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GEOGRAPHICAL RESEARCH INSTITUTE
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QUATERNARY STUDIES IN HUNGARY

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PREFACE

"Quaternary Studies in Hungary" is published as a separate volume by the Geographical Research Institute of the Hungarian Academy of Sciences with the support of the Hungarian National Committee of the INQUA on the occasion of the 11th Congress of the Union. The studies on Quaternary topics by Hungarian researchers prepared for the previous congresses of the INQUA were published in the Földrajzi Közlemények /Geographical Review/, the periodical of the Hungarian Geographical Society /Földrajzi Közlemények 1969, 1973, 1977/. This time a Hungarian delegation of experts from many sciences can participate at the present INQUA Congress organized in Moscow and more research results are waiting for publication than could appear in the numbers of the Földrajzi Közlemények.

Quaternary research in Hungary looks back to a long history since an overwhelming part of the country is covered by Quaternary geological formations in which a number of already world famous biostratigraphic finds and ancient human settlements occur. A great number of geologists, geomorphologists, geobotanists and archaeologists study the Quaternary history of Hungary. Moreover, in the last decades the industrialization of the country and the agricultural development and melioration have necessitated the thorough elaboration and application of engineering geological research methods. The volume "Quaternary Studies in Hungary" is primarily aimed at the publication of scientific results achieved since the loth congress and in some papers more general surveys are given of the progress made in Hungary in the research concerning Quaternary litho-, biostratigraphy and chronology.

The 11th Congress of the International Quaternary Association to be held in Moscow also commemorates the semi-centennial anniversary of the first congress in Leningrad in 1932.

With the present volume of studies the Hungarian researchers of the Quaternary intend to contribute to the fifty-year productive activity of the Union and wish the members successful conferences and a fruitful international collaboration for the future.

M. Pécsi

PLIOCENE AND QUATERNARY CHRONOSTRATIGRAPHY AND CONTINENTAL SURFACE DEVELOPMENT OF THE PANNONIAN BASIN

KRETZOI, M. - PÉCSI, M.

Hungary is situated in the central part of the Carpathian or Danubian Basin.

We try to outline the Pliocene and Pleistocene biostratigraphical and morphochronological geological evolution of Hungary, i. e. practically of the Carpathian Basin, when attempting at a correlation with regions to the east and west.

When establishing the correlation two aspects were taken into account: the first is to use the data of events which can be fixed in time and not repeated in other periods, i.e. versible and which affected wider regions. In other words, the data concerning events which might have been repeated or might have been independent of time were neglected. The second aspect was the critical application of radiometric data.

Only the lithological and paleomagnetic results were accepted which were verified by at least one of the methods above within the limits of sedimentation.

We aimed to correlate and clarify the geological events of global or at least on regional scale by means of which the historical reality and the significance of our correlations can be assured.

From this point of view the events as well as their imprints are assigned to three groups:

1. Large-scale changes in marine water quantity, salinity and extension - at stratigraphic-chronological points determined either by biological methods or by the study of evaporite horizons.

2. Global climatic changes of cosmic origin in the Pleistocene investigated by paleobiological, glaciological, geomorphological and some other methods.

3. The reconstruction of the ancient surface by means of detecting unconformity surfaces and other sedimentation hiatuses /terraces, travertine layers, etc./ with the possible stratigraphic correlations of large-scale zonal events.

The events indicated under point 1 are as follows: first of all the Middle and Upper Miocene "salinity crises" of Rögl-Steininger-Müller /RÖGL - STEININGER - MÜLLER, 1978/, the Sarmatian /Pannonian drying crisis of Zalányi /ZALÁNYI,B. 1944/ as well as Lóczy's Upper Pannonian aridization crisis /LÓCZY, L. in KORMOS, T. 1911/ the latter being cited as the "Messinian salinity crisis" testified by the evaporite horizons explored in the boreholes of the Mediterranean Sea.

In the second point the cross-checked data of the geomorphologist, the sedimentologist and the biostratigrapher have been collected.

Finally, under point 3 the documentation of the geomorphologist have been collected for a final synthesis.

Regarding the manysidedness of the complex topic, the sedimentologist-geomorphologist /PÉCSI, M./ and the paleontologist-biostratigrapher /KRETZOI, M./ try to give this review together.

