uplands)
   - Sarmatian pediment (in the Mátra and Zemplén Mountains)
2. Pannonian (Upper Miocene) raised beaches and travertine horizons
   - Lower Pannonian (Monacian*) raised beach (at Diósd-Sóskút in the Buda Mountains and in the Balaton Uplands)

- delta deposits (Precsákvárian-Csákvárian*; the "Billege" and "Kálla" gravels in the Balaton Uplands)
- Upper Pannonian (Csákvárian) raised beach - two surfaces (?) (in the Bakony, Vértes and Buda Mountains)
- Upper Pannonian (Csákvárian-Sümegian*-Baltavárian) travertine occuring on two or three surfaces (Nos 10-12) (at Nagyvázsony, Szentkirályszabadja and Várpalota in the Bakony Mountains; on Széchenyi-hegy and Szabadság-hegy in the Buda Mountains; on Újhegy and Kőhegy in the Gerecse Mountains)
- Upper Pannonian-Pliocene deltaic gravels (on Kőpite in the Gerecse Mountains)
- Upper Pannonian-Pliocene basalt lava on pediment (subdivided into two levels?) (as on Kabhegy and Somló, and Somhegy at Pula)

3. <u>Pliocene pediments and travertines</u>
   - Pliocene pediment (Baltavárian-Csarnótan*) locally lowers down and forms a double surface (between 360 and 220 metres above sea level along the margins of the Transdanubian Mountains)
   - Pliocene (Ruscinian*-Csarnótan) travertine horizons lying on pediment (Nos 8 and 9; in the Buda Mountains; on Kőpite and Haraszt-hill at Süttő in the Gerecse Mountains)
4. <u>Upper Pliocene (Ruscinian-Csarnótan-Lower Villányian*) gravel mantles, old alluvial fans and travertine horizons</u>
   - the Kemeneshát—Ezüst-hegy—Kandikó gravel sheet
   - terrace No VIII and travertine No 8 (in the Danube Bend Mountains)
   - terrace No VII and travertine No 7 (Lower Villányian residual terrace hills of the Kemeneshát)

III. QUATERNARY FLUVIAL TERRACES, ALLUVIAL FAN TERRACES AND TRAVERTINE HORIZONS
   - terrace No VI and travertine No 6 (Upper Villányian-Kislángian*)
   - terrace No V (Kislángian-Lower Biharian*) and travertine No 5 (Middle Biharian /?/, of reverse polarity)
   - terrace No IV (Middle Biharian, Vértesszőlős phase) and t·avertine cover (Vértesszőlős phase, > 350 KA), terrace deposits and travertine are of normal polarity
   - terrace No IIIa and travertine No 3a (270 KA) (in the W. Gerecse Mountains)
   - terrace No IIb (R-W-W_1) with travertine cover (120 to 70 KA old)
   - terrace No IIa (W_3), cca 26 to 12 KA
   - flood-plain No I and Holocene travertine No 1, from cca 11 KA to present

GEOMORPHOLOGICAL SURFACES OLDER THAN THE NEOGENE

Much circumspection is needed when studying older geomorphological surfaces. As PÉCSi (1970, 1984) already has argued the Mesozoic horsts of the Transdanubian Mountains with tropical

* KRETZOI, M.-PÉCSI, M. 1982, Table 1

paleokarst forms (tower karst with bauxite) on their surface and covered by thin Upper Cretaceous, Eocene and locally Oligocene deposits, are to be considered remnants of the Mesozoic tropical peneplain. This erosion surface, as a fundamental morphogenetic unit existed as early as the Middle Cretaceous and was not subject to any major transformation during subsequent, primarily Tertiary, burial and partial or complete exhumation induced by slight uplift. It was therefore mainly during the tectonic movements of the Neogene and the Quaternary that varyed locally in intensity, that this Cretaceous erosion surface was elevated to varying heights.[1] The Transdanubian Mountains, at least, lay under a thick sedimentary cover during most of the Oligocene and early Miocene, and the general processes of peneplanation could not therefore have operated on these mountains during this period.

Tertiary erosional-planational surfaces are usually marginal surfaces arranged in a step-like fashion. Along the whole range of the Hungarian Mountains, Neogene raised beaches and marginal pediments dominate, and traces of similar marginal surfaces formed during the Eocene and Oligocene only locally occur.

NEOGENE RAISED BEACHES AND PEDIMENTS

Previous investigations have revealed well-developed Neogene raised beaches dating from the Middle Miocene (Karpatian, Badenian and Sarmatian stages) *(Table 1)*. Along the margins of certain Neogene volcanic members of the Hungarian Mountain Range pediment remnants formed during the Sarmatian have also been found (SZÉKELY, A. 1970, PINCZÉS, Z. 1970). Associated with the andesite volcanic mountains of Danube Bend, also in a marginal position, the Badenian raised beach of 400 to 500 m a.s.l. is accompanied by gravelly limestone.

Raised beaches of Pannonian (Upper Miocene) age are generally represented by two or three geomorphological surfaces again in a marginal position around the horsts of the Transdanubian Mountains. In addition, at least two gravelly deltaic formations of various age have been identified.

These various geomorphological surfaces, however, are found at different elevations regionally as a result of the varying rates of tectonic movement during the late Neogene and early Quaternary. It is also a particular feature that the remnants of Sarmatian and locally of Lower Pannonian raised beaches occur at lower elevations than those of Upper Pannonian age (as is the Buda Moutains, *Fig. 1*).

Moreover, the Neogene raised beaches in the Transdanubian Mountains are in lower positions than the summit horsts with paleokarsts. In some cases however, the Pannonian raised beach

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[1] BULLA, B. (1958, 1962) interpreted these exhumed, step-like Mesozoic horst surfaces as peneplains formed during the Neogene and earlier under conditions of tropical peneplanation.

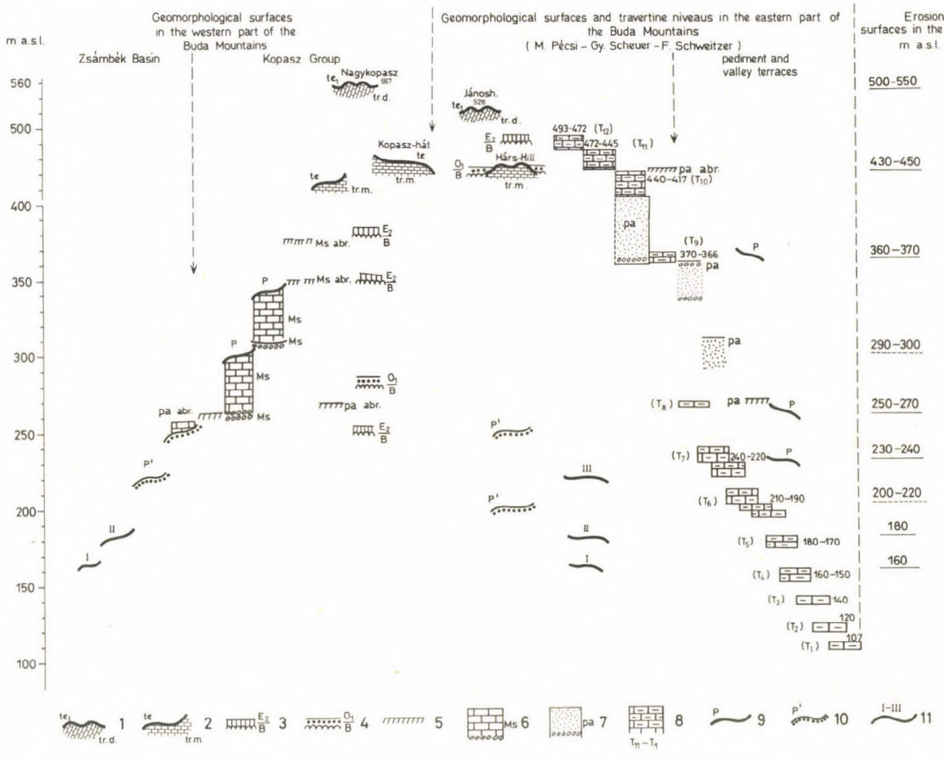

Fig. 1 Geomorphological surfaces in the Buda Mountains (PÉCSI, M. 1980 - based on data by PÉCSI, M. 1963, 1975; SCHEUER, Gy. - SCHWEITZER, F. 1974; WEIN, Gy. 1977). - 1 = exhumed Mesozoic peneplain in summit position (te_1) on Upper Triassic dolomite (tr.d.), 2 = remnants of exhumed Mesozoic peneplain (te) on Upper Triassic 'Dachstein' limestone (tr.m.) 3 = buried Mesozoic peneplain, remains of tropical karst and bauxite under Eocene limestone (E_2/B) 4 = buried Mesozoic peneplain, bauxite and tropical tower karst under Oligocene sandstone (O_1/B) 5 = raised beach, 6 = Miocene (Sarmatian) gravel and coarse-grained limestone (Ms/s) 7 = Pannonian (pa) gravel, sand and clay, 8 = travertine horizons (T_{12} -T_1), 9 = Pliocene pediment (P) on solid rock, 10 = Pliocene pediment on unconsolidated deposits (pl), 11 = Pleistocene derasion terraces, tall and gentle slope segments on unconsolidated deposits

and overlying travertine of roughly the same age is found on horsts uplifted to 400 to 500 metres a.s.l. height which were buried during the Paleogene (e.g. on the Széchenyi- and Szabadság-hills in the Buda Mountains). Nor is it uncommon to find (Upper) Pannonian travertine deposits on the surface of the Mesozoic peneplain occurring of around 300 metres above sea level on the margins of the Balaton Uplands.

Subsequent to the formation of the last Pannonian raised beach that resulted from general uplift and the regression of the Pannonian sea, the wide foreland zone of the Hungarian Mountains was also elevated.[2]

In this zone composed mostly of Pannonian deposits or covered by them[3] a piedmont erosion surface began to form as early as the late Neogene (Pliocene). This phase of *pedimentation* was prolonged since the proper climatic and tectonic conditions for this process prevailed.

Even during the initial stage of pedimentation the (Upper) Pannonian strata were substantially eroded, while a subsequent phase of temporary stability led to the formation of true red clays, which form a unique index horizon in the Neogene. During the climax of red clay formation another intensive subsidence of the basin and uplift of the marginal mountains may have taken place, which resulted in the dissection of the pediment covered by red clay into interfluvial ridges and which are now only preserved in patches. Subsequently, late Neogene pedimentation continued at a lower elevation (see *Tables 1* and *2* and PÉCSI, M. 1985: Fig. 3, in this volume).

During the formation of the late Neogene higher pediment, before and during the deposition of the red clay, the major streams flowing from the Alpine-Carpathian mountains built up enormous alluvial fans around the basin margins (Ruscinian-Csarnótan stage).

Although basaltic volcanism in the Hungarian Mountains began in the Upper Pannonian, the tuffs and lavas from several eruptions cover the late Neogene high and low pediments and even the alluvial fans. Indeed the superficial products of basaltic volcanism which lasted for many millions of years overlie geomorphological surfaces which are now at various altitude and display different degrees of dissection.

The Pliocene initial high pediment was a gently sloping surface even during its formation and was subsequently affected by tectonic activity and erosion. Locally, the lower surface continued to form during the early Quaternary and occasionally was buried along the margins of the basins. Thus, in the mountain foreland pediments mostly represent two geomorphological surfaces. The higher pediment can locally be associated with the Upper Pannonian raised beach, but in other places it is separated from the mountain foreland by a submontane erosion basin.

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[2] The early basalt volcanic activity in the Hungarian Mountains was connected with tectonic movements

[3] A similar situation is also found in other marginal areas of the Carpathian basin

Table 2. LATE CENOZOIC GEOMORPHOLOGICAL SURFACES
Acc.: PÉCSI, M. 1985.

Polarity epoch	Stratigraphy		Travertine	Terraces	Pediment, foothill surface	Loess, paleosols fluvial, lacustr. sed.	Localities and notes
Brunhes	Holocene		N°1	N°I		flood plain sed.	
	Upp.	PLEISTOCENE	N°2	N°IIa N°IIb		Young loess with 5 paleosols	Paleosol: Mende F. 29 000 y. (1) N°2 Tata: 101 000 y. (2) Paleosol: Mende B.~120 000 y. (3)
	Middle		N°3	N°III		Upper Old loess of Paks 2-3 paleosols	N°3 Buda, Kiscell: 190 000 y. (4) alluvial sand in old loess Paks: ~240 000 y. (3)
			N°4 ⊕	N°IV ⊕	↑	Lower part of old loess of Paks, 2 paleosols	N°4 Vértesszőlős: >350 000 y. (2) Paleosol: Paks PD_1, PD_2 both ⊕ ⊞
0,7 My Matuyama	Lower		N°5 ⊟⊞⊟	N°V	glacis formation of the mountains foreland	Lowermost part of old loess of Paks Pink colored sand	Oldest loess and paleosol (PDk) at Paks ⊖⊟⊖, at Dunaföldvár ⊕⊟
			N°6 ⊟⊖	N°VI	Lower lying foothill surface formation N°B	Red paleosol in N°6 Old alluvial fan of Kisláng	N°6 Dunaalmás Kisláng ⨺
			N°7 ⊟⊞				N°7 Dunaalmás ⊟⊞
2,4 My Gauss	Upper	PLIOCENE			↑	Mottled clay; sand and red clay formation of Dunaföldvár: paleosol (Df_1 – Df_6) ↑	Upper Dunaföldvár Complex (Df_1-Df_4) ⊖⊕⊕
			N°8 ⊟	N°VII			N°VII Kemeneshát; N°8 Dunaalmás ⊟
				N°VIII		Correlative sediment of pedimentation of the Mátra foothill	N°VIII Kemeneshát gravel
3,3 My Gilbert			N°9 ⊕		Climax of the pediment formation		N°9 Kőpite-hill ⊕ Pediment of Mátra Mts
	Lower		N°10a ⊟⊞⊟	oldest alluvial fan of the Danube	foreland of Mátra, Villány and other mountains N°A ↑	Optimum of the red clay formation, bentonite formation, sand formation ↓	Oldest red clays: Dunaföldvár ⊕⊖, Kulcs ⊕, Bag, Hatvan, Gyöngyösvisonta ⊞ N°10a Újhegy ⊟⊞⊟ sand formation of Gödöllő ⊖
5,4 My 5	Upper	MIOCENE	N°10 ⨹	in the foreland of mountains beginning of the formations of river system	Beginning of the pediment formation	fluvio-lacustrine sand, delta, dune sand formation ↓	N°10 Gerecse-Kőhegy, Várpalota Bérbaltavár sand ⊕⨹
6							
7 ?			N°11 ⨺	Marine terrace n°1			N°11 Széchenyi-hill ⨺ n°1 Széchenyi-hill
			N°12 ⨹	Marine terrace n°2		delta gravel delta gravel	N°12 Szabadság-hill ⨹ Travertine of Kapolcs n°2 Vértes-hill at Csákvár Szabadság-hill (Buda Mts)
				Marine terrace n°3		delta gravel and sand	n°3 Balaton – Upland (Balatonfüred) Buda Mts: Diósd, Kálla, Billege

Paleomagn. analysis made by:
○ Pevzner, M. A.
□ Márton, P.
△ Opdyke, N. D.

Th/U and ESR analysis made by:
(1) = Lab. Hannover, Moscow
(2) = Lab. Köln (Hennig et al.)
(3) = Lab. Debrecen (Borsy, Z. et al.)
(4) = Lab. Tallahassee/Florida (Osmond, J. K.)

QUATERNARY TERRACES

Along the major drainage axes crossing the Hungarian Mountains, late Neogene pedimentation and alluvial fan accumulation was followed by *formation of a series of fluvial terraces*. For instance along the Danube valley, where it traverses the Mountains, six to eight terraces (geomorphological surfaces) have been formed *(Table 1 and 2)*. They are associated with up to 150 to 200 m differential uplift during the Quaternary as well as with cyclic climatic changes (PÉCSI, M. 1971). The higher terraces were transformed into gentle hillslopes, cryoplanated valley pediments, by subsequent periglacial processes, and are only generally preserved where they were overlain by travertines resistent to erosion.

GEOMORPHOLOGICAL SURFACES AND THE OCCURENCE OF TRAVERTINE

Most of the above outlined Neogene geomorphological surfaces (raised beaches, pediments) in the margins of the Mesozoic horsts of the Transdanubian Mountains have been preserved from erosion under hard travertine horizons.[4] In the Danube Bend Mountains ten to twelve geomorphological surfaces are so covered, specifically in Gerecse, Buda and Pilis Mountains (see *Fig. 1, 2)*.

These overlying travertines are referred to two groups (SCHEUER, Gy. - SCHWEITZER, F. 1984, PÉCSI, M. - SCHEUER, Gy. - SCHWEITZER, F. 1982, 1984):

a) a more extended travertine series found on raised beaches and pediments at 250 to 450 metres above see level, and
b) a travertine series occuring in valley side positions between 107 and 250 metres above sea level.

This unique geomorphological-geological position is of unpaired significance as regards denudation chronology, as it is assumed to promote the complete temporal reconstruction of the evolution of relief during the Upper Neogene and Quaternary. Therefore, in order to date travertine horizons arranged in a step-like or terrace-like fashion, besides the consideration of the relevant geological, stratigraphical, paleontological research results, paleomagnetic and other absolute chronological (Th/U, ESR, C14) investigations have also been performed during the last two decades as part of a major research project. International teams also participated in the project along with Hungarian experts.[5]

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[4] Travertines were generally deposited from warm karst spring waters at the base level of erosion. In some places fauna indicating their age is preserved in them

[5] The participants include

Hungarian teams:

1. Great Plain Department, Hungarian State Geological Institute, led by A. RÓNAI;
2. Geomorphological Department, Geographical Research Institute Hung. Acad. Sci. - M. PÉCSI;
3. Geophysical Department, Eötvös Loránd University - P. MÁRTON;
4. INQUA Hungarian National Committee - M. KRETZOI;

Teams abroad:

1. Dalhousie University, Halifax, Canada - H. B. S. COOKE;
2. Geological Institute, Acad. Sci. of the USSR - M. A. PEVZNER;
3. Department of Geology, University of Florida, Gainesville - N. D. OPDYKE;
4. Department of Geosciences, The University of Arizona, Tucson - E. H. LINDSAY;
5. Geologisches Institut der Universität zu Köln, Lehrstuhl für Eiszeitenforschung - K. BRUNNACKER

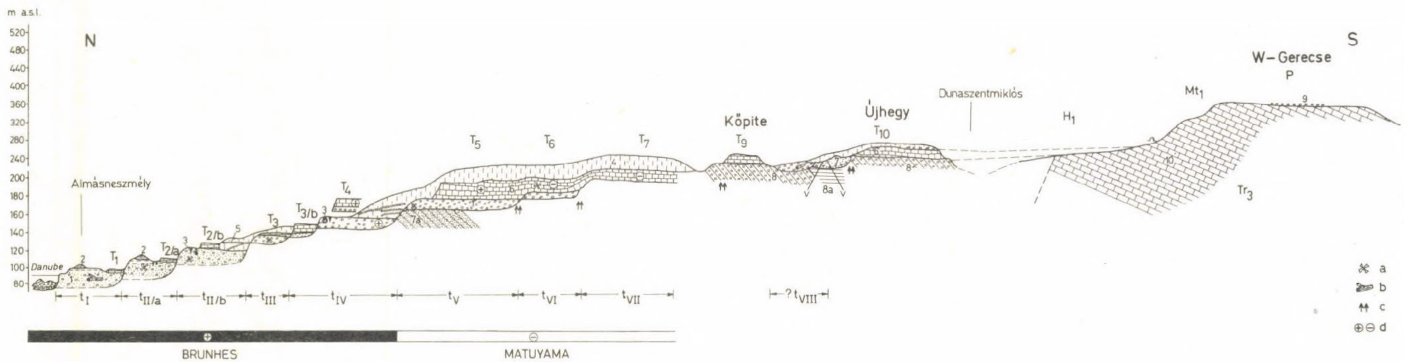

Fig. 2 "Geomorphological surfaces" in the Western Gerecse Mountains in the section of Almásneszmély and Dunaszentmiklós (PÉCSI, M.-SCHEUER, Gy.-SCHWEITZER, F.-PEVZNER, M. A.-MÁRTON, P.).