Nevertheless, the knowledge on glacial forms, terrace research and the study of marine terraces absent in the intra-continental zone and explored in other regions and classified into the chronological system will hardly be touched upon or will completely be neglected. Instead, when exploring and classifying the ancient surfaces the data concerning the research of large surfaces have been collected since the terrestrial geological history attaches greater importance to "geomorphological surfaces" than to marine stratigraphy and takes into account both these and the sediment complexes in the reconstruction of former geological conditions. Research in this field increasingly relies on data obtained by other disciplines /e.g. archaeology, climatology, astronomy, isotope and nuclear physics, geophysics etc./ in order to reach a synthesis which is a special requirement of terrestrial geohistory as opposed to marine geology.

Consequently, in this paper a geomorphologist and a biostratigrapher jointly attempt to outline the Late Cenozoic stratigraphic, morphogenetic, paleoclimatic, paleobiological synthesis of the Carpathian Basin.

Theoretically our review should be launched at the beginning of the Late Cenozoic, i. e. with the early Miocene. However, this is avoided for two reasons. First, although abundant marine biostratigraphic evidence is available from the periods preceding the Miocene/Pliocene boundary /apart from the rich Oligocene vertebrate fauna of Bodajk/, practically only few and small terrestrial vertebrate faunas from pre-Pliocene localities were found in this area. In Western Europe on the other hand, in France in particular, a variety of rich vertebrate fauna is known from the whole of the pre-Pliocene period. These provide an almost closed, uninterrupted chronological faunal succession for nearly the whole Tertiary period. Our terrestrial stratigraphy, ending with the Miocene, should be linked in this respect, to the existing classifications in the West, based on biosuccessions /MEIN, 1975. etc./. Secondly, the oldest "living surfaces" in our region date back to the very beginning of the Pliocene and hence the succession of "geomorphological surfaces" could only be traced in the Pliocene and the Quaternary.

Relying on the basic concepts of terrestrial stratigraphy and chronology, which started with POMEL /1853/, our chronological history restricted to the Pliocene and Quaternary, was elaborated in the past sixty years, founded on continuous biosuccessions with stratotypes mostly in the Carpathian Basin /MÉHELY, L. 1914; KORMOS, T. 1915-1937; ÉHIK, Gy. 1921; KRETZOI, M. 1927-198o; MOTTL, M. 1938, 1942; JÁNOSSY, D. 1965-1979; KORDOS, L. 1976/.

In the area of the Central Paratethys the Sarmatian strata subsequent to the Badenian marine sediments /SUESS, 1866/ can be regarded to be the closing member of the Miocene /KRETZOI, M. 1979, 1981/. In the littoral zone, in limestone-marly-clayey-sandy formations these sediments are characterized by Miocene marine and brackish faunal elements of restricted species number /BODA, 1966/, while in the intra-basin occurrences clay-sand sequences alternate with special faunas of small species number. Downwards, to the Badenian it shows transitions while upwards to the Pannonian it is closed by a sharp boundary both in the littoral sequences /sharp deposition unconformities, basal conglomerate, etc./ in the intra-basin occurrences /pyritic-sapropelitic, fauna-free drying horizons with the overlying Lower Pannonian transgressional sediments with fundamentally new fauna/.

The regression and practical disappearance of the Sarmatian sea followed immediately by the large-scale Pannonian transgression that can be identified with the Sarmatian-Pannonian and with the sharp Miocene-Pliocene boundaries, respectively. The profile section traversing the depth interval of 25-3o m of the borehole Tisztaberek No 3 representing this transition, can be indicated as a boundary stratotype in the interpretation of Zalányi, B. /ZALÁNYI, B. 1944/.

It is to be noted here that partly due to incomplete knowledge on the Sarmatian terrestrial fauna, this boundary is characterized by the appearance of humid-forest elements at the beginning of the Pannonian as opposed to the arid-forest and savannah-like faunal assemblages characteristic of the Badenian; otherwise only percentage changes of the fauna elements can be observed.

The boundaries in the central Paratethys Basin can be observed to the west in the Vienna Basin in the more frequent occurrence of unconformities due to the smaller scales and further to be west by the earlier completion of filling in the shallow North-Alpine margin /Obere Süsswasser Molasse/. To the east, however, at the end of the Bessarabian /Rostovian/ of the Sarmatian stage /BARBOT de MARNY, 1869/ the sapropelic phenomena and the impoverishment of the fauna /except Mactra/ show the drying out as a boundary sharply drawn by Zalányi in the sedimentary basin of the Great Plain. By its geological importance this can be regarded as the Sarmatian-Pannonian boundary, in marine stratigraphy as the Miocene-Pliocene boundary. Consequently, in can presumably[x] be parallelled with the Serravallian /Tortonian boundary if the radiological age difference of 1.5 to 2 million years would not question the validity of this assumption.

POST-SARMATIAN TERRESTRIAL STRATIGRAPHY AND EVOLUTION

The regression of the Sarmatian brackish sea from the central and western part of the Paratethys as well as the development of a new Pannonian brackish inland sea is the closing event of European "orthostratigraphy" based on the history of the Mediterranean and a local brackish, and, when filled up the deposition of a terrestrial stratigraphic sequence was initiated independent of the Metatethys[xx]-Paratethys system. The European terrestrial stratigraphic system is the continuation and completion of the European Tertiary biochronology started in Western Europe /POMEL, A.N. 1853; GAUDRY, A. 1873, 1878/ and developed recently /KRETZOI, M. 1927-1981; v.d. WLERK - FLORSCHÜTZ, 195o? CRUSAFRON-PAIRÓ, 195o, 1965; THALER, 1966; MEIN, 1975, etc./. This biostratigraphic succession is independent of marine stratigraphies, but by means of its well-known possibilities for correlation it is suitable to solve correlation problems especially where the individual marine basins separated from one another are unsuitable in themselves to direct correlation. Thus, though in this paper the terrestrial development of the Carpathian Basin will be outlined by means of connecting the biosuccessions and morphological events, the correlations with Lyell's and Mayer-Pareto's units of marine stratigraphy will always be indicated /though the correlations are not indispensable and not always of the same order of magnitude/.

The Post-Sarmatian biosuccession sequence extends temporally over two formation groups: the sediment sequence of the Pannonian brackish inland sea /i.e. Pannonian formation/, and the fluvio-terrestrial Danubian formation subsequent to the Late

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[x] Taking the difference between the Serravallian and Tortonian as the respective form of the Mediterranean Sea.

[xx] The Tethys basin persisted after the separation of Paratethys.

Pannonian drying period /LÓCZY's "Pontian aridization", 1911, i.e. the so-called "Messinian salinity crisis" determined recently in the basin of the Mediterranean Sea/. The former corresponds to the Pannonian of the malacological stratigraphy of Hungary /Eppelsheimium and Baltavárium/, the latter, i.e. the Danubian formations include the Montpellierium, Villafranchium, Biharium and Pilisium /Peribaltium/ with some phase shortening corresponding to the acceleration of events. Three fauna succession periods are found in the Eppelsheimium /Monacium, Bodvaium, Rhenohassium/, four in the Baltavárium /Csákvárium, Sümegium, Hatvanium and Bérbaltavárium/, two in the Montpellierium /Ruscinium and Csarnótanum/, two in the Villafranchium /Beremendium and Villányium/, two in the Biharium /Gromerium and Mosbachium/ and two in the Peribaltium[x] /Oldenburgium and Utrechtium/. A brief outline of their biochronological and morphological development will be given below along with an attempt to make correlation with Eastern and Western European stratigraphies and with those of other principles and nomenclature /TABLE 1/.

Outside the area of Lower Pannonian sedimentation marine forms /wave-cut platforms, sandy pebbly bars/ around the Transdanubian Mountains are represented by geomorphological surfaces lying lower than the younger Upper Pannonian marine terraces. It is probably caused by the relationship between the substrate and the Lower or Upper Pannonian sedimentation. The exposed Lower Pannonian formations have in all cases a Paleozoic-crystalline rock base. The Upper Pannonian layers on the other hand overlie a Mesozoic-Tertiary substrate. A plausible explanation for this phenomenon may be that the mountains had undergone repeated subsidence after the Lower Pannonian and only the submerged blocks were affected by Upper Pannonian transgression and were overlain by its sediments. The blocks situated higher at the time of the transgression, the marginal areas were not inundated in this latter stage and only have a Lower Pannonian sedimentary cover.