1 = fluvial terrace gravel and sand; terraces No I to VIII - for chronological subdivision of terraces see Tables 1 and 2. There is an erosional discordance between the gravels of the terrace hypothetically marked as t_{VIII} and the overlying Upper Pannonian delta gravel, has destroyed both the topmost Pannonian sands and the sand series with pebbles; 2 = blown-sand; 3 = remnants of Pleistocene cryoturbation; 4 = loess, slope loess; 5 = paleosoils interbedded in loess; 6 = travertine niveaus; T_1-T_{10} = travertine niveaus of different ages (chronological subdivision is shown in Table 1 and 2); 7 = Upper Pannonian sand with fine rounded pebbles with boulders deposited in the base; 7a = Upper Pannonian cross-bedded sand; 8 = Upper Pannonian clay; 8a = Pannonian delta gravel; 9 = Miocene (?) terrestrial gravel; 10 = Upper Triassic limestone. H_1 = remnant of Upper Pliocene pediment, in the fringe the second Upper Pannonian raised beach was preserved; Mt_1 = remnant of Upper Pannonian raised beach; P = Prepaleogene-early Paleogene planation surface, in patches covered by Miocene (?) terrestrial quartz pebbles; a = location of vertebrate fauna sites; b = carbonized tree-trunk; c = traces of thermal springs in the travertine or the gravel; d = paleomagnetic polarity

The results in dating the travertine horizons in question are summarized in *Tables 1* and *2*. In the list of references recent publications on this topic, as well as unpublished data revealed by the investigations, are included.

DISCUSSION

In spite of the recent efforts to draw the Neogene/Quaternary boundary in Hungary and several other European countries, there are differences in opinion and criteria even within a single country. The international stratigraphic commission engaged in the study of the Plio-Pleistocene boundary has suggested that this boundary be extended back to 1.8 MA B.P. Although it may therefore be fixed as the outcome of an international compromise, but geomorphological, lithostratigraphical and even biostratigraphical evidence in Hungary and throughout the Carpathian basin does not fit in with this compromise.[6]

- In the Carpathian basin, the lower boundary of the typical loess formation is a marked lithostratigraphical boundary, dated as 0.9 MA B.P. (PÉCSI, M. - PEVZNER, M. A. 1974, MÁRTON, P. 1979).
- Beneath the typical loess formation in Hungary, there is a series of transitional subaerial deposits (loess-like loams and red soils of Mediterranean type and variegated clays) which are postulated to have been formed under predominantly Neogene paleogeographical conditions. It particularly refers to the true red clays at the base of the series which were undoubtedly produced under subtropical climatic conditions.
- The climax of the true red clays may be placed, by geomorphological, stratigraphical and paleomagnetic evidence as early Gilbert epoch (4.5 to 5.0 MA B.P. - see *Table 1*).

In the profile of the Dévaványa borehole from the Great Hungarian Plain, the repetition of red clay intercalations at depths of between 900 and 1100 m (rounded figures) cover the early Gilbert epoch and even the fifth paleomagnetic epoch as attested by paleomagnetic analysis (RÓNAI, A. 1983, COOK, H. B. S. - HALL, J. M. - RÓNAI, A. 1979). Red clays in the Carpathian basin started to form as early as 5.0 to 5.5 MA B.P., while part of the series of red and purplish soils and variegated clays younger than the true red clays date back to the Gauss epoch and ceased forming in the first part of the Matuyama (cca. 2.0 to 2.2 MA B.P.).

In a *lithogenetic sense* this date may also represent the lower boundary of the transitional Eopleistocene in the Carpathian basin and may serve as a compromise for the N/Q boundary. In the mountain forelands of the United States, glacial till of 2.2 MA has also been found (EASTERBROOK, D. J. - BOELLSTORFF, J. 1982, RICHMOND, G. M. 1983).

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[6] In the Soviet Union, between the Olduvai event (1.8 MA B.P.) and the Brunes-Matuyama boundary (0.72 MA B.P.) the Plio-Pleistocene transitional period is referred to as Eopleistocene by many, conceived as part of the so-called Anthropozoic

- The evidence from the geomorphological surfaces about the establishment of the supposed Plio-Pleistocene boundary may be summarised as follows.
- The Pannonian raised beaches (Nos 1, 2 and 3) and the overlying travertine horizons (Nos 11 and 12 and possibly No 10) as well as the littoral gravelly deltas are, in accordance with the dating of the new Mio-Pliocene boundary (5.4 MA), referred to the *Miocene*.
- The higher pediment with local patches of true red clay or where it is overlain by travertine horizons Nos 9 and 10a is believed to have formed during the first half of the Pliocene. In our opinion, the so-called fluvio-lacustrine sand (Gödöllő type) and gravelly deltaic sediments of the Danube also belong here. The former is locally characterized by red clay and the latter also by a bentonitic cover.
- Terraces Nos VIII and VII with their travertine covers Nos 8 and 7 date back to the second half of the Pliocene. Pedimentation at a lower level also took place in the Upper Pliocene, since its correlative sediments characterized by Mastodon Borsoni and purplish soils mostly belong to the Gauss epoch (KRETZOI, M. et. al. 1982, PÉCSI, M. 1985, in this volume). The formation of the lower pediment, however, continued into the Lower Pleistocene.
- Our investigations indicate that *terrace No VI may extend over the Plio-Pleistocene boundary*, as the overlying travertine horizon (No 6) encloses a red soil layer in which Upper Villányian-Kislángian fauna has been found. The travertine series manifests reverse polarity throughout its profile (lower part of Matuyama, 2.0 MA).
- Danube terrace No V (along the mountainous reaches) with the overlying travertine *may represent the lower Pleistocene*. The travertine cover is almost 25 m thick with reverse polarity in its top two-thirds and normal polarity in the lower one-third. According to the paleomagnetic analysis of MÁRTON, P. the whole of the cover formed during the late Matuyama epoch and during the Jaramillo event (0.73 to 0.9 MA B.P.).
- Terraces No IV and younger with their travertine covers all formed during the Brunhes paleomagnetic epoch, i.e. they are younger than 0.73 MA (*Table 1;* HENNIG, G. J. et al. 1983, KRETZOI, M. - PÉCSI, M. 1979; PÉCSI, M. et al. 1984).
- Terraces Nos VIII and VII and the large alluvial fans, commonly contiguous in the mountain foreland and which converge with terraces Nos V and VI are difficult to separate. This is why they were previously dated as Pliocene but are now placed in the Quaternary (Quaternary time-table, Hungarian Geological Institute, 1983). Further research is necessary here in order to seperate this formation from older deltaic gravels. Nevertheless it is impossible to hold the view that the accumulation of gravelly fans stretching into the Carpathian basin from the encircling mountains is associated with the beginning of the Pleistocene.
- The true red clays deposited on post-Pannonian pediment remnants or at the base of the subaerial red soils and variegated clays below this sequence, are older than Pleistocene and we suggest they should be correlated mostly with the

early Pliocene. The red clays mainly composed of montmorillonite and kaolinite underwent very intensive subtropical weathering (PÉCSI, M. 1985: Fig. 3 this volume) and in several places cover layers of volcanic tuff or bentonite (Tengelic, Gyöngyös, Hatvan, Bag - HALMAI, J.-JÁMBOR, Á. et al. 1982, PÉCSI, M. 1985, SZOKOLAI, Gy. 1982).

Since the above outlined denudation chronology of the geomorphological surfaces of the Hungarian Mountains is based on several decades of observations and on the activity of an interdisciplinary team of local and foreign experts, it may be accepted as more than a working hypothesis. Acknowledgements are made for the help and contribution of the members of the team, who are aware of the need for future collaboration and comparisons with the views of representatives of other schools of thought.

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ON UNDERSTANDING THE RANGE AND STRATIGRAPHIC POSITION OF THE PANNONIAN

M. A. PEVZNER - E. A. VANGENGEIM

ABSTRACT

Based on a joint analysis of mollusc, ostracod and mammal fauna as well as available geological and paleogeographical information an attempt was made to correlate the Pannonian sediments with those of Eastern Paratethys and Mediterranean.

The Pannonian A and B zones of the Vienna basin are attributed to the Sarmatian. The Congerian Pannonian is correlated with the Pontian s.l. of the Euxinian basin and the lower part of the Mediterranean Messinian. The Lower Pannonian of Bartha's scheme (C,D and E zones of the Vienna basin) corresponds to the Lower Pontian, the lower subhorizon of the Upper Pannonian to the Middle Pontian, and the middle subhorizon of the Upper Pannonian (F,G and H zones of the Vienna basin) to the Upper Pontian. The Unio wetzleri beds (the upper subhorizon of the Upper Pannonian of Bartha) corresponds to the lower part of the Kimmerian as well as to the upper half of the Messinian. There is a stratigraphic break between the Sarmatian and the Pannonian in Pannonian basin.

The Pannonian and Euxinian basins were joined during the Early Pontian, due to the Early Pontian transgression of the Euxinian basin.

* * *

INTRODUCTION

Debate has continued for nearly a century concerning the interrelation of the Pannonian of the Central Paratethys and the stratigraphic subdivisions of the Eastern Paratethys. This is due partly to different views about the range of the Pannonian and partly to the specific nature of Pannonian molluscs.

According to some authors the Pannonian represents a sedimentary unit resting above the Sarmatian (s.str.) and containing *Congeria*. Others add overlying beds containing *Unio wetzleri* (the Pannonian s.l.). A third group of authors believe that the Pannonian consists only of the lower part of the Congerian Pannonian (the Pannonian s.str.) and higher beds are attributed to the Pontian.

Ideas on the stratigraphic nomenclature and position of the Pannonian has been frequently discussed in the literature (ANDRUSOV, 1894, 1917; STRAUSZ, 1969; TAKTAKISHVILI, 1977; BARTHA et al., 1971 and others). We shall therefore not review the problem in this paper, nor shall we analyse the numerous schemes for correlation of the Pannonian with the stratigraphic divisions of the Eastern Paratethys. Rather we shall introduce a few typical schemes out of this whole variety.

According to some investigators (MENNER - MERKLIN, 1968; BARTHA et. al., 1971) the Pannonian s.l. is correlated with sediments from the middle part of the Middle Sarmatian to the Kimmerian inclusively *(Table 1)*. Others (GABUNIA, 1959; KRETZOI, 1971, after BARTHA et. al., 1971) correlate the Pannonian with the Eastern Paratethys deposits from the middle part of the Middle Sarmatian to the Pontian inclusive. And, finally, there are some who correlate the Pannonian with the Upper Meotian, the Pannonian and most of the Kimmerian (STRAUSZ, 1969; SZÉLES, in BARTHA et al., 1971).

The majority of investigators now accept the Pannonian in its narrow meaning and correlate it with sediments of the Euxinian basin assigning it to the upper half of the Sarmatian and Meotian, while the upper part of the Pannonian of earlier workers is attributed to the Pontian. It was this opinion that formed the basis of the scheme of correlations between the Mediterranean stratigraphic divisions (the Tethys and Paratethys) adopted at the VIth Congress on Mediterranean Neogene stratigraphy held in Bratislava, Czechoslovakia in 1975 (MENNER et al. 1976).

SUBDIVISION OF THE PANNONIAN BASED ON MOLLUSCS

One of the most acceptable recent scheme for the zonation of the Pannonian s.l. was proposed by A.PAPP (1948, 1951). In the Pannonian of the Vienna basin he identified a number of zones and lettered them as follows: zones A,B,C,D constitute the Lower Pannonian; zone E, the Middle Pannonian; and zones F,G,H the Upper Pannonian. These letter designations were introduced because the zonal sequences proposed by previous authors and named after index-species suffered from serious disadvantages. Some species had a stratigraphic range wider than the zones named after them, while typical forms of certain supposed index-species were detected in the beds of other zones. Moreover, some differed in their interpretations of the volume and naming of beds using one and the same index-species. In addition, certain species used as zonal indicators are found only in marginal facies and are absent in the central part of the basin (PAPP, 1951, p.105). It should be noted, however, that later PAPP again used these index-species though he failed to offer clear faunal substantiation for several of the zones identified by him.

In this study of Pannonian outcrops in the Vienna basin, a marginal part of the Pannonian basin, PAPP determined sedi-

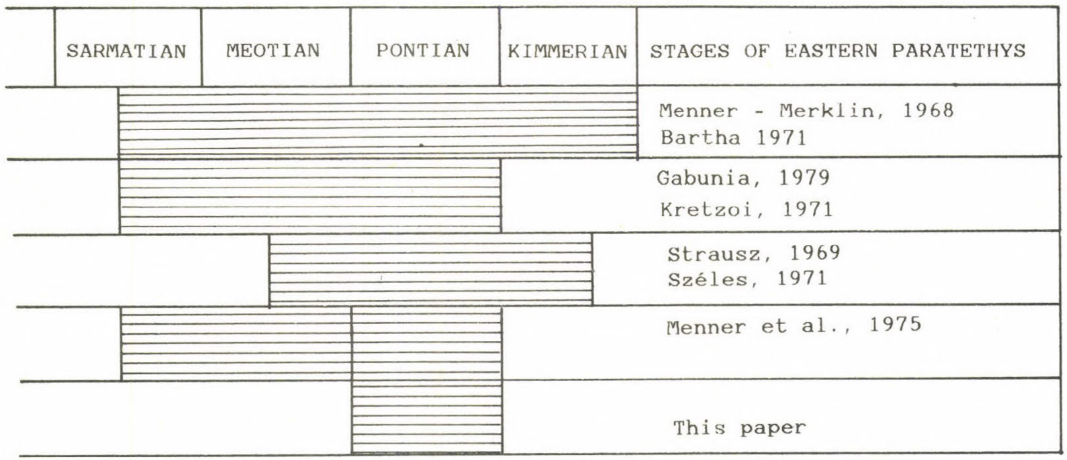

Table 1. Range of the Pannonian according to different authors

ments with *Congeria ornithopsis* to be the most ancient within the Pannonian. He named this zone B, assuming that more ancient beds might be recognized in the central part of the basin which would be referred to zone A.

Zone A. This zone is similar to the impoverished regressive phase of the Sarmatian. It is absent in the marginal facies and is represented by basin facies only (PAPP, 1951,p.143). We may observe in this zone the survival of marine Sarmatian foraminifers and cardiids (*Replidacna)* as well as brackish-water forms from the Sarmatian (PAPP , 1951,p.184). According to PAPP zone A species are known from the Sarmatian and persist due to the selection of species in the Sarmatian fauna that can dwell in brackish water.

Zone B. In the Vienna basin the sediments of this zone occur transgressively on the Sarmatian deposits. The fauna is mainly represented by brackish-water forms. Zone B contains 27 species and subspecies of molluscs. Seventeen of them are known from the Miocene (fourteen are Sarmatian species) and the rest are new (p.144). Three of the five *Congeria* species are representatives of the Sarmatian fauna while two species, *C.praeornithopsis* and *C.ornithopsis* are new. Neither the first nor the second forms have been identified in the younger sediments of the Congerian Pannonian.

Zone C. The fauna of this zone sharply differs from that of previous zones. According to PAPP 63 new species and subspecies unknown from zone B, spontaneously appear here.
A flourishing fauna can be observed in zone C and many species and subspecies characteristic of the Lower Congerian Pannonian make their first appearance here (PAPP, 1951,pp. 109,147,184). Deposits of this zone lie unconformably on sediments of zone B (the Leobersdorf section) or on the Sarmatian (the Wiesen section). In the marginal facies the basal beds of this zone often contain coarse sand and gravel (p.146).

Zone D. According to PAPP the fauna of this zone is generally similar to that of zone C. Large *Limnocardium* and *Congeria* species appear here. Zone D differs from zone E by the absence of distinctive E zone ostracods (PAPP, 1951, p.185). *Congeria partschi* is characteristic of this zone (p.132).

Zone E. *Congeria subglobosa* is most characteristic of the fauna of this zone. *Congeria zsigmondyi* and *Limnocardium carnuntinum* occur often. *Melanopsis vindobonensis* is present here, too. According to PAPP the fauna of zone E is the most distinctive of the Congerian-Pannonian of the Vienna basin (PAPP, 1951,p.151).

Zone F. This zone differs from the underlying one in containing numerous freshwater forms, though some transitional species still persist. *Congeria neumayri* is typical of this zone. Zone F is considered to be the first stage of the intensive desalination of the Vienna basin.

Zones G and H. These zones are characterized by the fauna of fresh-water and terrestrial molluscs (*Viviparus*, *Valvata*, *Anodonta*, *Unio* and others). PAPP has specified these zones in the Vienna basin mainly on the basis of lithological features. Blue clay dominates in zone G while in zone H there is a predominance of freshwater limestone, marl and variegated clays.

It should be remembered that zonation of PAPP refers only to the marginal deposits of the Pannonian basin. For the central part, it is F. BARTHA who has proposed a stratigraphic scheme for the Pannonian (BARTHA et al., 1971). BARTHA studied data on Hungarian molluscs both from outcrops and boreholes and published a summary of the stratigraphic ranges of significant species of Pelecypoda and Gastropoda. He also divided the Pannonian into lower and upper parts. The Upper Pannonian includes three subhorizons *(Table 2)*. The lower and middle horizons as well as the Lower Pannonian contain *Congeria*. The upper subhorizon is represented by beds with *Unio wetzleri*.

Thus, BARTHA does not subdivide the Lower Congerian Pannonian, although he divides the Upper Congerian Pannonian into two subhorizons. BARTHA correlates his Lower Pannonian with zones B,C,D and E of the Vienna basin and his lower subhorizons of the upper Pannonian with zones F,G and H (BARTHA et al.,1971)

According to borehole data covering practically the whole territory of Hungary it has been determined that the Pannonian sediments occur transgressively on deposits of various age, the youngest of which are of Upper Miocene age (the Sarmatian).

The thickness of the Lower Pannonian ranges from dozens of meters to more than 1500* m while that the Upper Pannonian ranges in thickness from a few dozen meters to more than 1000** m.

Several different schemes for detailed subdivision of the Pannonian have recently been proposed for various parts of the Pannonian basin.

Our discussion will concentrate on some of the schemes submitted at the meeting of the working group of the IGCP Project N25 (Stratigraphic correlation of the Tethys and Paratethys Neogene) (CICHA et al., 1975). *Table 3* contains only those columns showing relatively detailed subdivisions of the Pannonian s.l. These subdivisions are based on mollusc fauna. The table contains data obtained by independent investigators. Examination of the table shows that the sequence of beds with fauna in various parts of the Pannonian basin coincides neither in the Lower nor in the Upper Pannonian.