EPPELSHEIMIUM /POMEL, 1853/

Stratotype: Eppelsheim /BRD/, Hipparion fauna of Dinotherium sands; parastratotype: Rudabánya /NE-Hungary/, Hipparion fauna and rich paleoflora /KRETZOI, M. et al. 1976/ in lignitiferous Pannonian formation. - Terrestrial stratigraphic analogue: Vallesiense /CRUSAFRONT-PAIRÓ, 1951/. - Characteristics: the Late Miocene arid forest fauna type is mixed with a lot of marsh-forest element, the genus Hipparion becomes predominant, the Miocene elements resp. their major part show evolutionary species change. - In the history of Paratethys remarkable change followed when the brackish sea regressed and dried up, this has been manifest in the neighbouring terrestrial parts only by the humidization effect of the inundation of the inland sea, though this

[x] See footnote "x" on page 14.

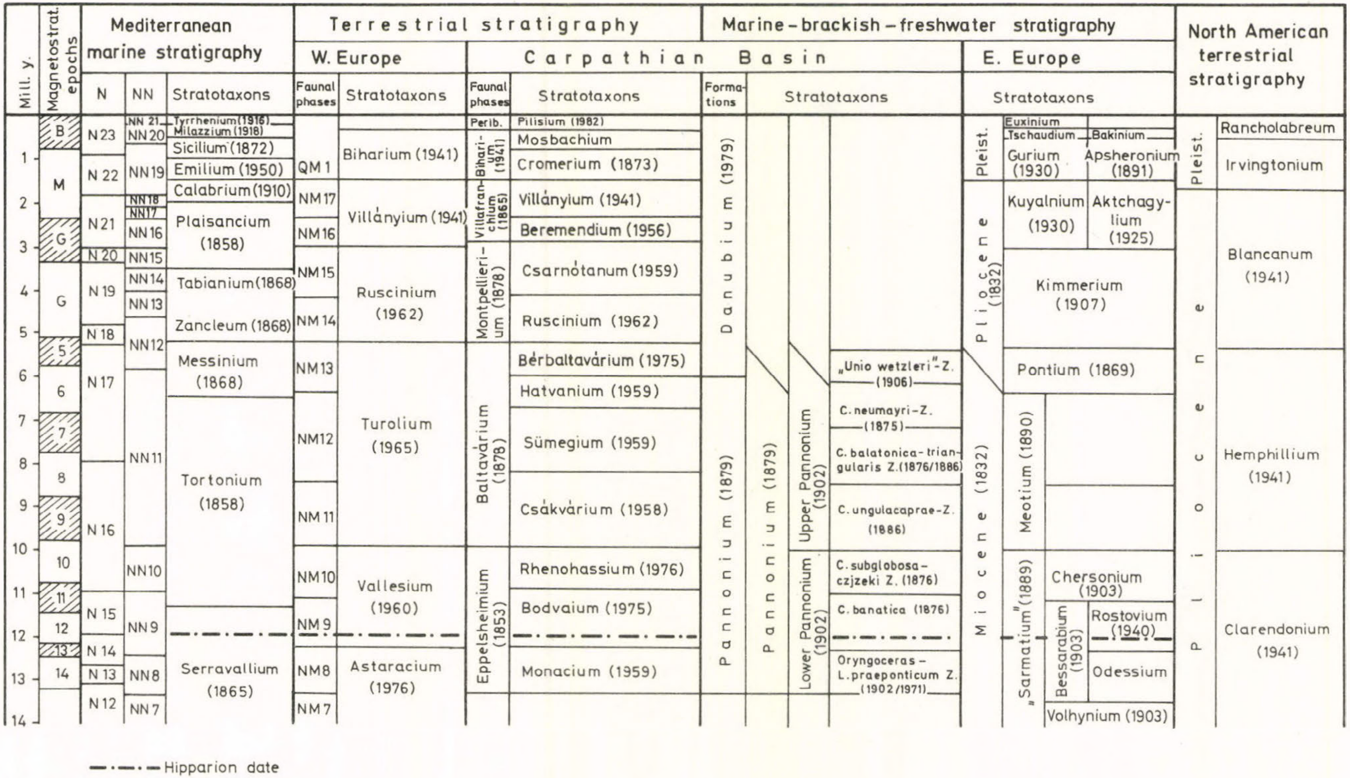

TABLE 1 Stratigraphy of the Carpathian Pliocene and Quaternary with accepted correlations

proved to be sudden. The lower boundary was outlined in the foregoing part; in its upper boundary aridization and the sudden decrease of salinity of the inland sea can be demonstrated /KORIM, K. 197o / this phenomenon being accompanied by the large-scale though gradual disappearance of the Miocene elements transient to the Eppelsheimium. This boundary is manifest more sharply by the new feature of the terrestrial fauna of the Baltavárium /see there/. The correlation downwards was discussed earlier, its upper boundary can be drawn locally in the west by the Vallesium /Turolium/and can be identified by the progress of new fauna elements /Muridae, Leporidae, Ochotonidae, etc./. The correlation with the Sarmatian-Meotian sequence of Eastern Europe as well as its upper boundary are not clear yet. Three members can be distinguished: Monacium, Bodvaium and Rhenohassium.

M o n a c i u m /KRETZOI, M. 1969/ - stratotype: Munich, Flinzsande /BRD/. - Its main faunistic characteristics are that in addition to the appearance of new taxons developed from Miocene elements, the Hipparion which predominates later in the Bodvaium is absent. The sedimentological change accompanied by malacofaunitic changes are much more sharper, indicated also in case of the Sarmatian/Pannonian boundary, which separates it from the Miocene and relates to fundamentally new, the Paratethyan conditions. Analogues in the Carpathian Basin: sand mines at Diósd and Sopron, the locations of foundry and glass sands /KRETZOI, M. 1941, 1961/

B o d v a i u m /KRETZOI, M. 1975/ - stratotype: Rudabánya /NE-Hungary/, lignite-bearing grey clay-sand formations with vertebrate rate and mollusc fauna and paleoflora /KRETZOI, M. et al., 1976/. - Characteristics: appearance of Hipparion fauna which fundamentally preserved the Miocene structure and the more humid warmer character, showing the predominance of the wet-biotop elements. Due to the Hipparion invasion its lower boundary provides exact biostratigraphic date for Europe, being at the same time a significant terrestrial-geohistoric date, as well /concerning the marine evolution this is given by the lower boundary of the Monacium/. The correlation with the marine stratigraphy of Western Europe is uncleared yet /Hipparion in the Seravallium/ and in Eastern Europe also only the Hipparion date assures the correlation.

R h e n o h a s s i u m /KRETZOI, M. 1976/ - the upper member of the Eppelsheimium the stratotype being the Dinotherium sand with Hipparion fauna at Eppelsheim. In addition to the forms of Bodvaium the newly immigrated elements relating to South Asia are characteristic /"Microstonyx", Machairodus etc./, their appearance being accompanied by the disappearance of forms of partly the same cenologic role /e. g. Albanosmilus/. Its upper boundary is the same as that of the Eppelsheimium /see there/. Its analogue in the Carpathian Basin includes the upper sandy members of the Lower Pannonian /the asphalt-sand fauna of Tataros/.

Following the end of the Lower Pannonian transgression the rivers arriving from the Alp-Carpathian mountain arc deposited their sandy, gravelly coarse debris in large deltaic fans reaching in places the margins of the Transdanubian Mountains /Bakony Mts.; Billege gravel; Gerecse Mts.; Dunaalmás, Dunaszentmiklós/. These sediments may form truncated patches of geomorphological surfaces in the Western Gerecse and Buda Mountains /SCHEUER, Gy. - SCHWEITZER, F. 1978; WEIN, Gy. 1974/, however in these mountains they remain mostly buried under the travertines /FIG. 1/.

BALTAVARIUM /GAUDRY, A. 1878/

Stratotype: Baltavár /nowadays: Bérbaltavár/, W-Hungary, Hipparion fauna in the clayey lenses of the sands with Margaritoides flabelliformis /sands with Uno wetzleri/. - Synonyms /in the terrestrial stratigraphy/: Pikermiense /CRUSAFONT-PAIRÓ, 195o; recalled in 1965/, Turoliense /CRUSAFONT-PAIRÓ, 1965/. - Characteristic fauna: as against the fauna of Eppelsheiumium these are exactly Pikermian faunas with Hipparion-antelope predominance with more open, and at the end with extreme steppe elements. The faunal composition differs from that of the Eppelsheimium in the appearance of Muridae, true Ochotonidae, Agriotheriidae, gigantic Dinotherium and others, as well as in the disappearance of most of the Miocene relict species. The period is characterized by the frequent change of the fauna which relates to the rapid and frequent changes of paleoecological conditions.

Four substages can be distinguished: Csákvárium, Sümegium, Hatvanium, Bérbaltavárium, which differ from one another so that the historic reconstruction of the Baltavárium seems to be outlined when describing each substages. The reason is that the upper boundary of Baltavárium does not coincide with the upper boundary of the Pannonian stage /i.e. the Pannonian brackish inland sea formations/ since the upper part of Baltavárium extends over the lower members of the Danubian formations.