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* 2500 m (Redaction)

** 3000 m (Redaction)

Table 2. Stratigraphic range of some species of molluscs in Hungarian part of the Pannonian basin (after BARTHA et al., 1971).

Sarmatian	Lower Pannonian	Upper Pannonian: Lower	Upper Pannonian: Middle	Upper Pannonian: Upper	Molluscs
———	———				Hydrobia stagnalis Bast.
———	———————				Melanopsis impressa Kraus.
———	———				Orygoceras dentaliformis Brus.
	—·—·—·—				Paradacna lenzi (R.Hörn.)
	—·—·—·—				Paradacna abichi (R.Hörn.)
	—·—·—·—				Congeria banatica M.Hörn.
	—·—·—·—				Congeria cžjžeki M.Hörn.
	——————				Congeria partschi Czjz.
	—·—·—·—				Congeria zsigmondyi Hal.
	—·—				Melanopsis vindobonensis Fuchs
	—·—·—·—				Melanopsis fossilis Mart.-Gmel.
	———	——			Valenciennesia reussi Neum.
	———	····			Limnocardium banaticum Fuchs
	———	······			Congeria zagrabiensis Brus.
	———	·······			Caladacna steindachneri (Brus.)
	——	·····			Limnocardium majeri M.Hörn.
	——	·······			Limnocardium schmidti M.Hörn.
	————	······			Didacna desertum Stal.
	——	————	···		Limnocardium apertum Munst.
	—	————	···——		Micromelania laevis Fuchs
		———			Phyllocardium complanatum (Fuchs)
		—·—·			Congeria croatica Brus.
		—·—·—			Congeria ungulacaprae Munst.
		—···——			Congeria rhomboidea M.Hörn.
		————	—		Limnocardium penslii Fuchs
		—·—·—			Limnocardium rothi Hal.
		————			Limnocardium hungaricum M.Hörn.
		————			Valvata variabilis Fuchs
		————	—		Gyraulus inornatus (Fuchs)
		————	—		Gyraulus tenuis (Fuchs)
		—·····	—		Melanopsis pygmaea Partsch
		———			Dreissenomya intermedia Fuchs
		———			Limnocardium riegeli M.Hörn.
		————	·····—		Prosodacna vutskitsi (Brus.)
		————	———		Gyraulus homalosomus (Brus.)
		————	·····——		Congeria triangularis Partsch
		—·····—	···—		Melanopsis decollata Stol.
		—····—	——		Dreissena auricularis Fuchs
		————	·····—		Dreissena fuchsi Bartha
		—	·····—		Congeria balatonica Partsch
			——···—		Limnocardium decorum Fuchs
			—····—		Congeria neumayri Andr.
		———	·····		Dreissena serbica Brus.
			———		Theodoxus vetraniči (Brus.)
			————		Theodoxus crenulatus (Klein)
			————		Viviparus sadleri Partsch
			——····—		Melanopsis fuchsi (Handm.)
			———		Planorbis krambergeri Hal.
			———		Planorbis confusus Soos
			———		Unio atavus Partsch
				————	Viviparus mazuraniči Brus.
				————	Viviparus stricturatus Neum.
			—	————	Tacheocampylaea doderleini (Brus.)
			——	··———	Helicigona pontica Hal.
			——	···———	Unio wetzleri Dunk.
				——·····	Planorbis spirorbis L.
				————	Prososthenia sepulcralis Partsch

———— 1
········ 2
—·—·— 3

1 = stratigraphic range of species; 2 = the species is dominating; 3 = the species occurs only in a single stratigraphic unit

Table 3. Subdivision of the Pannonian s.l. in different parts of the Pannonian basin (after Cicha et al., 1975)

	The Pannonian basin		The Vienna basin	Western Slovakia
	Slovenia 18	Croatia 19	Austria 20	23
PONTIAN	"Rhomboidea beds"	"Rhomboidea beds"	H. Freshwater limestone, variegated clays G. Blue clay prevailing	Candoniella albicans Cyclocypris laevis Cyprideis seminulum
	"Abichi beds"	"Abichi beds"	F. Clay with C.zahalkai, C.neumayri	Congeria neumayri
PANNONIAN	C.czjžeki beds	"Banatica beds" C.subglobosa C.partschi	E. Beds with C.subglobosa D. Beds with C.partschi C. Beds with C.hoernesi B. Beds with C.ornithopsis	E. C.subglobosa D. C.partschi, Erpetocypris recta C. Cyprideis sulcata B. Congeria sp.
	C.ornithopsis, V.velutina	"Croatica beds"	A. In synclines "Zwischensand"	A. Silicoplacentina
SARMATIAN				

Table 3. (cont. 1)

	Northern Hungary 25	East and north-east of Hungary 27	Maramures, Rumania 29	Transylvania 30
PONTIAN	C.balatonica beds C.ungulacaprae beds	C.neumayri Pr.vutskitsi C. balatonica D.auricularis C.ungulacaprae	C.balatonica beds	
PANNONIAN	C.partschi beds	C.cžjžeki C.partschi C.banatica L.abichi P.lenzi L.praeponticum	C.subglobosa zone Sand and clay with C.partschi and C.zsigmondyi C.banatica C.ramphophora M.vindobonensis	Sand with C.subglobosa Marls with C.banatica and P.lenzi
SARMATIAN				

Table 3. (cont. 2)

	Central and south-western Hungary 33	Banat, Rumania 34	Southern Hungary 35
PONTIAN	C.neumayri P.vutskitsi C.balatonica beds C.rhomboidea C.ungulacaprae	Marls with Unio wetzleri and C.rhomboidea C.balatonica beds C.ungulacaprae zone	C.neumayri P.vutskitsi C.balatonica C.unçulacaprae
PANNONIAN	C.cžjžeki C.partschi L.abichi C.banatica P.lenzi C.ornithopsis	C.subglobosa zone C.partschi, C.zsigmondyi C.ramphophora M.impressa C.ornithopsis	C.cžjžeki C.partschi C.banatica L.abichi C.praeponticum
SARMATIAN			

For instance, beds with *Paradacna abichi* in the Yugoslavian part of the Pannonian basin (18,19)* are placed above beds with *Congeria cžjžeki* (18) and above beds with *Congeria banatica* and *C.subglobosa* as well as *C.partschi* (19). In southern Hungary (35) as well as in eastern and north-eastern Hungary (27) the beds with *Paradacna abichi* are placed below beds with *Congeria partschi*, *C.cžjžeki* and *C.banatica.* In south-western Hungary (33) beds with *Paradacna abichi* are shown above beds with *Congeria banatica*, but below beds with *Congeria cžjžeki* and *C.partschi*.

In the majority of the columns beds with *Congeria subglobosa* are placed in the highest part of the Lower Pannonian. In Croatia (19), however, they are placed below the beds with *Congeria banatica*. In Yugoslavia (19) beds with *Congeria banatica* are placed below those with *Paradacna abichi* and above beds with *Congeria subglobosa* as well as above beds with *C.partschi*. In eastern and north-eastern Hungary (27) as well as in southern Hungary (35) beds with *Congeria banatica* are placed below beds with *C.partschi* and above beds with *Paradacna abichi*. In south-western Hungary (33) beds with *Congeria banatica* are placed under beds with both *C.partschi* and *Paradacna abichi*.

One may conclude that the local faunal sequences simply reflect local facies conditions and that these so-called "index species" cannot be used for detailed subdivision of the sediments of the Pannonian basin as a whole. Consideration of BARTHA's data for the central part of the basin (BARTHA et al., 1971) makes this quite obvious. According to *Table 2* *Paradacna lenzi*, *P.abichi*, *Congeria banatica*, *C.cžjžeki* as well as *Congeria partschi* and *C.zsigmondyi* all have a similar stratigraphic range within the Lower Pannonian (s.l.).

The zonal scheme compiled by A.PAPP for the Austrian part of the Pannonian basin has been used by some workers as standard for the detailed division of the Pannonian, and the stratigraphic schemes of various regions are correlated with this scheme. Nevertheless, a comparison of the Vienna basin fauna with the fauna of the Hungarian part of the Pannonian basin shows that the zonal scheme is not well-founded.

Table 4 shows the stratigraphic ranges of molluscs known both in the Vienna basin and in the Hungarian part of the Pannonian basin. *Melanopsis vindobonensis* occurs in zones C,D, and E. In the Hungarian part of the basin this species is found in the upper half of the Lower Pannonian only.
Congeria cžjžeki has been identified in zones C and E while *Congeria partschi*, proposed by A.PAPP as an index-species for zone D, is also known in zones C and E. In Hungary the latter two species are found throughout the Lower Pannonian. *Congeria subglobosa*, considered by PAPP as an index-species of zone E, is identified in zones D and E. In Hungary this form occurs rather rarely, being found in the Lower Pannonian only.

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* Figures in brackets refer to the stratigraphic column numbers in Table 3.

Table 4. Stratigraphic range of species of molluscs in the Austrian and Hungarian parts of the Pannonian basin

Molluscs	Vienna basin							Hungarian part of the Pannonian basin (after Bartha et al., 1971)			
	The zones (after Papp, 1951)							Lower Pannonian	Upper Pannonian		
	B	C	D	E	F	G	H		Lower	Middle	Upper
Melanopsis fossilis		+						—·—·—·—·—			
Melanopsis vindobonensis		+	+	+				—·—·—			
Congeria cžjžeki		+		+				—·—·—·—·—·—			
Congeria partschi		+	+	+				— — — — — — — — —			
Congeria subglobosa			+	+							
Congeria zsigmondyi				+				—·—·—·—·—·			
Congeria neumayri					+				—	—••••—	
Melanopsis fuchsi							+			—•••••—	

Thus, the above-mentioned species have no definite zonal restriction. They testify that zones C,D and E of the Vienna basin correspond to the Lower Pannonian of Hungary. *Congeria zsigmondyi* known from zone E is also characteristic of the Lower Pannonian. *Congeria neumayri* and *Melanopsis fuchsi*, which characterize respectively zones F and H of the Vienna basin cannot be used for detailed subdivision of the Upper Pannonian because these two forms have similar stratigraphic range. They are characteristic of the middle subhorizon of BARTHA's Upper Pannonian.

Comparing the scheme of the Vienna basin with the scheme compiled by BARTHA it can be assumed that there is a stratigraphic break between zones E and F which corresponds to the lower subhorizon of BARTHA's Upper Pannonian. It seems that this break can explain the lower stratigraphic position (the Upper Pannonian basement) of the beds with *Congeria neumayri* in both the Czechoslovakian and Austrian parts of the Vienna basin (23, 20), whereas in the Hungarian part of the basin (27, 33, 35) these beds are placed in the uppermost part of the Pannonian (see *Table 3*).

Summing up, we conclude that there is no basis for detailed subdivision of the Pannonian into beds or zones based on single index-species only. We believe that the subdivision of the Congerian Pannonian proposed by BARTHA is the most reasonable because it is based on malacofaunal complexes.

CORRELATION OF THE PANNONIAN

Most investigators divide the Panonnian s.l. into the Lower Pannonian (the Pannonian proper) and the Upper Pannonian (the Pontian). In general, the boundary between the two divisions is identified by different authors in the same way, although its exact position with respect to the zones of PAPP has been interpreted differently. Nor is there a consensus about the position of the upper boundary of the Pannonian with respect to these zones.

For example, M.SENEŠ (1974, in STEININGER et al., 1975) considers the lower part of zone E to be lower than the boundary of the Upper Pannonian and he correlates the middle part of zone E with the Upper Pannonian (or the Pontian in the narrow meaning of the term) whereas the upper part of zone E and zones F,G and H are referred to as Dacian *(Table 5)*. In the Excursion Guidebook of Congress VI on the Mediterranean Neogene (STEININGER et al., 1975) the lower boundary of the Upper Pannonian is also considered to be between the lower and middle parts of zone E, and the middle and upper parts of zones E and F are correlated with the Pontian, and zones G and H are attributed to the Dacian. PAPP (STEININGER et al., 1975) refers zones F,G and H to the Pontian (s.str.), while in the work dated 1979 STEININGER and PAPP correlated zones F,G and H with the Lower Pontian only. L.K.GABUNIA

Table 5.
Correlation of the Pannonian with deposits of Eastern Paratethys

SARMATIAN	MEOTIAN	PONTIAN	KIMMERIAN	Stages of Eastern Paratethys
	PANNONIAN	PONTIAN	DACIAN	Seneš, 1974
	A B C D E_1	E_2	E_3 F G H	
	PANNONIAN	PONTIAN	DACIAN	Steininger et al., 1975
	A B C D E_1	E_2 E_3 F	G H	
SARMATIAN	PANNONIAN	PONTIAN	DACIAN	Papp, 1975
	A B C D E	F G H		
SARMATIAN	PANNONIAN	PONTIAN	DACIAN	Steininger-Papp, 1979
	A B C D E	F G H		
SARMATIAN	MEOTIAN	PONTIAN		Paramonova et al., 1979
	A B C D E			
SARMATIAN	PANNONIAN	PONTIAN		Gabunia, 1979
	B E H			
SARMATIAN L. M. U.	MEOTIAN	PONTIAN L. M. U.		This paper
A B		C,D,E (L.); F,G,H (U.)		

(1979) attributes zone H to the Lower Pannonian.* Thus *Table 5* shows that there is not yet a consensus concerning either the range of the Pannonian or its relation to the stratigraphic subdivisions of the Euxinian basin.

Before considering the correlation of the Pannonian with the stage sequence of the Eastern Paratethys the authors would like to dwell on their own understanding of what is to be included in the Pannonian. We consider the Pannonian to be the sediments containing *Congeria* and overlying the Sarmatian. This includes the Lower Pannonian and two lower subhorizons of the Upper Pannonian (excluding the beds with *Unio wetzleri*) in the BARTHA scheme. PAPP's zones C,D,E,F,G and H are attributed to the Pannonian, whereas zones A and B are considered to be Sarmatian in our interpretation.

I. G. TAKTAKISHVILI (1977, p. 23.) pointed out that "to draw a conclusion about the Lower Congerian age of zone A according to the data compiled by A. PAPP is rather difficult as this fauna is represented by the impoverished fauna of the Sarmatian and judging by the same author's own data does not contain new faunal elements". There is also no basis for attributing the sediments of zone B (beds with *Congeria ornithopsis*) to the Congeria Pannonian. The fauna of this zone cannot be properly regarded as transitional between the Sarmatian and the Pannonian because it contains none of the typical species of the Congerian Pannonian. According to STEVANOVICH (1978) beds with *Congeria ornithopsis* should still be attributed to the Sarmatian as these "represent the facies of the upper part of the Bessarabian substage, typical of the desalinated parts of the late Bessarabian reservoir" (p. 65).

In our opinion the base of the Congerian Pannonian should be zone C because it is in this zone that faunas typical of the Congerian Pannonian appear. At this very stratigraphic level a rather vivid geological boundary can be observed; because zone C sediments rest transgressively on older deposits of various ages. .

We believe that there are no grounds for correlating the Lower Pannonian with the Upper Sarmatian and Meotian as the majority of investigators have done. In the Lower Pannonian there are forms typical of the Pontian of the Euxinian and Dacian basins. Thus, *Paradacna abichi* in the Euxinian basin is typical of the Pontian only (ILINA et al., 1976). In the Pannonian basin this species is known low down in the Lower Pannonian (BARTHA et al., 1971). In the Pannonian basin *Paradacna lenzi* is observed in the Lower Pannonian only. The important fact is that between the Olt and Vilsan Rivers in the Dacian basin it occurs together with *Paradacna abichi*, *Congeria zagrabiensis* and other forms in Lower Pontian sediments over-

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* In this work Gabunia does not letter the zones of the Vienna basin but indicates the stratigraphic position of the mammalian localities in Austria, that is Eichkogel (zone H), Vösendorf (zone E) and Gaiselberg (zone B).

lying the Meotian (MIHAILA, 1971). Genus *Valenciennesia* in the Euxinian basin is known from the Pontian only, whereas in the Pannonian basin this genus is identified in both the Lower Pannonian and lower part of the Upper Pannonian. These observations show that the Lower Pannonian corresponds to at least part of the Pontian of the Euxinian basin.

When comparing the Pannonian with the sediments of the Euxinian basin the great importance of the rhomboidea beds should be taken into consideration. The rhomboidea horizon of the Pannonian and Dacian basins contains many mollusc species described by BARTHA from the lower subhorizon of the Upper Pannonian. The lists of Pontian fauna from these basins are given by I.G. TAKTAKISHVILI (1977).

In the Euxinian basin the beds with *Congeria subrhomboidea* and *Congeria rhomboidea** are attributed to the Middle Pontian. Therefore the lower subhorizon of BARTHA's Upper Pannonian, containing *Congeria rhomboidea* and a number of other forms typical of the Middle Pontian of the Dacian basin, may be correlated with the Middle Pontian of the Euxinian basin. This suggests that the Lower Pannonian sediments must be of Lower Pontian age. *Caladacna steindachneri* is also a common species in sediments of the Pannonian and Euxinian basins. In the Pannonian basin this form is known from the upper part of the Lower Pannonian but it dominates the lower subhorizon of the Upper Pannonian. In the Euxinian basin it is known from the Middle and Upper Pontian only (CHELIDZE, 1974), lending support to the conclusion that the Lower Pannonian may be correlated with the Lower Pontian.

The middle subhorizon of BARTHA's Upper Pannonian may be correlated with the Upper Pontian because of this subhorizon overlies Middle Pontian sediments containing *Congeria rhomboidea*. A continuous succession is observed between the faunas of the lower and middle subhorizons and this fact excludes the possibility of a stratigraphic break between them. Besides, quite a number of forms typical of the Pontian of the Dacian basin is found here.

Congeria disappear at the boundary between the middle and upper subhorizons in the Pannonian basin. We thus correlate the whole Congerian Pannonian of Hungary with the Pontian. The beds containing *Unio wetzleri* (the upper subhorizon of the Upper Pannonian of BARTHA) can be correlated with part of the Kimmerian. It is not yet possible to state conclusively whether or not the upper boundary of the Pontian coincides with upper boundary of Congerian Pannonian.

Fossil mammals are of great importance for confirming the age and correlation of upper Pannonian sediments. In several localities in Hungary and Austria fossil mammals are found in beds that also contain Upper Pannonian molluscs. These can be divided into two groups on the basis of age and stratigraphic position.

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* Congeria rhomboidea is known from the Urthian beds of Georgia (CHELIDZE, 1974).

The Baltavár locality in Hungary is an example of the younger group. The Baltavár locality is, in fact, the stratotype for beds containing *Unio wetzleri*, which constitutes the upper subhorizon of BARTHA's Upper Pannonian. Polgárdi, a cave locality, contains a mammalian fauna similar to Baltavár (KRETZOI, 1952, 1969; BARTHA et al., 1971) and thus belongs to the younger group.

The Hatvan, Rózsaszentmárton and Pestszentlőrinc (Hungary) localities belong to the older group. The shells of *Congeria triangularis*, *C.Balatonica*, *C.neumayri*, forms typical of the middle subhorizon of the Upper Pannonian (KRETZOI, 1952; BARTHA et al., 1971), were found with the fossil mammals at these localities.

The Eichkogel locality (Austria) (PAPP, 1951), where mammals occur along with shells of *Melanopsis fuchsi* being typical form of the middle subhorizon of the Upper Pannonian, belongs to this older group.