At the beginning of the Baltavárium /early Upper Pannonian substage: Csákvárium/ the Pannonian transgression entered the valleys and embayments of the mountains, abraded marine platforms and left sediments /sand, travertine/ over on the older planated surfaces of the relatively lower parts of the horst blocks /Balaton Highland, Vértes, Buda Mountains/. The marine terraces around the horst blocks are situated at different elevations /Gerecse, Buda Mountains; FIG. 1 and 2/.

C s á k v á r i u m /KRETZOI, M. 1958/ - Stratotype: the Hipparion fauna of the Esterházy-cave at Csákvár /W-Hungary/. - Faunal characteristics: in addition to the predominating European Hipparion-Cervida fauna elements the appearance of Leporidae, Ochotonidae, Muridae, Neocricetodon, great Agriotheriidae /Agriarctos, Agriotherium/ and Tapiriscus, and in case of rodents their large-scale appearance. The mollusc faunas give the horizon of Congeria ungulacaprae. Its analogue is first of all the Gau-Weinheim fauna assemblage of the Rhine trench.

The rich vertebrate fauna /of the stratotype of Csákvár/ in the Esterházy cave seems to indicate that the marine terrace marked by the presence in several places of abrasional gravel conglomerates Vértes and Buda Mountains /FIG. 1/ had formed in the earlier period of the Upper Pannonian. On the basis of its geological and geomorphological position it may be supposed that the oldest /Kapolcs/ travertine niveau of the Balaton Highland /being older than the Nagyvázsony travertine/ which lies on top of the Lower Pannonian sediments was also formed during the Csákvárium substage.

S ü m e g i u m /KRETZOI, M. 1959/ - Stratotype: the fauna of the clay filling the fissures of Eocene limestone at Sümeg-Kajmát /KRETZOI, M. 1979/. - Characteristics: fauna assemblage sharply differing from the fauna type of the Csákvárium, with apparently great number of southern elements /Graphiglis, Hyaenictis, Hipparion "matthewi" etc./ with some new forms /Allospalax/ and with some immigrating forms from Central Asia and Asia Minor /Ovina/. - Similarly to immigrants from the south, the flora /Rózsaszentmárton/ relates to the warm climax of the Baltavárium /palm. etc./. The mollusc fauna constitutes the horizon of Congeria balatonica-triangularis, with the first appearance of Viviparus in the Pannonian Basin.

Regarding the general surface evolution it should be mentioned that the Várpalota marine terrace foothill of Eastern Bakony is covered by freshwater limestone formed in the middle and later phases of the Upper Pannonian /BARTHA, F. 1955/. The marine terrace had then probably been formed during the Csákvárium substage at the beginning of the Upper Pannonian. A marine terrace of similar age and relative position is situated along the southern margin of the Vértes Mountain. Occasionally two such platforms were found here, situated one above the other /marine terraces Nos 2 and 2a/.

In other cases, in the northern margin of the Gerecse Mountains deltaic gravels cemented with sand and sandbanks constitute the substratum of the Upper Pannonian travertines. In the thick travertine cover of Kőhegy /292 m a.s.l./ in the Gerecse Mts. abundant specimens of the "Unio wetzleri" mollusc assemblage were discovered. Below the travertine cover on the Kőpite /292 m. a.s.l./of Gerecse Mts. in several meter thickness of delta gravel were deposited. At the bottom of those layers /and even in the white sand/ angular blocks of travertine and debris could be observed. This would indicate that the formation of the Bérbaltavárium sands was preceded by at least one /or two/ stages of Upper Pannonian travertine deposition.

It is possible therefore that the travertine niveaus around Nagyvázsony /28o-32o m a.s.l./ in the Balaton Highland, and in the Gerecse and Buda Mountains /33o, 4oo-48o m a.s.l./ are somewhat older, or of different age than the travertine cover of Várpalota. The travertines of the Széchenyi-hill, in the Buda Mountains may belong to the Sümegium /KRETZOI, M. 1976/.