As *Table* 6 shows the mammal faunas of both groups are referred to the Turolian (from 9 to 5.5-5.2 m.y. old). Alongside long-ranging forms (Vallesian-Turolian), there are quite a number of species known only from the Turolian. In the localities of the younger group, a number of forms typical of the Ruscinian (genus *Cricetus*, true Arvicolidae) appear. A.M.FORSTEN (1968) points out that *Hipparion* from Baltavár and Polgárdi has greater hypsodonty than *Hipparion* in the older populations. These data lead us to equate the mammal faunas from the two younger localities with the final phase of the Turolian.

It is more difficult to determine the position within the Turolian of the older group of localities. The presence of such genera as *Epimeriones* and *Prosplax* at Eichkogel (DAXNER-HÖCK - RABEDER, 1971; DAXNER-HÖCK, 1972) suggests, however, that this fauna is also of Late Turolian age.

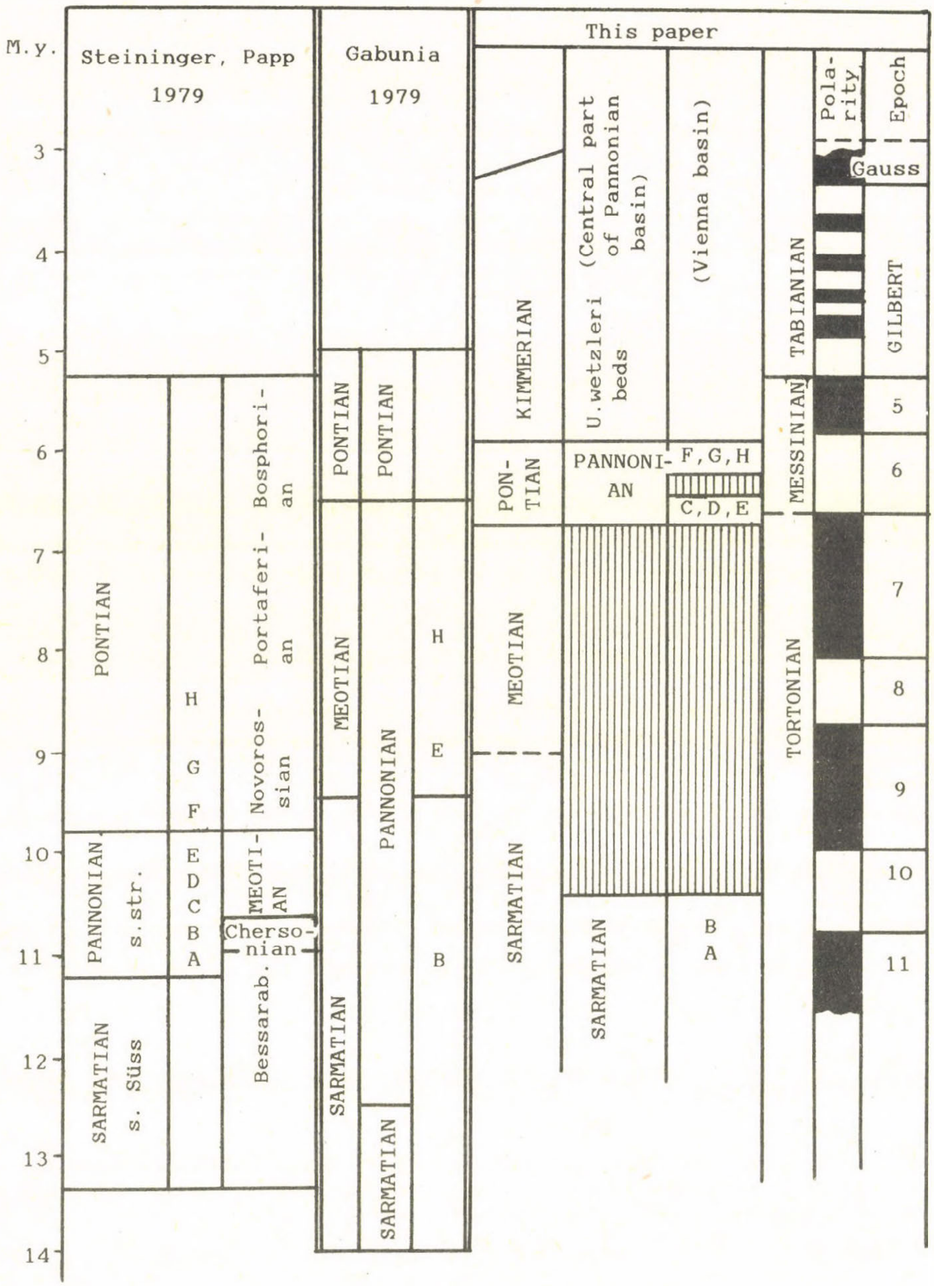
The strata in which the younger group of mammalian faunas are found can be correlated with the upper part of the Messinian based on the presence of *Cricetus kormosi*, which is also present at the Messinian localities of La Alberca and Crevillente VI in Spain (De BRUIJN et al., 1975).

Two important conclusions should be drawn from the above. Firstly, the entire Pannonian (including beds containing *Unio wetzleri*) belongs to the Miocene. Secondly, the Pontian should also be dated as Miocene rather than Pliocene, as some authors have done. Since the Pontian deposits are of reversed magnetization, the Pontian is correlated with the lower part of the Messinian (SEMENENKO - PEVZNER, 1979.) Thus the whole Congerian Pannonian may be correlated with the lower half of the Messinian. When applied to the magnetochronological scale this means that the Congerian Pannonian as well as the Pontian correspond to the very upper part of the 7th and the greater part of the 6th geomagnetic epochs and that the beds containing *Unio wetzleri* (the upper subhorizon of the Upper Pannonian s.l.) correspond to the uppermost part of the 6th epoch and the 5th epoch *(Table 7)*. However it should be noted that the correlation of the middle subhorizon of the Upper Pannonian with the Upper Pontian is rather tentative and that the precise correlation of the middle and

Table 6. Stratigraphic range of mammalia of the Pannonian localities

Mammalia	Eichkogel	Hatvan	Pestszentlőrinc	Rózsaszentmárton	Baltavár	Polgárdi	Vallesian	Turolian	Ruscinian	Villafranchian
Galerix	+						- - -	- - -		
Eomellivora						+	- - -	- - -		
Ictitheriinae				+		+	- - -	- - -		
Machairodus ex gr. aphanistus					+	+	- - -	- - -		
Gomphotherium longirostris			+			+	- - -	- - -		
Mastodon pentelici					+		- - -	- - -		
Hipparion primigenium	sp.	sp.	sp.		+	+	- - -	- - -		
Aceratherium incisivum			+		+		- - -	- - -		
Dicerorhinus schleiermacheri		+		+	+		- - -	- - -		
Microstonyx erymantheus		+			+	+	- - -	- - -		
Mesopithecus pentelici		+			+	+	-	- - -		
Adcrocuta					+	+	-	- - -		
Lycyaenops			+							
Deinotherium giganteum			+		+	+	- - -	- - -		
Kowalskia	+						- - -	- - -		
Chilotherium		+					- - -	- - -		
Chalicotherium				+	+		-	- - -		
Cervocerus		+						? - - - ?		
Tragocerus			+				- - -	- - -		
Helladotherium		+			+	+		- - -		
Parapodemus	+					+		- - -	- - -	-
Gazella					+	+		- - -	- - -	- - -
Epimeriones	+							-	- - -	
Alilepus						+		- - -	- - -	
Petenyia hungarica	+							- - -	- - -	- - -
Procapreolus		+		+	+	+		- - -	- - -	
Petenyiella	+							-	- - -	- - -
Prospalax priscus	+							?	- - -	- - -
Cricetus						+		-	- - -	- - -
Pannonicola / Arvicolidae					+				- - -	- - -

Table 7.
Correlation of the Pannonian with deposits of the Euxinian basin and Mediterranean



upper subhorizons of the Upper Pannonian with the geomagnetic time scale needs to established more precisely.

From the above it follows that zones A and B singled out by PAPP (1951) in the Pannonian of the Vienna basin can still be associated with the Sarmatian and that the Congerian Pannonian begins from zone C. Zones C, D and E have been correlated with the Lower Pontian because their mollusc faunas can definitely be compared with those of the Lower Pannonian in other areas of the Pannonian basin. Zones F, G and H have been referred by some authors to the Upper Pontian, because *Congeria neumayri* and *Melanopsis fuchsi*, known from zones F and H are forms typical of the Upper Pannonian middle subhorizon, which is correlated, in turn, with the Upper Pontian.

Thus, in the Pannonian basin, sediments of the Congerian Pannonian rest with stratigraphic break on Middle Sarmatian sediments; this break can be observed in the Vienna basin as well as another unconformity which corresponds to the Middle Pontian. The idea of a stratigraphic break between the Middle Sarmatian and the Pannonian is not new and was mentioned by JEKELIUS (1944), STRAUSZ (1941) and several others. The data acquired during the last ten years, mainly by drilling, enables us, however to support this point of view.

The correlation suggested here between the Pannonian and the stratigraphic sequence in the Eastern Paratethys differs considerably from the ideas of previous authors *(Table 5)* and this difference becomes more evident when one takes into account various interpretations of the duration of the Meotian and the Pontian.

ON THE SIGNIFICANCE OF OSTRACODS FOR THE SUBDIVISION AND CORRELATION OF THE PANNONIAN

Ostracods are used along with molluscs for the division and correlation of the Pannonian sediments. N. KRSTIČ (1974) provides a detailed subdivision of the Pannonian and the Pontian in the south-eastern part of the Pannonian basin based on ostracods. Four ostracod zones are distinguished in the Lower (Slavonian) and Upper (Serbian) Pannonian respectively, while two ostracod zones have been identified in the Lower and one in the Upper Pontian. A long list of ostracods typical of these subdivisions is given (KRSTIČ, 1974).

Table 8 lists selected ostracod species from KRSTIČ's list known from the Hungarian Pannonian (BARTHA et al., 1971). The number of boreholes at which each species occurs in Hungary is indicated. As the table shows, the ostracods including those of Upper Pontian age occur mainly in the Lower Pannonian of Hungary. Many of the ostracods considered by N.KRSTIC to be confined to different stratigraphic levels were found jointly in the Hungarian Pannonian, where in some cases stratigraphic occurrences are reversed compared to KRSTIČ's (1974) scheme. Thus the Upper Pontian *Candona labiata* was found in the Rem-2 borehole stratigraphically below the Lower Pannonian

Table 8. The comparison of stratigraphic range of ostracods in the Yugoslavian and Hungarian Pannonian

The south-eastern part of the Pannonian basin, Yugoslavia (after Krstič, 1974)				Hungary, Pannonian: Lower	Hungary, Pannonian: Upper
Pontian	Upper		Candona lobata	1	-
Pontian	Upper		Candona labiata	11	1
Pontian	Upper		Candona balcanica	5	-
Pontian	Upper		Candona alta	3	-
Pontian	Lower		Candona alta	3	-
Pannonian	Serbian	Upper	Candona trapezoidalis	7	-
Pannonian	Serbian	Upper	Candona reticulata	2	1
Pannonian	Serbian	Lower	Cyprideis heterostigma	3	-
Pannonian	Slavonian	Upper	Leptocythere (Amnicythere) parallela	2	-
Pannonian	Slavonian	Upper	Loxoconcha rhombovalis	11	-
Pannonian	Slavonian	Lower	Amplocypris sinuosa	1	2
Pannonian	Slavonian	Lower	Aurila (Hemicytheria) hungarica	2	1
Pannonian	Slavonian	Lower	Cyprideis pannonica	8	-
Pannonian	Slavonian	Lower	Aurila (Hemicytheria) lörentheyi	35	1
Pannonian	Slavonian	Lower	Leptocythere (Callistocythere) egregia	2	-
Sarmatian					

Hemicytheria loerentheyi. In the Rem-5 borehole *Candona labiata* was detected below the Lower Pannonian *Loxoconcha rhombovalis*, *Cyprideis pannonica* and *Hemicytheria loerentheyi*, which occur jointly. The Upper Pontain *Candona balcanica* was found in the Érsekcsanád-1 borehole below the Lower Pannonian *Leptocythere parallela and Hemicytheria loerentheyi. In the Érsekcsanád*-5 borehole, *C.balcanica* was traced below the Lower Pannonian *Aurila (Hemicytheria) hungarica* while in the Rem-2 borehole *C. balcanica* was identified alongside the Upper Pannonian *Candona trapezoides*.

In the Vienna basin among the ostracods characterizing zone F at the Vösendorf locality, there are four species common to the Pannonian ostracod faunas of Yugoslavia, but in Yugoslavia they are confined to different stratigraphic levels. *Loxoconcha hodonica* is typical of the upper part of the Slavonian and *Cyprideis heterostigma* of the lower part of the Lower Serbian, while *Candona lobata* and *C.labiata*, as mentioned above, are typical of the Upper Pontian of Yugoslavia.

In the north-eastern part of the Pannonian basin in the Transcarpathian Ukraine, ostracod species common to Yugoslavia and Hungary are known in the lower part of the Izovskaya suite, according to I.V.VENGLINSKII ((Stratigrafiya URSR, 1975). Present are *Loxoconcha mulleri*, known in the upper part of the Lower Slavonian of Yugoslavia and *Hemicytheria loerentheyi*, also known in the Lower Pannonian of Hungary. *Hemicytheria tenuistriata*, known from the lower part of Upper Slavonian, occurs in the upper part of the Izovskaya suite. The mollusc fauna of the Izovskaya suite indicates that it is to be correlated with the upper half of the Lower Pannonian, according to F.BARTHA. In this case ostracod dating is generally consistent with the age determinations based on molluscs, though the ostracods from the upper part of the suite would appear to be more ancient than the species from the lower part.

The lower part of the Koshelevskaya suite, which overlies the Izovskaya suite, is correlated on the basis of molluscs with the lower and middle subhorizons of the Upper Pannonian of BARTHA and is thus of Middle and Upper Pontian. In the Koshelevskaya suite the following ostracod species have been identified: *Candona lobata*, known from the Upper Pontian of Yugoslavia and the Lower Pannonian of Hungary, *Candona acuminata*, and *C.trapezoida*, known from the Lower Pannonian of Hungary, *Loxonconcha rhombovalis*, known form the lower part of the Lower Slavonian and Upper Pannonian of Hungary, and *Hemicytheria tenuistriata*, known from the Lower Slavonian. In the upper part of the Koshelevskaya suite, *Candona balcanica* and *C.labiata*, known from the Upper Pontian of Yugoslavia and the Lower Pannonian of Hungary have been found.

Thus the detailed subdivision suggested by N.KRSTIČ based on ostracods for the Pannonian and Pontian of Yugoslavia cannot be used for the subdivision and correlation of the Pannonian sediments of the Pannonian basin in the neighbouring regions of Hungary, Austria and the Transcarpathian Ukraine.

CONCLUSION

Although scientists of various countries have attempted to subdivide and correlate the Pannonian sediments for nearly a century, they have not yet been able to agree on range, detailed subdivision, and correlation with the sediments of the Eastern Paratethys. Of all the schemes for detailed subdivision of the Pannonian, that by BARTHA (1971) seems to be most well-founded. The complex analysis of data on the mollusc fauna, ostracods and mammals together with geological and paleogeographical data makes it possible to correlate the Pannonian with the sediments of the Paratethys and Mediterranean.

The A and B zones of the Pannonian of the Vienna basin are attributed to the Sarmatian. The Congerian Pannonian is correlated with the Pontian of the Euxinian basin and the lower half of the Messinian of the Mediterranean; the Lower Pannonian of the BARTHA's scheme (zones C,D and E of the vienna basin) is correlated by us with the Lower Pontian; the lower subhorizon of the Upper Pannonian is correlated with the Middle Pontian, and the middle subhorizon of the Upper Pannonian (zones F, G and H of the Vienna basin) with the Upper Pontian. The beds containing *Unio wetzleri* which comprise the upper subhorizon of the Upper Pannonian of BARTHA correspond to the lower part of the Kimmerian of the Euxinian basin and the upper half of the Messinian of the Mediterranean respectively.

The correlation of the Pannonian with the Pontian and the transgressive relationship in which Pannonian beds overlie deposits of quite diverse (Archaic to Sarmatian s.str.) age from place to place in the Pannonian basin supports the idea of a stratigraphic break between the Sarmatian and the Pontian as proposed by earlier authors. The Pannonian and Euxinian basins were joined in our interpretation in early Pontian time as a result of an early Pontian transgression of the Euxinian basin.

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THE NEOGENE RED CLAYS OF THE CARPATHIAN BASIN

M. PÉCSI

ABSTRACT

Opinions differ as to whether the true red clays mostly deposited on Upper Pannonian lacustrine sediments are dated as Pliocene or early Quaternary.

In the marginal zone of the Great Hungarian Plain (Fig. 1), below the older loess series, which is dated as around 0.9 million years B.P. a subaerial series of rhythmically repeated gleyed clays and red clays (the "Dunaföldvár series") has been deposited. The lowermost member of this series is a true red clay which is several metres thick and also occurs in patches on the pediment surface rising above the Pliocene terraces (Fig.2). This red clay was formed during the process of sedimentation in the uppermost Pannonian or immediately after it, under extreme Mediterranean climatic conditions. Geomorphological and stratigraphic evidence shows that it is not Quaternary in age.

Biostratigraphic and lithostratigraphic data together with paleomagnetic results and stratigraphic and geomorphological position show that these non-rewashed residual deposits of red clay belong to the Gilbert or to even earlier epoch (4.0--5.5 m.y. B.P.).

* * *

ON THE AGE OF LOESS FORMATION IN GENERAL

In recent years, during lithostratigraphic and chronostratigraphic investigations of loess exposures in the Carpathian basin, paleomagnetic evidence shows that the formation of loess could not have begun before the Jaramillo event (about 0.9 m.y. B.P.) (*Fig. 1;* PÉCSI, M. - PEVZNER, M. A. 1974, MÁRTON, P. 1979, PÉCSI, M. 1979, 1982, PEVZNER, M. A. - PÉCSI, M. 1980, BUTRYM, J. - MARUSZCZAK, H. 1984).

In Czechoslovakia, according to KUKLA, J. G. (1970), the lower horizons of the Central European loess series can be placed between the Brunhes-Matuyama boundary (0.72 m.y. B.P.) and the Jaramillo event. LAUTRIDOU, J. P. (1979) only mentions normal polarity for W-European loesses (Normandy). In the Uk-

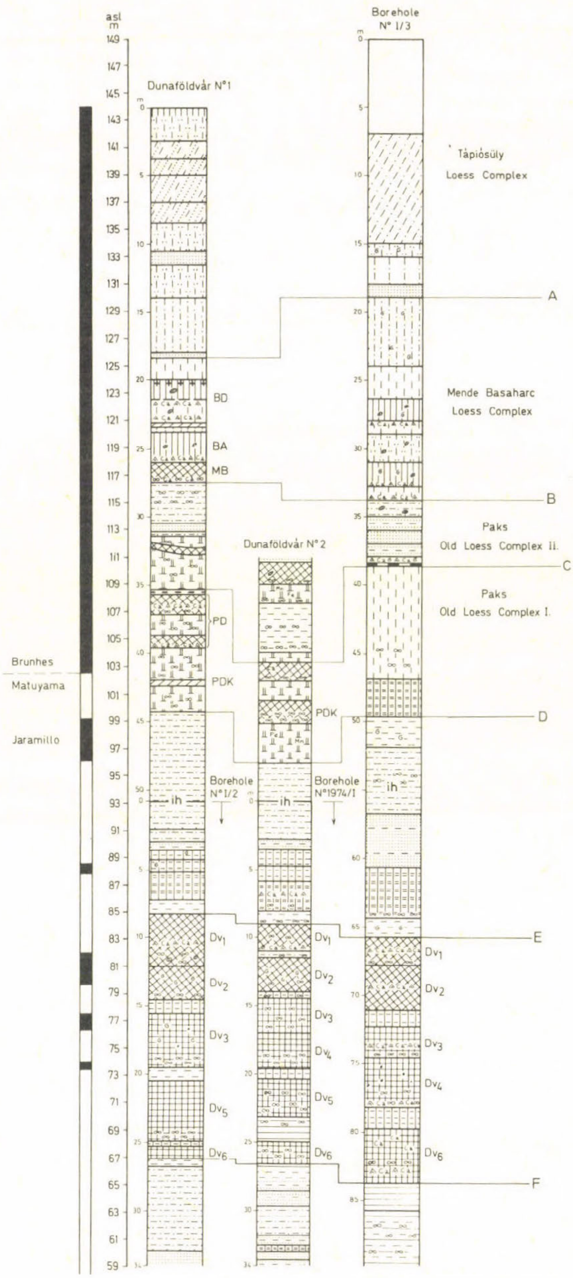

Fig. 1 Correlation of the different exposures and borehole profiles at Dunaföldvár
(PÉCSI, M. -- SZEBERÉNYI, E. -- PEVZNER, M. A.)

raine the absolute age of the older loesses was found to be about 1 m.y. (VEKLICH, M. F. 1979, VEKLICH, M. F. - SIRENKO, N. A. 1984).

In Siberia, on the loess plateau along the Ob river (Pri--Ob' Plateau), only the lowermost loess horizon in the about 100 m thick loess sequence is of reverse polarity and, consequently, its formation dates back to the upper Matuyama epoch (ARKHIPOV, S. A. - DEVJATKIN, E. V. - SHELKOPLJAS, V. N. 1982).

In Central Asia, according to the investigations of SHERMATOV M. Sh. - TOICHIEV, K. H., paleomagnetic evidence proved "Tashkent loess" to be about 0.7 m.y. old. In the famous exposures in Tajikistan, the lower horizon of the loess sequence s. str. began to develop just before the B/M boundary (DODONOV, A. E. - PENKOV, A. V. 1977, LAZARENKO, A. A. et al. 1977, DODONOV, A. E. 1982, 1984).

In China, the absolute age of the oldest horizons of the Lishih loess series has been determined as 0.9 m.y. to 1.1 m.y. B.P. by paleomagnetic analysis (HELLER, L. - LIU Tungsheng 1982, WANG Yongyan - YUE Le-ping 1982, SASAJIMA, S. - WANG Yongyan 1984). The deep Wucheng series under the Lishih series consisting of a series of loess-like loams and red soils stretches over the whole of the Matuyama epoch (2.4 m.y.) and is referred to the Lower Pleistocene, while the true red clay horizon frequently occurring at the base of the Wucheng series (ZHANG Zhonghu 1982) may be regarded as Neogene (Gauss epoch or older) from the evidence of its normal polarity.

In Tajikistan, under the true loesses reddish brown clayey soils occur in great thickness (the "Kulibab series"), the lower part of which may be referred to the Gauss epoch of 3.4 m.y. B.P. or even earlier if the paleomagnetic evidence is accepted (DODONOV, A. E. 1979).

FINK, J. (1979) claimed that in the Krems and Stranzendorf exposures in Austria, the older loesses accumulated before the Jaramillo event while the lower loess horizons date back to the Matuyama-Gauss boundary (2.4 m.y. B.P.). These, however, are loess-like deposits and not typical loesses.

A similar situation is found in the Carpathian basin, where under the typical loess sequence a further 30-40 m series of mostly sub-aerial loamy and clayey paleosols, gleyed clays and silts occurs, characterised by its reddish soils, red clays and locally true red clays. In order to distinguish these from the loess sequence proper, they have for some time been termed the "Dunaföldvár Formation" (PÉCSI, M. 1975, 1982, PÉCSI, M. et al. 1979). In the loess bluffs along the right bank of the Danube, where it touches the margins of the Great Hungarian Plain, boreholes has revealed it in several places. Incomplete series are also found in the marginal zone of the Great Plain Basin, on pediment remnants and, as a correlative sediment of pedimentation, in the material of alluvial fans which are older than the Lower Pleistocene *(Fig. 2.)*. They rest on Upper Pannonian sands or sandy clays.

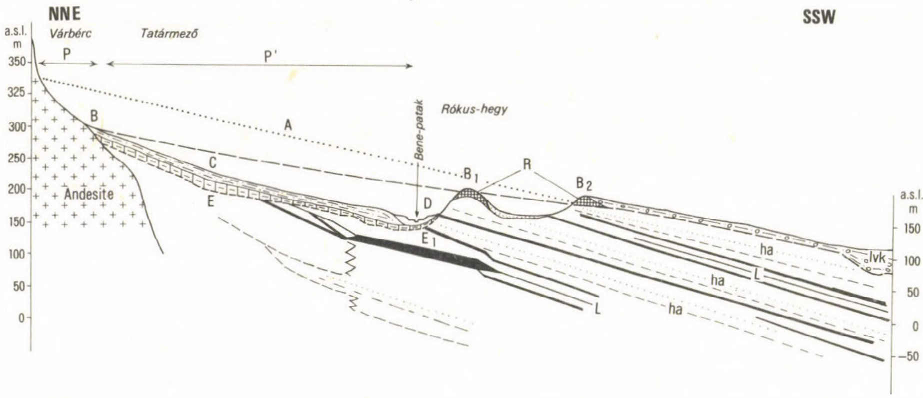

Fig. 2 Position of the red clays at the Mátra Foothills (Abasár)
A = reconstructed surface of the Lower Pannonian layers; B, B_1, B_2 = Pliocene pediment surface; C-D = Upper Pliocene--Lower Pleistocene alluvial fan; E-E_1 = strongly eroded Pannonian surface; L = lignite; h = sand; ha = sand, clay; P = pediment; P' = pediment-glacis; l,v, = loess, loam; k = gravel; R = red clay; T = Upper Pleistocene terraces

THE VARIEGATED CLAYS, GLEYED CLAYS AND THE RED CLAYS OF THE DUNAFÖLDVÁR FORMATION

In the exposures and boreholes at Dunaföldvár this formation begins with 5 to 6 metres of microstratified, pale pink, slightly silty sands (indicated as "ih" in *Fig. 1.*) with rhythmically alternating thin cemented sandstone beds or concretions. Below this follows a 3 to 5 metre complex of dark grey clay meadow soils, containing according to pedological analysis, 2-3 per cent humus and 40 to 60 per cent $CaCO_3$ in the various C horizons. The soil profile also includes horizons of dolomitic lime concretions.

The most characteristic part of the Dunaföldvár Formation is the 10 to 15 metre sequence of ochre-red soils which has been found in several boreholes at Dunaföldvár. In *Fig. 1* five or six reddish fossil soils were identified intercalated with thin gleyed silty-clay beds. From among these red soils DV_3, DV_4 Dv_5 and locally Dv_6 have undergone intensive weathering, (clayification - PÉCSI, M. et al. 1979). It is also typical that the $CaCO_3$ content is extremely high in their B_2 and Cca horizons. It is therefore presumed that these red paleosols in the Dunaföldvár Formation are remnants of a xerophylic forest soil formed under a Submediterranean climate.

The subaerial sequence of the Dunaföldvár Formation is underlain by either Upper Pannonian clays of a lacustrine-inland sea origin or a loosely cemented sandstone mostly defoliated into highly micaceous wafers in the boreholes of *Fig. 1*.

Below the red paleosol series *(Fig. 1)* 5 to 6 metres of gleyed clay beds and silty sands occur with sand intercalations, which are also presumed to belong to the Upper Pannonian Formation.

Based on paleopedologic, lithostratigraphic and paleomagnetic data it may be supposed that the development of the Dunaföldvár Formation began long before the Gauss epoch. - Its youngest deposit, a pale-pink silty sand, may have accumulated immediately after the Jaramillo event.

From a lithostratigraphic and paleopedologic point of view the "non-loessic" formation at Dunaföldvár is clearly distinct from the Paks older loess (along the line D in *Fig. 1)*. The marked stratigraphic boundary separating them probably represents the Eopleistocene-Lower Pleistocene boundary (about 850.000 y. B.P.).

It is also presumed that the oldest red clay of the Dunaföldvár Formation (Dv_6) represents the boundary between the Upper Pannonian lacustrine-inland sea formation (5.4 m.y. B.P.) and terrestrial deposits of early Upper Pliocene or Levantine age (line F in *Fig. 1)*.

The boundary between the Pliocene and the so-called Eopleistocene is most suitably drawn at the top of the red clay series (Dv_1; about 2.0 m.y. - 2.2 m.y.). The formation of the mottled and[1] red clays covered most of the Gauss and Gilbert paleomagnetic epochs (from about 5.5 m.y. to 2.4 m.y.), a conclusion supported by the detailed analysis of the Dunaföldvár boreholes (PÉCSI, M. - PEVZNER, M. A. 1974), the Vésztő and Dévaványa boreholes (RÓNAI, A. 1983, COOKE, H. B. S. - HALL, M. - RÓNAI, A. 1979) as well as from the series overlying the lignite in the Gyöngyösvisonta open cast mine (KRETZOI, M. - MÁRTON, P. et al. 1982; PÉCSI, M. - MÁRTON, P. et al. 1985, see in this volume; *Fig. 2)*.

PEDIMENTS AND THE RED CLAYS

In the foreground of the North Hungarian Mountain Range, the red clays associated with pedimented residual hill illustrate the geomorphological or geological position *(Fig. 2)*. On the partly eroded surface of an Upper Pannonian lignite formation, a red clay series has been preserved in the position indicated by B_1-B_2 (on the pedimented summits of residual hills). By further

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[1] In the 1220 m deep core at Dévaványa, Great Hungarian Plain numerous red clay layers occur between 900 m and 1100 m (rounded figures); by the results of the paleomagnetic investigation, they date back to the early Gilbert or even before, to the 5th paleomagnetic epoch.

tracing the patchy remains of the red clay, from B_2-B_1 towards the mountains at point B, a reconstructed surface is achieved. This geomorphological surface represents a former pediment eroded into Pannonian strata (removal of 20-30 m of material) and the true red clays are therefore to be viewed as residual deposits.

Subsequently, the pediment (B-B_1) and superficial red clays were considerably dissected producing the surface E-E_1, upon which an alluvial fan of thickness C-E or D-E_1 accumulated.

The lower part of the alluvial fan yielded a Mastodon skull and teeth *(Zygolophodon pavlovi Osborn)* excavated from clayey tuffaceous debris layer which also contains much fragmentary red clay and lignite (see PÉCSI, M. et al. 1985 in this volume).

The deposit with the Mastodon finds is composed of fluviatile sand overlain by a purplish red paleosol series, which partly corresponds to the Dunaföldvár Formation. This evidence puts the beginning of alluvial fan accumulation here back to the (Upper) Pliocene (KRETZOI, M. - PÉCSI, M. 1979).

In the upper one-third of the alluvial fan, 10-14 m below the surface, the almost complete skeletons of numerous southern elephants *(Archidiskodon meridionalis meridionalis Nesti)* were found. The clayey loam horizon containing the finds lies immediately below the Brunhes-Matuyama (0.72 m.y).

The middle part of the alluvial fan in question accumulated during the Lower Pleistocene (see PÉCSi, M. - MÁRTON, P. et al. 1985. in this volume; *Fig. 1)*.

In the foreground of the Mátra Mountains, in a pediment position, and also in other places such as the exposure in the Hatvan brickyard, several red clay horizons have been deposited on Upper Pannonian strata *(Fig. 3)*. Here it is particularly worth noting from the geological and geomorphological points of view that the clayey-sandy series in the Hatvan brickyard represent the final phase of the Upper Pannonian formation: the *Congeria neumayri* zone with the vertebrate fauna of Hatvanium, the Baltavár sand with *Unio wetzleri* and in some part of the exposure bentonite is the base of red clays. The red clay series was deposited on the eroded sand and bentonite horizon over a long interval and is subdivided by at least three horizons of intensive lime and dolomite accumulation, where $CaCO_3$ has accumulated in large concretions or in locally heavily cemented beds. The preservation of the pedimented residual hill can be attributed to this phenomenon[2].

Red clay here could only form under prolonged Subtropical (Mediterranean) climatic conditions as in the case of other occurrences of true red clay in the Carpathian basin, which are mostly deposited on sediments of Upper Pannonian age. Only in the late Neogene (in Pliocene) did climatic circumstances favour the prolonged accumulation of red clays and the formation of extensive pediments. The implications of this fact for the

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[2] Red clay layers in similar position were exposed in several road cuts during the construction of the M_3 motorway on the outskirts of Gödöllő and Kisbag.

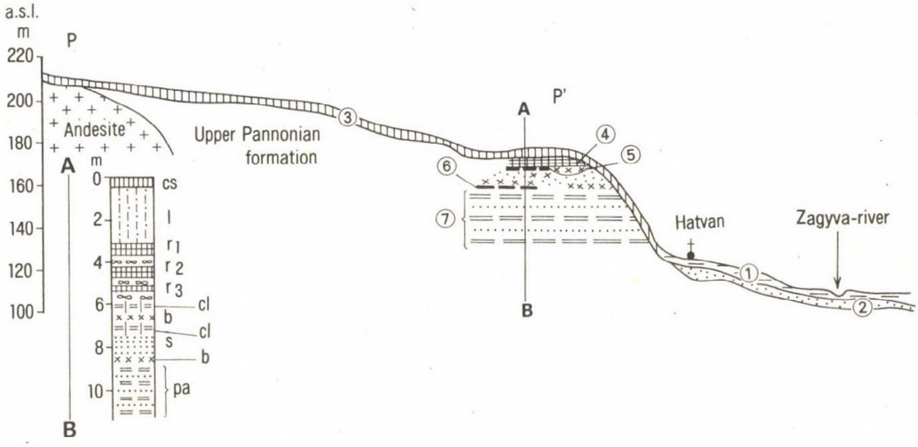

Fig. 3 Geological profile of the remnant of Pliocene pediment at the Mátra Foothills (Hatvan brickyard)
1 = fluviatile terrace clay; 2 = fluviatile sand, pebble; 3 = loess, slope loess, sandy loam; 4 = red clay layers; 5 = bentonite; 6 = grey clay; 7 = Upper Pannonian clay; cs = chernozem; l = loess, sand, loam; r_1, r_2, r_3 = red clay layers; cl = grey clayey soil; b = bentonite; s = sand; pa = Upper Pannonian clay, sandy clay

Earth's history and geomorphical evolution have not yet been sufficiently tackled in the literature.

In our opinion, efforts to refer the red clays in the Carpathian basin to the Quaternary need further checking.

Recently HALMAI, J. - JÁMBOR, À. et al. (1982) analyzed red clays of 5 to 6 m in thickness which were also intercalated with bentonite and were unconformably deposited on the Upper Pannonian formation. They term this deposit the Tengelic Red Clay Formation and refer it to the Lower Pleistocene and early Middle Pleistocene as a formation of less than 2 m.y. old.

According to our investigations the true red clays, which mainly overlie Postpannonian pediment remnants[3] or occur (below the loess formation) at the base of the subaerial red soils and variegated clays termed by us the Dunaföldvár Formation, cannot be dated as early Quaternary, but are rather to be included in the early Pliocene.

These red clays are predominantly characterized by montmorillonite and considerable amounts of kaolinite and may have undergone intensive subtropical weathering. The bentonite horizons

[3] This pediment is dated as a geomorphological surface from the Miocene-Pliocene boundary or the subsequent period (PÉCSI, M.-SCHEUER, Gy. et al. 1985 in this volume).

of various thickness in the underlying sediment may have originated from volcanic dust or tuff due to intensive weathering.

The bentonite horizon deposited mostly on an eroded surface formed of Upper Pannonian sediments are widespread in the piedmont zone of the North Hungarian Mountain Range; after more detailed investigations and more exact dating they may function as a key horizon in future.

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TYING THE BASALTS FROM THE TRANSDANUBIAN CENTRAL MOUNTAINS (HUNGARY) TO THE STANDARD POLARITY TIME SCALE

E. MÁRTON

ABSTRACT

Palaeomagnetic direction and K/Ar isotope ages of the youngest volcanics from the Transdanubian Central Mountains are compiled.
K/Ar ages indicate that the basalt volcanism took place between 6.0 and 2.8 Ma., and also fix the succession of the individual flows.
Magnetic polarity serves as a control in reference to the standard polarity time scale. Although no major mismatch is observed, the results of the two different disciplines are not in perfect harmony.
The K/Ar ages indicate that the main paroxism took place between 5.0-3.4 Ma. with minimum two distinct phases. During this interval the magnetic field changed the polarity several time and was not biassed either to the normal or the reversed side. On the other hand, the monotonously reversed magnetizations of the rocks belonging to the above mentioned age group seem to point to a single, short-lived violent explosion phase.

* * *

INTRODUCTION

Basalts from the Balaton Highlands were among the first rocks to be the subject of palaeomagnetic study in Hungary (MÁRTON and SZALAY, 1968). DAGLEY and ADE-HALL (1970) also collected basalts from the same area and resampled some of the earlier studied lavas.

Based on the available geological information, these early workers assumed that the measured directions characterized the late Pliocene - early Pleistocene magnetic field of the Earth (Pliocene - Pleistocene boundary about 1.5 - 2.0 Ma).

The presence of both normal and reversed polarities indicated that the basalt eruption took place during a minimum of two polarity phases, and the Hungarian authors suggested that the lavas with reversed polarity could represent an earlier and those with normal polarity, a later eruptive phase. The first group was considered to be of Pliocene, and the second of Pleistocene age.

However, mapping and drilling activity during the 1970s (JÁMBOR et al., 1981) and K/Ar isotope dating (JÁMBOR et al., 1980; BALOGH et al. 1982) suggested that the basaltic volcanism was older and of longer duration than had previously been assumed.

The most recent palaeomagnetic work has been undertaken on both the basaltic lavas and tuffs from the Balaton Highlands, mainly within the framework of a cooperation programme between the Eötvös Loránd Geophysical Institute, Budapest and the Geomagnetski Institut, Grocka. This has yielded a sizable body of new palaeomagnetic, K/Ar isotope and stratigraphic results which call for a modern re-interpretation of the palaeomagnetic directions. The early palaeomagnetic determinations can safely be included within this new synthesis because they are reliable, even by modern standards.

PALAEOMAGNETIC INFORMATION

Fig. 1. shows the distribution of all studied palaeomagnetic localities with reliable mean directions (scatter reasonably small). With the exception of sites 14., 15., 16.a and 16.b (tuffs), the samples were collected from lavas at each locality.

Orientation in the field and laboratory treatment of the remanence for the samples from the various localities varied between the different research workers. DAGLEY and ADE-HALL oriented the cores with Sun compass and employed alternating field demagnetization (AF) to clean the natural remanent magnetization (NRM).