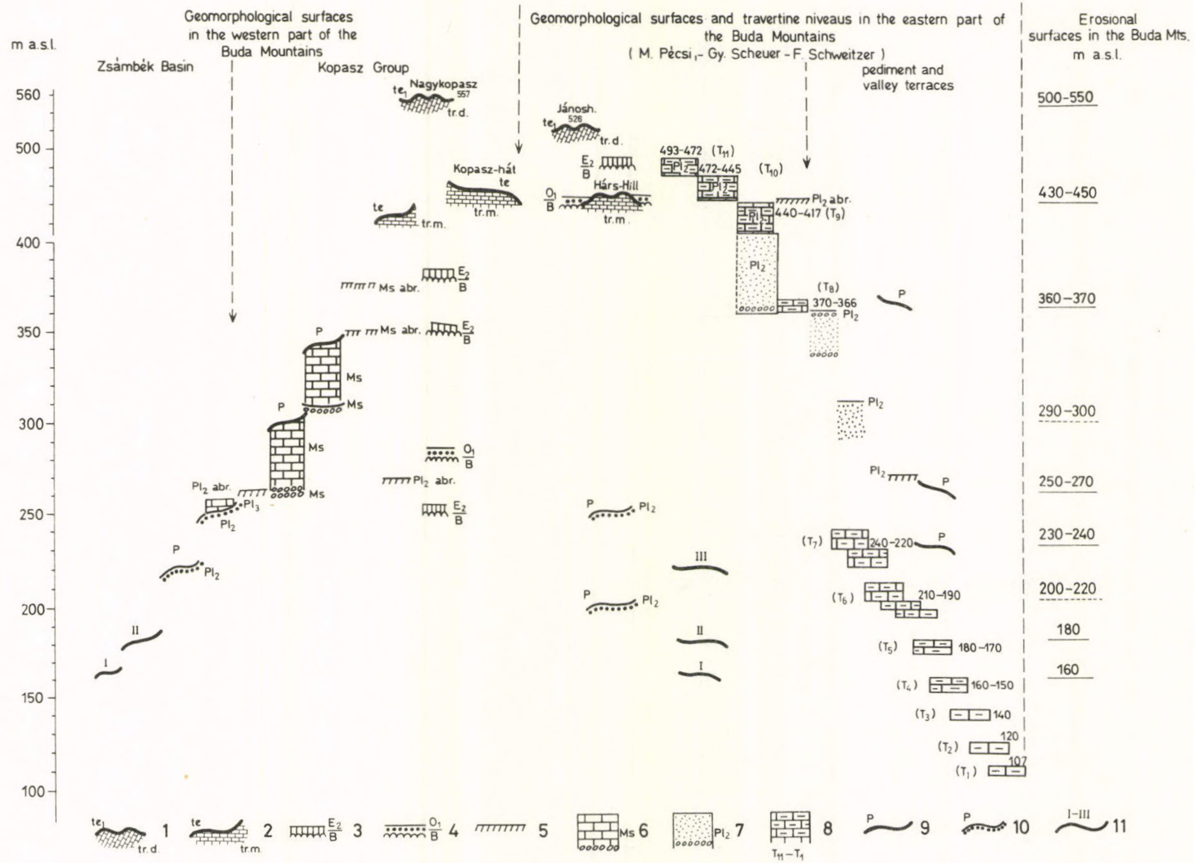

FIG. 1 Sketch of the main "geomorphological surfaces" in the Buda Mountain /PÉCSI, M.198o - based on data by PÉCSI, M. 1963, 1975; SCHEUER, Gy. - SCHWEITZER, F. 1974; WEIN, Gy. 1977/

1: exhumed Mesozoic peneplain in summit position on Upper Triassic dolomite /Tr.d/; 2: remnant of exhumed Mesozoic peneplain on Upper Triassic Dachstein limestone /Tr. m/; 3: buried Mesozoic peneplain, remains of tropical karst and bauxite under Eocene limestone; 4: buried Mesozoic peneplain, bauxite and tropical cone karst under Oligocene sandstone; 5: wave-cut platforms; M_s: Sarmatian; Pl_2: Upper Pannonian; 6: Miocene Sarmatian gravel and "coarse" limestone; 7: Upper Pliocene gravel, sand, clay; 8: freshwater-limestone /travertine/niveaus: Upper Pannonian Pl_2 - Pleistocene; 9: Upper Pliocene pediment on hard rock; lo: Upper Pliocene pediment on unconsolidated sediments; ll: Pleistocene derasional terraces, debris fans and flat slope segments on unconsolidated sediments.