MÁRTON and SZALAY collected magnetically oriented hand samples and treated the NRM with AF, while most of the recently drilled cores (MARTON and VELJOVIC, in preparation) have been oriented with both Sun and magnetic compass and the NRM cleaned with AF and/or with thermal demagnetization.

In order to estimate the reproducibility of the palaeomagnetic directions, two or three independent determinations may be compared for a selection of the localities (*Table 1.* and *Fig.2.*). Although the polarities always agree, the locality means by different authors are not exactly the same. The differences can partly be attributed to orientation and measuring error but may also reflect real changes in the direction of the local magnetic field during cooling, since the acquisition of the remanence even in a single lava body, is not instantanous and are likely to be collected from different parts of an igneous body. (Orientation error - judging from the available azimuth values measured with both magnetic and Sun compass on the same core - exceeds 3° but for a few cores; measuring error is certainly less than 3°).

With the exception of localities 8., 10., 14., the directions cluster around D=9.0° I=62.6° (k=78 α_{95}=6.9°) on the normal

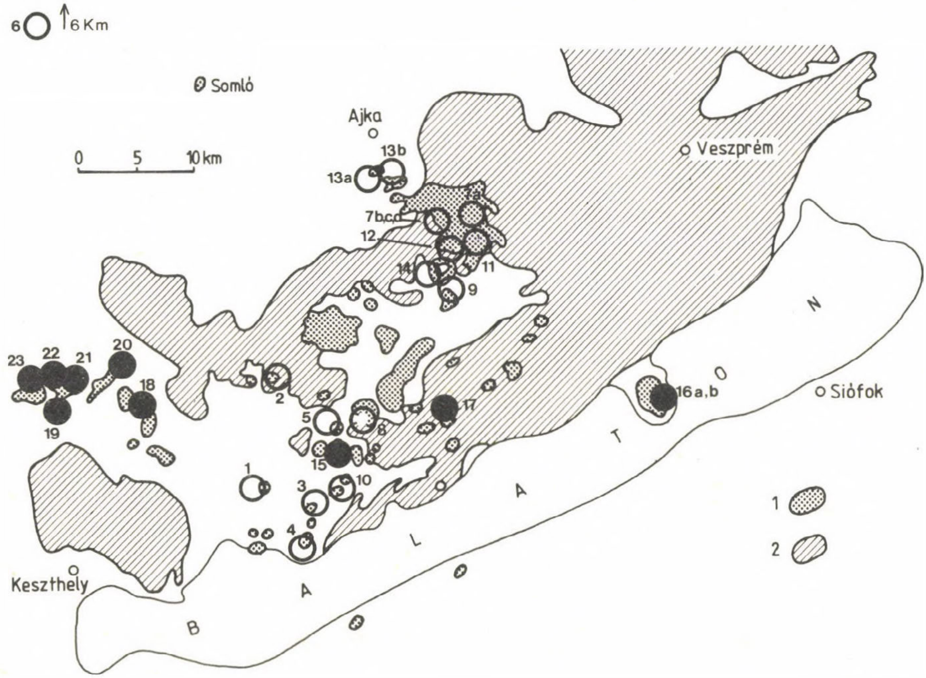

Figure 1 Paleomagnetic sampling localities in the Balaton Highlands. Localities 1-13 and 17-23 are on lavas, and 14-16 on tuffs. Hollow circles: reversed polarity, full circles: normal polarity. The geological map is after JÁMBOR et al., 1981.

1 = Basalts and tuffs

2 = Exposed Mesozoic and older sediments

side and around D=175.0° I=-59.2° (k=32 α_{95}=6.9) on the reversed side *(Fig.3.)*, i.e. both are close to the present field direction and its reversed counterpart. However, the mean declination for the reversed polarities is rotated slightly counterclockwise relative to the mean declination for normal polarities.

Concerning the spatial distribution, the lavas with normal polarity are concentrated in the Tapolca area, N of Keszthely, with the exception of locality 17.

Table 1 Palaeomagnetic data on basalts and tuffs of the Balaton Highlands

Labels 1a-23 are referred to in the text and figures

Sampling locality		N	D°	I°	K	α°_{95}	Reference
Szentgyörgy Hill western side	(1a)	5	153.5	-53.4	80	8.6	1
Szentgyörgy Hill western side	(1b)	11	153.0	-57.9	410	2.3	3
Szentgyörgy Hill western side	(1c)	8	159.0	-53.1	1051	2.0	2
Szentgyörgy Hill upper flow	(1d)	8	194.9	-55.6	620	2.0	2
Haláp, quarry	(2a)	10	187.0	-56.3	50	6.9	1
Haláp, quarry	(2b)	12	215.4	-50.5	163	3.0	2
Gulács, quarry	(3a)	9	164.6	-74.4	67	6.5	1
Gulács, quarry	(3b)	10	167.7	-74.5	1282	1.0	2
Badacsony, quarry	(4a)	7	153.1	-74.5	54	8.2	1
Badacsony, quarry	(4b)	8	122.8	-73.1	731	2.0	2
Diszel, Hajagos quarry	(5a)	32	177.6	-78.5	185	1.9	2
Diszel, Hajagos quarry	(5b)	8	177.1	-74.3	300	3.2	3
Ság Hill	(6)	4	179.1	-72.9	75	10.5	1
Kab Hill, upper flow	(7a)	2	196.8	-51.1	-	-	3
Kab Hill, lower flows	(7b)	12	170.7	-56.1	69	5.2	1
Kab Hill, lower flows 1st site	(7c)	8	174.3	-49.2	116	5.2	3
Kab Hill, lower flows 2nd site	(7d)	7	157.4	-62.6	36	10.2	3
Sátorma	(8)	5	251.7	-33.6	59	10.1	4
Tálódi erdő	(9)	5	200.9	-47.5	11	24.0	4

N: number of samples
D°: mean declination
I°: mean declination
K: precision parameter
α°_{95}: radius of the confidence circle at the 95 per cent probability level

Sampling locality		N	D°	I°	K	α_{95}°	Rererence
Tóti Hill, quarry	(10)	8	81.1	-42.7	42	8.6	3
Pula, outcrop	(11)	8	182.3	-41.9	109	5.3	3
Öcs, outcrop at the lake	(12)	8	170.1	-59.5	93	5.8	3
Ajka, outcrop I.	(13a)	9	155.1	-57.7	20	11.8	3
Ajka, outcrop II.	(13b)	9	157.9	-41.9	36	8.7	3
Pula, tuffs	(14)	4	303.8	-18.7	17	23.4	3
Midszentkálla, quarry, tuffs	(15)	5	333.5	+63.0	173	5.8	3
Tihany, outcrop I. tuffs	(16a)	6	4.1	+70.7	70	8.1	3
Tihany, outcrop II. tuffs	(16b)	4	12.3	+58.7	220	6.2	3
Hegyestű	(17)	5	9.8	+65.4	36	12.9	1
Uzsa + Szebike quarries	(18)	7	14.1	+56.1	17	15.1	1
Uzsa, quarry, 3 sites	(18b)	26	14.5	+54.3	569	5.2	2
Zalaszántó	(19a)	8	7.5	+51.1	444	3.0	2
Zalaszántó	(19b)	6	8.5	+61.8	125	6.1	1
Sümegprága, quarry	(20a)	5	3.8	+61.8	100	7.6	1
Sümegprága, quarry	(20b)	8	22.8	+47.0	352	3.0	2
Tátika	(21)	5	17.6	+68.6	100	7.6	1
Bazsi, quarry	(22)	6	1.1	+58.9	167	5.2	1
Vindornyaszöllős	(23)	7	35.6	+53.3	9	21.6	1

Reference 1. Márton and Szalay, 1968
2. Dagley and Ade-Hall, 1970
3. Márton, E. and Veljovic, in preparation
3. Márton, E., unpublished

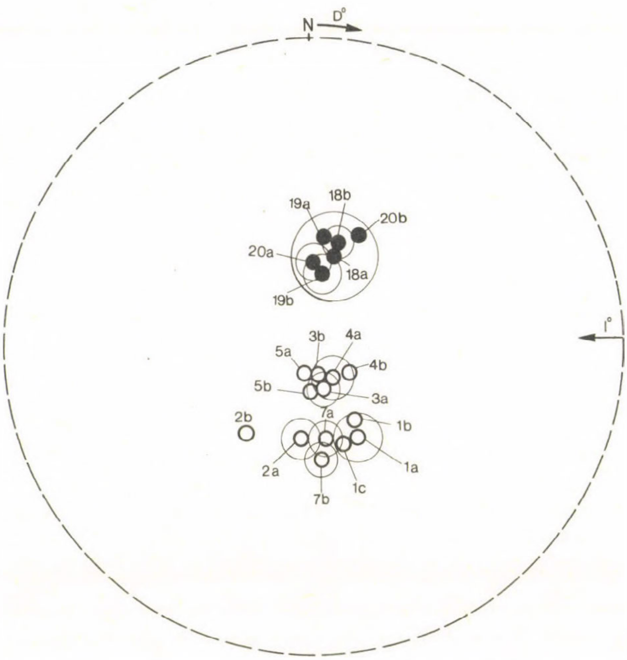

Figure 2 Comparison between the mean directions of the cleaned remanence determined by different authors. Stereographic projection. Hollow circles: negative inclinations, full circles: positive inclinations. Confidence circles at the 95 per cent probability level are shown only when the radius of the confidence circle is large enough to be shown. For labels refer to Table 1.

STRATIGRAPHIC INFORMATION

The palaeomagnetically studied localities belong to the upper part of the Pannonian Formation (JÁMBOR et al., 1981). Localities 6., 7.a., 8., 9., overly younger sediments (upper part of the Upper Pannonian) than the rest, they are therefore considered to be the youngest.

K/Ar DATING

Although the number of basalt occurrences with known K/Ar dates, (BALOGH et al., 1980, BALOGH pers. comm.) matches the number of palaeomagnetic localities, relatively few coincide *(Fig. 4.)*. The K/Ar isotope dates vary between 6 and 2.8 Ma. and this distribution in time suggests multiphase eruption activity. BALOGH et al. (1980) ascribe an error bar to each of the K/Ar isotope ages, which is generally moderate, but since they also suspect excess radiogenic ^{40}Ar in most samples, they conclude that the K/Ar dates for the basalts are probably in excess of their geological ages.

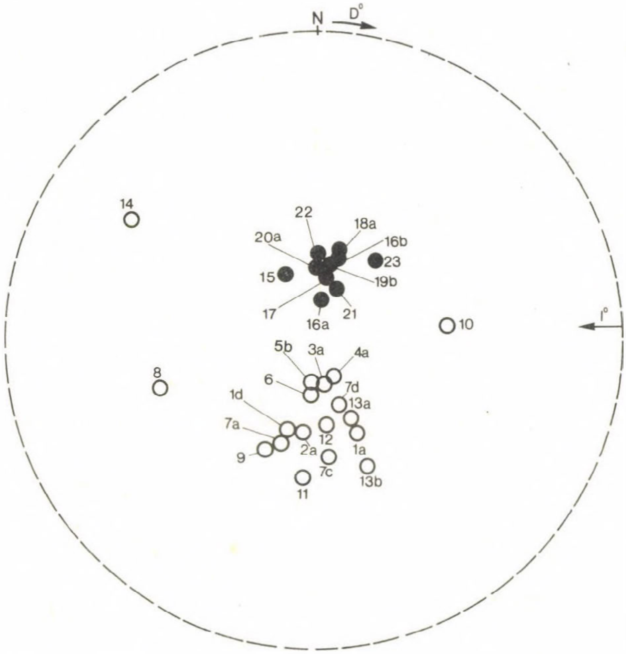

Figure 3 Mean directions of the cleaned remanences. One result for each locality. Stereographic projection. Hollow circles: negative inclination, full circles: positive inclination

DISCUSSION

Polarity zonation, when a reference polarity time scale is available, can be an effective tool for correlation and precise dating. The well-established polarity time scale for the last 5 million years, as well as older scales that slightly mismatch *(Fig. 4.)* can be referred to. Unfortunately, the succession

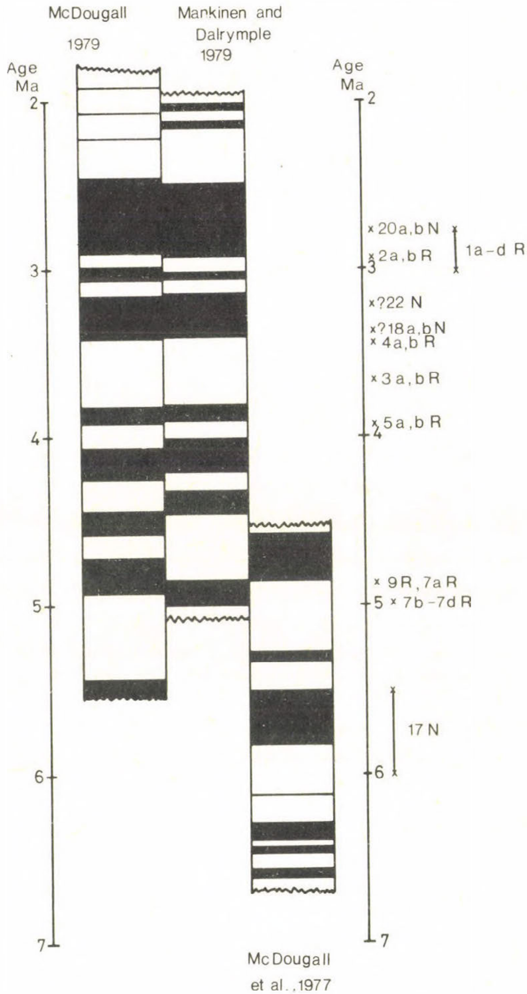

Figure 4 Reference polarity time scales and the K/Ar age + polarity information for some basalts from the Balaton Highlands. White: reversed polarity, black: normal polarity. K/Ar ages are plotted as crosses or crosses with an error bar between. Question marks mean uncertain age. Numbers refer to Table 1. N: normal polarity, R: reversed polarity

of the eruptions cannot be observed directly in the Balaton Highlands, except for a few volcanoes built up of more than one lava sheets (e.g. loc. 1. and 7. in *Table 1)*. The palaeomagnetic directions, however, can be tied to the reference scales via K/Ar or stratigraphic dating.

The upper and lower age limit of the upper part of the Pannonian Formation roughly correspond to 5 Ma and 1.8 Ma respectively, according to the 4th edition of the Geological Time Table (Elsevier, 1981, Amsterdam).

The overall K/Ar age of the basalt eruptions in the Balaton Highlands corresponds with this chronology. The K/Ar age of the individual lava bodies, however, provides a more refined subdivision than the stratigraphic observations. Assuming that the K/Ar age characterizes the age of the corresponding magnetization, the polarities together with the K/Ar age may be plotted against the reference scale *(Fig. 4.)*, which indicates that the reversed polarities are spread over a rather long interval, while the normal polarities are concentrated at the young end of the scale. The polarities, wherever known, agree with the expected polarity, i.e. the polarity zone of the reference scale. In other words, the available paleomagnetic observations and K/Ar ages for the respective localities do not contradict each other. It is interesting to note, however, that not a single normal polarity determination is known on lavas younger than 5 Ma, except in the Tapolca area. According to the reference polarity time scale, multiple reversals occurred between 5.00 Ma and 2.8 Ma, and one would therefore expect at least a few localities with normal polarity for instance in the Kab Hill area. Here the lava flows are thought to be early, middle and late Pannonian in age and even the K/Ar ages, although they narrow down the probable duration to the 5.00 - 4.25 Ma interval, would require magnetic reversals. The problems outlined above indicate that in spite of the significant progress made in the fields of stratigraphy, K/Ar age determination and palaeomagnetism, further efforts are needed to reconcile the results obtained from these different methods.

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THE ABSOLUTE CHRONOLOGY OF THE PLIO-PLEISTOCENE ALLUVIAL SEQUENCE OVERLYING THE PEDIMENT OF THE MÁTRA MOUNTAINS

M. PÉCSI - P. MÁRTON - F. SCHWEITZER - GY. HAHN

ABSTRACT

The North Hungarian Mountain Range consists mainly of Neogene (Miocene) volcanics. In the foreland of one of its members, the Mátra Mountains, the rock pediment can be followed as a narrow strip, and correlative sediments accumulated in the form of an alluvial fan along its subsiding margin. The alluvial fan series was deposited on top of littorial sediments of the Pannonian (Miocene-Pliocene) inland sea and contains lignite seams, which along with the cover deposits are exposed in open cast mine workings. The 25 to 35 metre series of alluvial fan deposits is interspersed with paleosols and horizons containing an exceptionally rich fauna. Biostratigraphic, morphochronological and paleomagnetic dating of this sediment enabled, the duration of Late Neogene pedimentation (about 5 to 2.5 m.y. B.P.) to be established in Central Europe for the first time.

* * *

The surface outcrop of the open cast lignite mine at Gyöngyösvisonta named after Yuri Gagarin allowed the establishment of the detailed chronological subdivision of the alluvial fan sedimentary sequence. The sequence is of Pliocene-Pleistocene age and was studied by an interdisciplinary team lead by M. PÉCSI. The geological, geomorphological, paleontological, paleomagnetic and lithostratigraphic findings of this research are briefly summarized below. For details see our English publication entitled "Quaternary Studies in Hungary" (KRETZOI, M. et al. 1982.).

GEOMORPHOLOGICAL, LITHOSTRATIGRAPHICAL, PALEONTOLOGICAL AND PALEOMAGNETIC EVIDENCE

When describing the lithology of the alluvial fan sequence (1 to 34 m) and interpreting its accumulation it was stressed

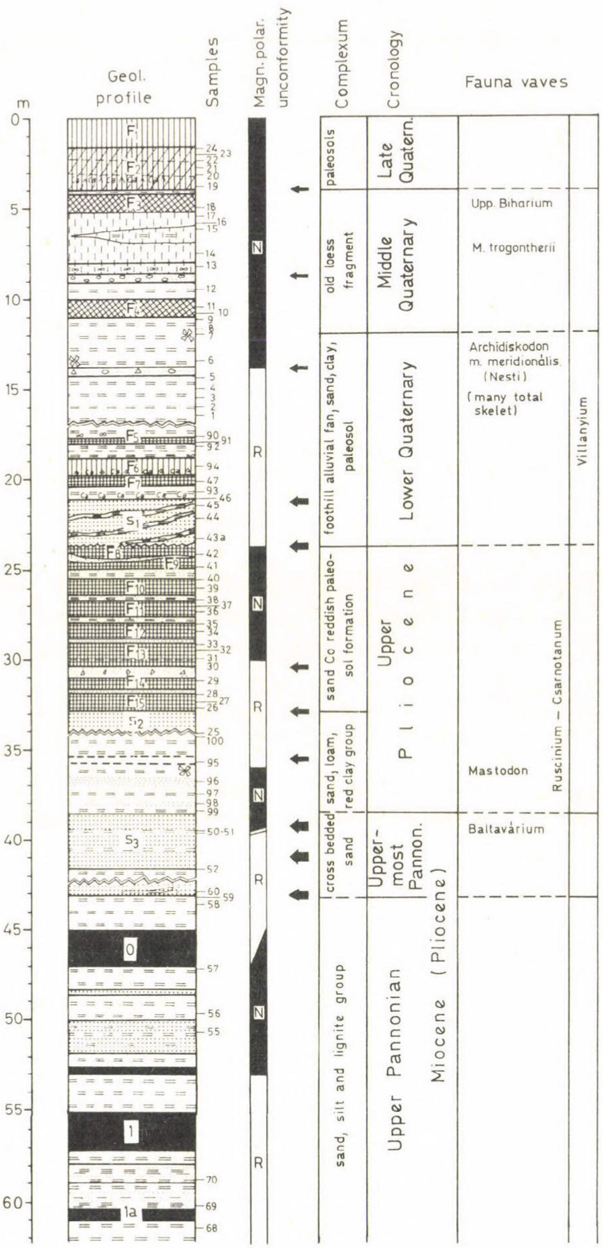

Fig. 1. Profile of the open cast lignite mine at the foot of the Mátra Mountains (1982)
The profile was surveyed and identified by J. BALOGH - P. MÁRTON - F. SCHWEITZER - Gy. SZOKOLAI under the guidance of M. PÉCSI.

Fig. 1

The correlative sediments for pedimentation are the reddish purple fossil soils (F_7 to F_{15}) and clayey rock detritus between fossil soil F_6 and sand layer H_3 .

(Profile is shown to 60 m, the lower part - 60-95 m - is only included in the description)

0.0- 1.6 m black meadow soil
1.6- 4.5 m old loess with remnants of B/BC soil horizon
4.6- 5.2 m brown forest soil
5.2- 8.1 m loess-like material, with yellow limy sandy intercalation at the base
8.1- 8.7 m yellow limy sand with tuff detritus
8.7- 9.2 m sand with andesite gravel and with Equus (Allohippus) süssenbornensis
9.2- 9.9 m flood plain clay soil
9.9-11.0 m dark-grey purplish flood plain clay soil
11.0-12.0 m $CaCO_3$ accumulation horizon
12.0-13.8 m grey clay with $CaCO_3$ concretions and tuff detritus (Mammuthus trogontherii and Bison sp.finds)
13.8-14.3 m sand with andesite gravel (Archidiskodon meridionalis find)
14.3-15.3 m clayey sand with tuff detritus
15.3-16.7 m grey clay soil of flood plain
16.7-17.7 m greyish-brown clay with tuff detritus
17.7-18.0 m purplish clay with tuff detritus
18.0-18.8 m greyish-brown clay with tuff detritus
18.8-20.4 m (reddish) brown clay soil
20.4-21.1 m limy, sandy old loess
21.1-23.7 m clayey sand (from 23.4 sand with tuff detritus)
23.7-25.0 m purplish aggregated clay (with yellowish-brown sandy tuffceous-detrital wedging)
25.0-25.5 m yellowish-brownish tuff detritus
25.5-26.4 m purple clay soil
26.4-26.7 m clayey sand with tuff detritus
26.7-27.6 m greyish-purplish clay soil
27.6-28.0 m clayey sand with tufa detritus
28.0-28.9 m purplish clay with tuff detritus at the base
28.9-29.1 m sand with tufa detritus
29.1-30.4 m purplish clay (from 29.9 m greyish-purplish clay)
30.4-31.0 m yellowish-brown coarse sand with tuff detritus
31.0-31.6 m purplish clay
31.6-31.8 m clay with tuff detritus
31.8-32.3 m purple clay with tufa detritus
32.3-32.7 m purple clay
32.7-34.0 m yellowish-brown sand with tuff detritus
34.0-35.8 m sandy clay with yellowish-grey purplish sand of tuff detritus and with Zygolophodon find
35.8-36.6 m crumbled clay with yellowish-grey ferrous precipitations of purplish shade
36.6-37.1 m coarse-grained sand with tuff detritus
37.1-37.9 m ferrous sandy clay

37.9-38.5 m sandy clay with tuff detritus with purplish tuff detritus at the base
38.5-41.5 m micaceous yellow sand with thin sandy mud intercalations
41.5-42.4 m greyish-greenish clay
42.4-43.1 m ochre-yellow clayey sand
43.1-45.0 m grey clay
45.0-47.0 m lignite
47.0-48.3 m grey clay
48.3-48.6 m yellowish-grey sand
48.6-50.0 m grey clay
50.0-51.8 m yellowish sandy clay
51.8-52.7 m grey clay
52.7-53.0 m lignite
53.0-55.3 m grey clay
55.3-57.2 m lignite
57.2-58.0 m grey clay
58.0-59.0 m greyish-yellowish muddy clay being more clayey at the base
59.0-60.5 m grey muddy clay
60.5-61.1 m lignite
61.1-62.4 m micaceous muddy clay
62.4-69.5 m micaceous fine-sandy mud interwoven with grey clay bands, from which water infiltrates
69.6-75.5 m grey clay
75.5-77.2 m grey fine-sandy mud
77.2-78.5 m grey fine-sandy mud
78.5-79.1 m muddy yellowish-grey clay
79.1-82.1 m micaceous yellow fine sand
82.1-84.2 m grey fine-sandy mud
84.2-89.6 m grey micaceous fine sand with clay bands
89.6-92.5 m grey micaceous fine-sandy clayey mud being more compact at the base
92.5-94.5 m lignite

that this formation was essentially produced by a combined erosion-accumulation mechanism during the course of which at least 15 episodes of soil formation and weathering took place; during soil genesis, there was no considerable sedimentation occurring. In addition, on 5 to 6 occasions, erosional unconformities were produced by sediment removal. These conditions as well as paleomagnetic sampling at intervals of 1 m are also to be taken into consideration.

Geomorphologically the sediments making up the profile represent an alluvial fan the surface of which is older than the Middle Pleistocene terraces of neighbouring small streams.

In the uppermost part of the alluvial fan, at depths of between 1 and 6 m, three fossil soils directly overlie each other; in the soil F_2 cryoturbation phenomena also occur. Paleontological finds derived from the base of the old loess between 6 and 9 m, as well as from sandy clays containing tuff detritus at depths of 12 to 13 m are assigned to the Early to Middle Pleistocene, starting at the beginning of the Brunhes epoch of normal polarity (0.7 m.y. BP.). This is supported by the fact that samples derived from this part of the profile are all of N polarity *(Fig. 1.)*.

The horizon containing *Archidiskodon meridionalis* jaws is separated from the horizon below it by an erosional unconformity *(Fig. 1.)*. According to the paleontological interpretation this find belongs to the Upper Villányium (KRETZOI, M. et al. 1982).

The sequence in the open cast mine at Visonta is interpreted at a 40 to 50 m wide and 6 to 10 m deep derasional valley infilling. The *Archidiskodon meridionalis ürömiensis* finds of Lower Biharian age found earlier in another section at a depth of 3 to 4 m suggests, that the upper third part of the alluvial fan also belongs to the lower part of the Middle Pleistocene. On this older alluvial fan surface derasional valleys were formed and then infilled during the Middle Pleistocene (Upper Biharium).

At a depth of 14 and 24 m the deposits exhibit reverse polarity and are subdivided by two or three redbrown paleosols (F_5 - F_7) underlain by several metres of sand. In connection with the deposition of this sand a considerable erosional gap was formed. Based on its position this section of the profile may be assigned to the lower *incomplete part of the Matuyama epoch.*

Biostratigraphic and paleopedological analogies (e.g. Dunaföldvár; PÉCSi, M. 1982, 1984) suggest that the purplish red soils (F_8 - F_{15}) were formed during the Csarnótanum, while the Mastodon-bearing purplish soil-bearing horizon at a depth of 36 to 39 m is Ruscinium in age *(Fig. 1.)*. According to the paleomagnetic measurements the upper and lower parts of the sequence are of normal and only the middle section is of reverse polarity. In the uncertain zone of R polarity two sand horizons and erosional unconformities are found. Based on comparative analyses of paleomagnetic, lithostratigraphic, paleopedological and paleontological data, the sequence can be related to the Gauss and Gilbert epochs.

The Upper Pannonian formation with lignite seams *(Fig. 1.)* is lithostratigraphically an index horizon in the Pannonian basin margins that can be correlated with the *Congeria balatonica* horizon in the lacustrine formations (BARTHA, F. 1971, JASKÓ, S. 1981) and with the Sümegium of the terrestrial biochronology (KRETZOI, M. - PÉCSI, M. 1982). Consequently, the major part of this sequence (N between 45 and 53 m, and R between 53 and 95 m) can probably be related to the 7th and 8th magnetostratigraphic epochs, respectively *(Fig. 1.)*.

The coarse sand and clay-sand formations (38.5 - 43 m in depth) lying between the lignite-bearing Upper Pannonian and the alluvial cover member overlie each other but are separated by considerable erosional unconformities. This stratigraphic unconformity extends over both the sands containing *Unio wetzleri* (Baltavárium) and the Mastodon-bearing tuff-detrital purplish clay (Upper Pliocene, Ruscinium). This phenomenon is characteristic of this whole zone throughout the North Hungarian Mountains and along the Great Plain margin (JASKÓ, S. 1981). The hiatus rapidly increases when moving towards the mountain margins, so that the lignite-bearing sequence and even the deeper Pannonian horizons are absent. It seems likely to that the zones of the H_3 sands in our profile with an R-N-R polarity are to be associated with the Gilbert and 5th and 6th magnetostratigraphic epochs respectively.

In the eastern exposures in the open cast mine at Gyöngyösvisonta this eroded lignite-bearing sequence is about 50 m thick, although in boreholes local occurrences of 100 to 200 metre thickness are also known. During its formation the mountain foreland and the basin margin periodically subsided with lignite formation occurring during relatively tranquil periods. The uplift and erosion of the lignite -bearing formation may have started at the boundary of the Gilbert and 5th paleomagnetic epochs (5.4 m.y. B.P.), i.e. at the beginning of the Ruscinium. Of the subsequent tectonic movements the Upper Biharian which resulted in the selective erosion and dissection of the older alluvial fan material in the mountain foreground zone is the most important.

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THE ECONOMIC GEOLOGICAL IMPORTANCE OF THE LIGNITE AT THE FORELAND OF THE NORTHERN HUNGARIAN UPLANDS

Gy. HAHN - Gy. OSWALD - L. SÁG

ABSTRACT

The defined productive area of 230 km^2 is situated north of the Budapest-Miskolc railway mainline, in a length of 120-140 km E-W with a N-S width of 8-12 km (FÜST, A. et al. 1980).

The cut-off values of the reserve calculations are:

- a subsurface depth of max. 200 m
- a seam thickness more than 1 m
- a thermal value above 4020 kJ/kg
- a maximum overburden ratio of 1:20 m/m

This is the economically most valuable portion of the area occupied by the so-called "Pannonian" (Upper Miocene) inland lake, where 81.6 per cent of the country's economically recoverable lignite base is concentrated, with an in situ value of Ft 300 billion (HAHN, Gy. et al. 1984).

The Cserhát-Mátra-Bükk foothills lignite area presents the most favourable parameters of all Hungarian lignite occurrences. The mineral resources requirements for the development plans of Hungarian power plants can be met the most easily from these sites, and that is the reason, why the establishment of open-pit lignite mines (with almost inexhaustible reserves) should have precedence among the long-term concepts of coal mining.

The implementation of these plants may give rise to Hungarian coal production, which has been stagnating at about a 25 million tonnes per year production level for many years.

MINERAL EXPLORATION AND MINING - A HISTORICAL OUTLINE

The geological investigation of the andesite mass of the Mátra Mountains began at the end of the 18th century with the description by the mineralogist FICHTEL, J. E. (1791). Lignite extraction in the Mátraalja dates back to the end of the last century (1890, Rózsaszentmárton). In the Bükkalja region lignite was mined at Bogács in the middle of the last century (1850-1870). Between the two world wars some enterprises were engaged in underground mining (CSILLING, L. et al. 1979).

The exploitation of the considerable lignite resources had not started earlier, since - on one hand - long-distance transport is not possible because of their low thermal value, and on the other, that only the reserves above +100 m above the level of the Adriatic sea could be taken in consideration, since technical conditions at that time did not allow mining below the water table or its subsidence. Between the two world wars the Lőrinci Power Plant and adjacent shafts were established north of the town Hatvan. The subsurface mining of lignite stopped in the late 1960s which was motivated partly by the exhaustion of reserves and partly by the changes in mining technology. The open-cast mine at Ecséd operated from 1957 to 1973 and it was the first successful experiment of economical open-pit mining of lignite. In the open-cast and subsurface mines of the Western Mátra area considerable reserves remained after their abandonment (150 million tonnes of geological reserves, of which 65 million tonnes were economically recoverable) (MADAI, L. 1976; HAHN, Gy. et al. 1984). Subsequently, the present production technology began to be employed at Visonta where, instead of through entries, an annual 23 million m^3 of water is removed through surface filtering wells. In 1968-69 the Gagarin Power Plant, based on the lignite resources and the approximately 7 million tonnes per year production of the Visonta open-pit mine, was adapted to produce 800 MW electric energy. At present, it is the economically optimal power plant in Hungary, although in the seventies hydrocarbon based plants were constructed, too.

Of the resources at the foothills of the Mátra Mountains about 130 million tonnes have been extracted to date - primarily to be used in power plants. Four-fifths of the production came from open-cast mines and one-fifth (cca 24 million tonnes) from underground mines; the latter part had a higher thermal value (SZOKOLAI, Gy. 1982, 1984).

The total lignite production of the Mátra-foothills area till 1984 is shown in *Table 1*.

STRATIGRAPHY

Among the xenolits of the volcanic formations of the Mátra Mountains, some probably Paleozoic or older rocks were found. Permian and Mesozoic formations of the Bükk type (limestone and slate) are also assumed to be present in the basement Eocene transgression was restricted to the northern margin of the Great Hungarian Plain. In the Southern and Southwestern Bükk Mountains Eocene formations occur in the area of Demjén, Egerszalók and Recsk. Oligocene sediments of 600 to 1000 m total thickness also occur in the area.

The marine sedimentation was interrupted in the early Miocene and rhyolitic tuff of great thickness covered the

Table 1. Data of lignite production at the Mátra foothills

	Shaft (Enterprise)	Operational interval	Production in tonnes
1	Ferenc Rádi and Associates	1912-1917	1.300
2	Mátravidék Coal Mines Corporation	1918-1947	3,290.360.4
3	Hungarian National Coal Mines Corporation	1948	132.355.0
4	Petöfi adit	1949-1964	7,594.525.4
5	Rózsa VII. shaft	1949-1951	308.840.0
6	Rózsa IX. shaft	1951-1969	5,443.264.5
7	Szücsi X. shaft	1955-1962	1,571.644.1
8	Szücsi XI. shaft	1955-1959	552.091.4
9	Gyöngyös XII. shaft	1950-1967	5,170.246.3
10	From investment funds	1958-1967	182.299.7
11	Total underground mining	1912-1969	24,246.926.8
12	Ecséd open-pit	1969-1983	15,080.914.3
13	Visonta (Thorez) open-pit	1969-1983	82,382.705.0
14	Total open-pit mining	1957-1983	97,463.619.3
15	Sum total	1912-1983	121 710.546.1

Bükk foothills and the surface of the variable andesite series subsided to a depth of 1000 m in the southern foreland of the Mátra Mountains.

After the volcanic phase ended, Upper Badenian Leitha Limestone and glauconitic--clayey sandstone and limestone were deposited at the western foothills of the Mátra Mountains. These formations are overlain by Pannonian (s. str.) to the west of the Sárhegy and at the eastern foothills, and by Sarmatian strata to the east. The Sarmatian series is constituted of alternating terrestrial and semihaline strata.

In the Pannonian basin a Caspian-type brackish-water sedimentary series of great thickness and of Pannonian (s.l.) age can be found. The non-productive beds of the series are characterized by an inland-type oligohaline fauna.

Lithostratigraphically the lignite-bearing sequence can be assigned to the Bükkalja Lignite Formation, which can be characterized by marine (littoral), semihaline (paludal and lagoonal) and freshwater (fluviatile) facies.

The middle part of the Upper Pannonian can be divided into two units on the basis of fossils, litho- and biofacies, paleoenvironmental and paleogeographical evidence.

At the foothills of the Mátra, the removal of Pannonian layers was less significant than at the foothills of the Cserhát and Bükk. The lower horizon with *Congeria balatonica* is characterized by shallow and contiguous water, while of the other, "oscillational" horizon, dissection into partial lakes and repeated marsh formation is typical. The first paludal intercalations occur at the top of the horizon with *Congeria balatonica and Prosodacna vutskitsi* which means that the main period of lignite formation was the upper level of the middle part of the Upper Pannonian formation, the so-called "oscillational" horizon. The final oligohaline bed of the "oscillational" horizon is called marker horizon; it is generally overlain by fluvial sand with *Unio wetzleri*, which is the base of the upper part of the Upper Pannonian (BARTHA, F. 1971, 1974, 1975).

In the lignite-bearing series, from the base to the cover the percentage of sand layers decreases (42.8-39.5-21.8), while that of clay layers increases (3.6-7.8-16.5); the percentage of lignite, clayey lignite and lignitic clay is around 15 per cent. In the footwall limestone beds, while in the hanging wall sandstone beds occur infrequently (SZOKOLAI, Gy. 1982, 1984). The regular order of deposition between the formation of the two lignite beds is coarse sand, sand, clayey sand, sandy clay--clay and lignite. The productive series is synorogenic, the lignite, closing the subsidence phase and the coarse sand, indicating the beginning of uplift are almost simultaneous. The final sediments of the upper part of the Upper Pannonian in the Mátra and Bükk foothills lignite area are shown in *Fig. 1*.

The lignite beds have a uniform gentle (1 to 3°) S-SE dip. This dip exceeds that of the covering layers which increase in thickness towards the south. The top of the lignite-bearing series was reached at 100 m depth in the zone of Hatvan--Kál--Kápolna--Mezőkövesd and at 250 to 280 m in the zone of Jászberény--Heves. The isopleth map of the closing

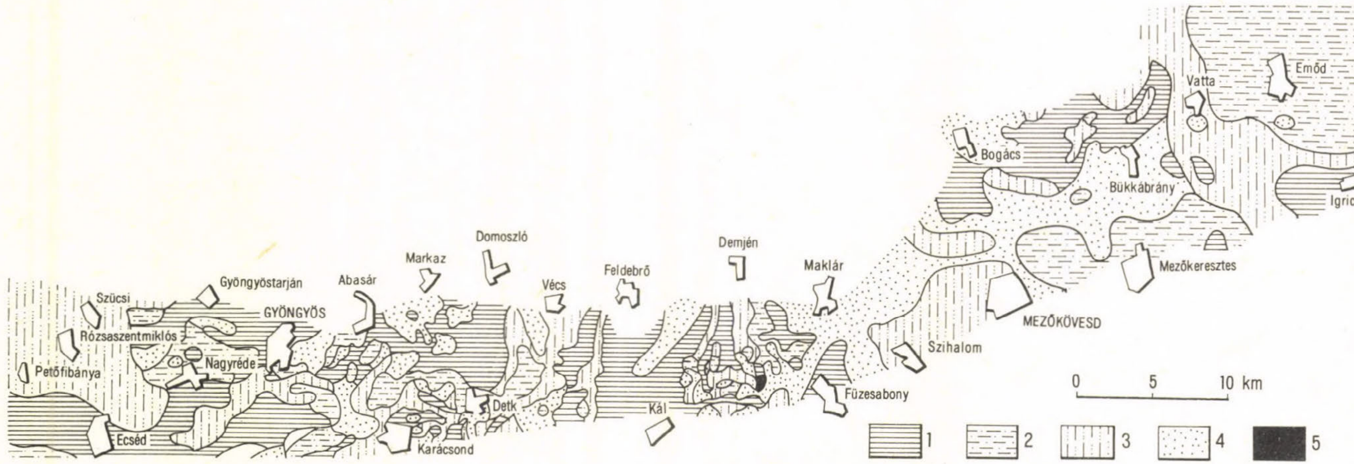

Fig. 1 Lithological map of the Upper Miocene-Pliocene and Pleistocene boundary in the southern foreland of the Mátra and Bükk foothills (by BALOGH, J., FLANEK, Z., HAHN, Gy., JUHÁSZ, Á., LÓCZY, D., MOLNÁR, K., NEMES, I., RINGER, Á., SÜDI, A. and TÓZSA, I.)
1 = clay; 2 = clayey sand; 3 = sandy clay; 4 = sand; 5 = rhyolite tuff

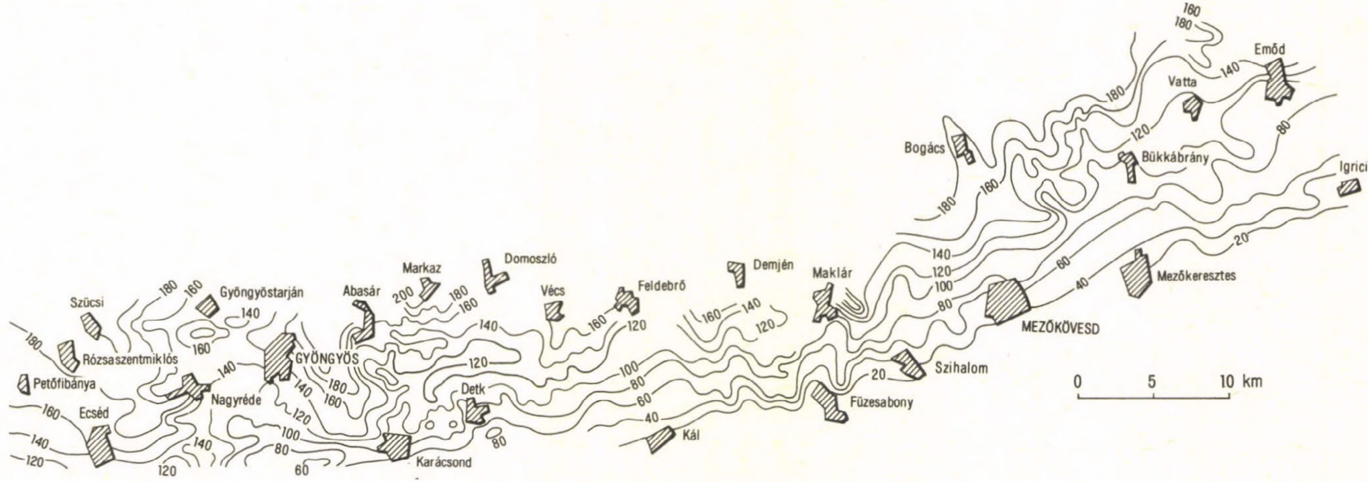

Fig. 2 Isopleth map of the Upper Miocene-Pliocene and Pleistocene boundary surface in the southern foreland of the Mátra and Bükk foothills (by BALOGH, J., FLANEK, Z., HAHN, Gy., JUHÁSZ, Á., LÓCZY, D., MOLNÁR, K., NEMES, I., RINGER, Á., SÜDI, A. and TÓZSA, I.)

member of the lignite-bearing series *(Fig. 2)* well demonstrates the tilting of the original surface towards the south. The total thickness of lignite beds grows with depth: it is 30 m to +100 m depth; 60 m to 0 m; 130 m to -100 m and 220 m to -200 m.

Where fully developed, the lignite-bearing series attains thicknesses of 150 to 250 m. In the southern forelands of the Cserhát, Mátra and Bükk Mountains no correlative sediments of denudation are found in the Upper Pannonian lignite-bearing series. This unambiguously supports the assumption that all the mountain ranges were uplifted during the Pliocene with the change of previous directions of denudation and accumulation. For the Upper Pannonian inland sea stage it can be postulated that material was not transported from areas beyond the present mountains through gaps, but the sediments arrived perhaps from the south, southeast or west (e.g. from Transylvania). The most obvious evidence for altered post-Miocene (post-Pannonian s.l.) relative relief conditions and of material transport from the north is the deposition of reworked rhyolite tuff of 50 to 80 m thickness of the lignite-bearing series in the area of Vatta and Mezőnagymihály. It cannot be accurately defined what degree of change took place in the direction of erosion associated with the geologically rapid change in relative relief. In lack of evaluation by main productive horizons, the original coastline cannot be reconstructed. The answer to this paleogeographical question would include information on the age and horizons of the terrestrial series deposited after the Upper Miocene (Pannonian s.l.).

PALEOGEOGRAPHICAL CHANGES SINCE THE SARMATIAN

As a result of the Middle Miocene uplift of the Carpathians, the contiguous system of Carpathian basins formed, with the present foothills of the Cserhát, Mátra and Bükk Mountains on its margin. The bulk of Pannonian (s.l.) sediments exceeds those of any other geological formations. The maximum thickness of neritic clay, clayey marl, aleurite and fine sand amounts to 3500 to 4500 m. The enclosure of the inland sea is indicated, apart from the complete absence of haline individuals, by rich brackish water fauna of molluscs and ostracods as well as various microplankton remains.

Above the Sarmatian sediments the Pannonian is of transgressional nature. The first stage of the Upper Pannonian is outranging even the previous formations; its middle member is transitional with oscillations and the arrival of typically freshwater elements. This series contains about 70 per cent of the hydrocarbon reserves of Hungary and 65 per cent of the production comes from them. Uppermost Pannonian sediments overlie earlier formations with the exception of the area of Bükkábrány. After the formation of beds II. and III. the upper part of the Upper Pannonian became of regressional character (CSILLING, L. et al. 1979; SZOKOLAI, Gy. 1982, 1984).

Relative uplift is observed both on the basin margin and on the area of denudation, and simultaneously subsidence becomes more intensive in remote parts of the basin. All these are manifested in the diversity of the lignite-bearing series, in the typical bed separations and in the common appearence of thin accompanying beds. Over the youngest beds clayey (montmorillonitic, kaolinic and other) sediments, deriving from the weathering of andesite and rhyolite tuffs in the northern foreland, occasionally occur. The further uplift of the basin margin and the slower subsidence of the basin represent the final phase of lignite bed deposition. With the uplift of the northern foreland a new drainage network become dominant. Lignite seams still formed south of the original shoreline in a freshwater environment.

The final event of the whole Pannonian is the intensive terrestrial denudation of the volcanic rocks of the Mátra and the Paleo-Mesozoic sedimentary rocks of the Bükk. The uplift of the mountain framework was not uniform, the elevation of the Bükk preceded that of the Mátra and thus, in the 6 to 8 km wide foreland of the former region Quaternary accumulation took place and the removal of Upper Pannonian sediments locally exposed Lower Pannonian. In the Pliocene (after the Pannonian s.l.), the character of deposition and the paleogeographical picture changed.

On the eroded surface of the Upper Pannonian inland lake formations, which include the lignite-bearing series of the foothills of the Mátra Mountains, a varied terrestrial cover sequence deposited during the Quaternary pedimentation.

To draw the boundary between the two periods is difficult, because in the series there are traces of unconformity surfaces in several horizons. In the final Upper Pannonian series a characteristic bentonite marker is also found, associated with a strong unconformity surface, separating clearly the two groups of formations. After the lignite formation in the Upper Pannonian the area remained continental. The denudation due to uplift was only resisted by hard rocks and, thus, scarps were formed. The submarine deltas of the Upper Pannonian major river are succeeded by the system of alluvial fans accumulated by several small streams in the Pleistocene.

The exposures of open-pit mines allowed an extremely minute subdivision of the alluvial fan sediments. The cover series on the pediment can be divided into two distinct terrestrial alluvial fans of different origin (KRETZOI, M. et al. 1982; PÉCSI, M. et al. 1985).

ECONOMIC GEOLOGICAL AND MINING PARAMETERS OF THE LIGNITE AREA

Within each explorational area separate numbering systems were developed; thus, for the identification and parallelization of the lignite seams the geologists of the Mátraalja Coal Mines created a unified registration system. All over the area, based on the analysis of the abandoned Western Mátraalja unit, to still operating Visonta and the best explored Bükkábrány units, 18 groups of lignite seams could be identified (06, 05, 04, 03, 02, 01, 0, I, I/a, I/b, II, III,

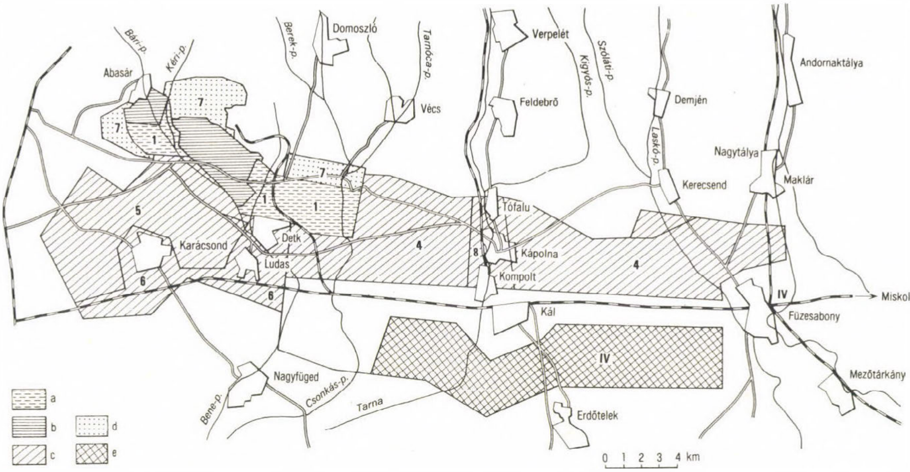

Fig. 3 Production units of the Eastern Mátra foothills lignite deposit (Visonta-Karácsond-Ludas-Kál-Füzesabony and vicinity)
a = operating mine; b = abandoned mine; c = explored area; d = reserve area; e = areas to be explored; 1 = Thorez open-cast mine; 4 = Kápolna-Füzesabony; 5 = Karácsond-Ludas; 6 = Karácsond abutments; 7 = Visonta-Tódebrő; 8 = Kápolna and vicinity abutment

III/a, IV, V, VI, VII, VIII) (CSILLING, L. et al. 1979; SZOKOLAI, Gy. 1982, 1984). The workable sections of beds are controlled by seam thickness, quality and subsurface depth.

In the middle Mátra foothills area, the *Karácsond--Detk* partial lignite basin was merged with the Visonta K I. open-pit mine. The reserves (from bed 0 to bed III) are of 9.5 m average thickness and include 250 million tonnes of recoverable lignite of 7300-8800 kJ/kg thermal value, with an 8 m^3/t overburden ratio on an area of 30 km^2. One third of the economically recoverable reserves (84 million tonnes) was judged in 1978 to be joined with the Visonta K I. open-pit mine (FAUR, Gy. 1978). The merger of the quarries would allow the increasing of the power plant capacity by 200 MW (see *Table 2*). In the meantime the almost complete exhaustion of the Visonta K I. open-pit mine and the allocation of the Visonta K II. mine made it impossible to turn from the above open-cast mine to the Karácsond-Detk lignite deposit (see *Fig. 3*, with the reserves of the area). Other difficulties are presented by the relocation of the M-3 freeway and by the proposal of the Central Office of Geology (HAHN, Gy.-OSWALD, Gy. 1978-1979) for the exploration of the Kápolna--Füzesabony area.

As a result of the explorational works performed during the last few years, the reserves of the *Kápolna--Füzesabony* area became better known and appeared more favourable than before (concerning its quality, quantity and the parameters of mining; see the data in *Table 2*) (FAUR, Gy. 1978). The alternative plan of mine allocation (1978) ranked this partial basin only second to the Bükkábrány one, although even then the supply of a 2500 MW power plant was intended to be ensured from here. The larger western half of the deposit is directly adjoinable to the operating Visonta K II. open-pit mine (see *Fig. 3*). The relief, geological and hydrogeological conditions of the western, Kápolna partial basin show similarities with those of the Visonta--Tódebrő area, with higher thermal values, but with more deeply situated lignite seams. Below the Quaternary cover of 60-90 m thickness, 5 workable beds can be found to Kápolna (Nos II, I, 0, 01, 02) and 3 beds to Füzesabony (Nos II, 0 and 02). In the former area the average thickness of seams is 16.5 m, the thermal value is 6500 to 7300 kJ/kg and overburden ratio is 5.8 m^3; the same data for the latter partial basin are 13.5 m, 6700-9000 kJ/kg and 6.2 m^3/t (FAUR, Gy. 1978).

In 1978 a mine and a power plant were planned. The open-pit mine and the power plant is to be located in the focal point of the two lignite fields. Rail access can be ensured from the Kál--Kisterenye line and road communication is to be provided from the M-3 freeway. Yet it can be assumed, that the Kápolna lignite deposit of considerable reserves and, in our present knowledge, of the most favourable parameters, will not serve an independent power plant, but shall be attached to the extended and reconstructed one at Visonta.

Since the 60s, as an alternative to Visonta, the *Bükkábrány* lignite field at the Bükk foothills is ready for mining *(Fig. 4)*. The slightly rolling area of 100 to 150 m a.s.l. is traversed by five water-courses which dissect it to 10 to 20 m depth. In the area the M-3 freeway, the Budapest--Miskolc main railway line and several high voltage transmission lines are aligned and their relocation has to preceed the allocation of an up-to-date major mine.

The mine and the power plant are included in several proposals since 1974, but in the 70s hydrocarbon based power plants and at present nuclear plants preferred, although feasibility studies prove that thermal plants are competitive with the previous types (see data in *Table 2*) (TAKÁCS, T. et al. 1977; FAUR, Gy. 1978).

The allocation plan of the Bükkábrány mine includes the simultaneous operation of two or three deposits, which equally serves the stability of production and overcoming the severities of the climate. In one part of the mine the extraction of lignite from a 6-10 m main bed and an underlying 2-3 m accompanying bed is planned; in the other part 3 to 7 beds, maximum 15 seams are to be mined, to a depth of about 80 meters. Almost 90 per cent of the geological reserves is planned to be exploited. Net seam thickness is 12 m on the average, water yield is only 1 m^3, ash content is 21 per cent and water content is 45 per cent. Mine production capacity would be 18.3 1o 21.2 million tonnes per year, while technical productivity and overburden ratio is also very favourable (see *Table 2*). The establishment. of the mine allows the construction of either a power plant of 2000 MW capacity,

Table 2 Major technical-economic parameters of the planned mine

Name		Bükk-ábrány	Kál and Kápolna	Nagy-réde	Erdö-tarcsa	Kará-csond-Detk
Operational coal reserve	(Mt)	550.9	693.1	158.7	286.2	84.1
Heat reserve	(Pcal)	905.9	1090.3	234.0	441.7	146.5
Thermal value	(kcal/kg)	1644	1573	1474	1543	1741
Overburden ratio	(m^3/t)	5.33	7.21	5.80	8.38	7.91
	(m^3/Gcal)	3.24	4.58	3.93	5.43	4.54
Basic investment	(10^9 Ft)	15.2	23.9	6.5	11.0	3.5
Supplementary investment	(10^9 Ft)	4.5	3.7	0.8	0.7	0.7
Related investment	(10^9 Ft)	2.8	2.1	0.6	1.0	0.3
Constant production	(Mt/year)	20.2	29.2	7.6	10.0	3.3
	(Pcal/year)	35.0	44.0	10.5	15.5	6.0
Investment cost per 1 tonne coal reserve	(Ft/t)	27.6	34.6	41.0	38.3	36.0
Basic investment cost per 1 tonne coal reserve	(Ft/t)	753	819	854	1100	913
Reduced prime cost	(Ft/t)	95	118	118	125	135
Total capacity	(t/plant)	23.7	23.4	17.1	15.8	8.0
Total demand for labour	(person)	3875	5715	2000	2805	1850

(After calculations by Dr Gy. Faur 1978)

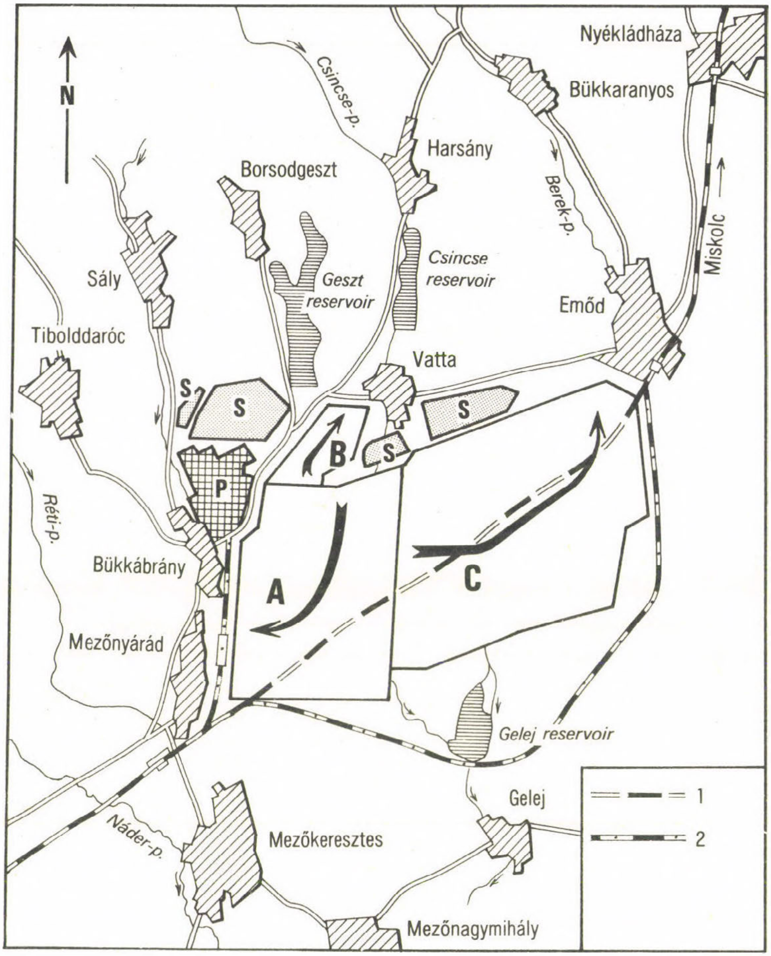

Fig. 4 The allocation plan of the Bükkábrány open-pit mine and power plant
1 = present railway to be relocated; 2 = planned new railway alignment; P = power plant; S = spoil-heap; A, B, C = open-pit mines

or the production of 2.1 billion m³ natural gas per year + 44o thousand tonnes of liquid hydrocarbon + 180 thousand tonnes of sulphur + 40 thousand tonnes of synthetical ammonia, or the extraction of 3 million tonnes of synthetical ammonia + 440 thousand tonnes of liquid hydrocarbon + 180 thousand tonnes of sulphur per year. The alternatives mentioned are variable within themselves and need about the same investments costs (TAKÁCS, T. et al. 1977).

The road and rail communication of the mine and the power plant are easy to ensure in this area of developed infrastructure.

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Recognizing the great significance of this field of research, several experts and teams from Canada, West Germany, the USA and the USSR also joined in the work of Hungarian specialists.

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