H a t v a n i u m /KRETZOI, M. 1969/ - Stratotype: the vertebrate fauna of the Pannonian profile of the Hatvan brick-yard /GAÁL, I. 1944/. Characteristics: as opposed to the Sümegium relating to warm climate and with southern relations, the fauna composition is completely changed, with forms immigrated from North-China and Siberia and with Colobinae /Mesopithecus/ relating to Asian forms. - The mollusc faunas show the last phase of the Pannonian brackish formation, the faunas with Congeria neumayri with well-developed freshwater-terrestrial element. From the geohistorical point of view this is the youngest formation of the drying Pannonian inland sea.

The 3o m thick travertine overlying the Várpalota marine terrace is a non-terrestrial stratotype of the middle and later phase of the Upper Pannonian /BARTHA, F. suggest that the upper layers should be fixed as "neostratotype"/. In this upper part he identified "Unio wetzleri" sand. According to the succession of vertebrate biozones the formation of the Upper Pannonian Várpalota travertines continued event into the Bérbaltavárium substage /sand formation/. In would also mean that at least part of the Upper Pannonian travertine, formed simultaneously with the pedimentation /with its major, climax stage/ of the mountain margins.

The Pula bituminous shales recovered from the bore drilled in a basalt crater in the Balaton Highland is of about the same age as the lower layers of sediments containing Congeria balatonica. The lower strata of the Nagyvázsony travertine are considered as correlative with the bituminous shales. A basalt tufa /No. 2/ is interbedded in the lower layer of the Nagyvázsony travertine. The upper stratum of the travertine contains the basalt tufa No. 3 with basalt overlying it. According to the detailed investigations by JÁMBOR, Á. and SOLTI, G. /1976/ based on borehole data the infilling of the basalt volcanic plug can be correlated with basalt No. 2. In their stratigraphic classification this latter is younger than the Congeria ungula caprae strata, hence it is younger than the Csákvárium. The above data suggest that the double stratum of the Nagyvázsony travertine is interfingered with the basalt, basalt tufa layers No. 2 and No. 3. The stratigraphic profile of Jámbor, Á. and

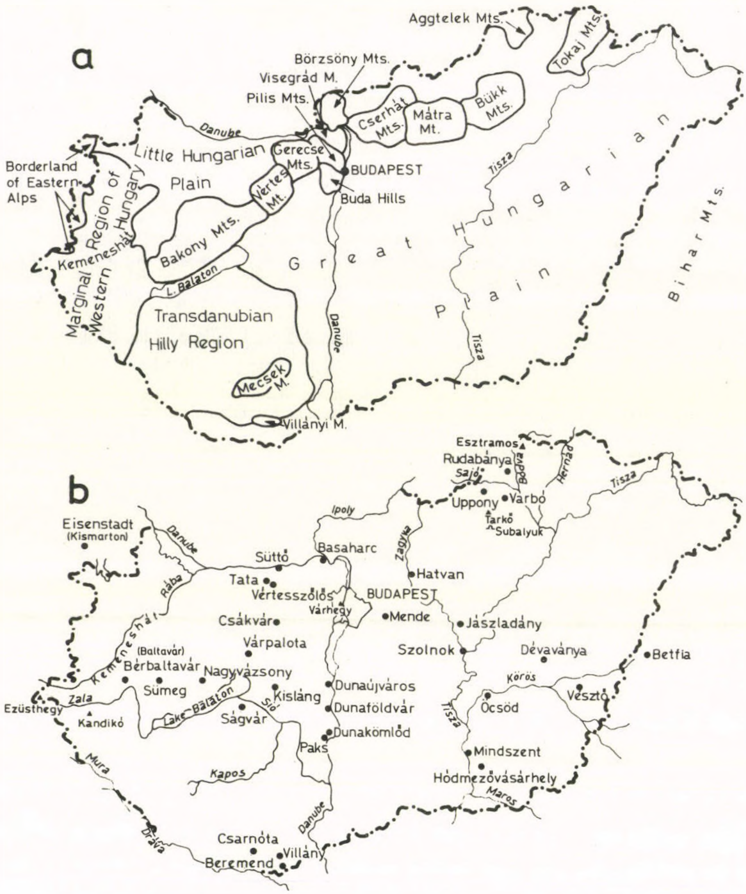

FIG. 2 /a/ Main physiographic units of Hungary
/b/ Late Cenozoic localities in Hungary

Solti, G. also depict older travertines overlying the Lower Pannonian clay marls. The so-called Kapolcs travertine of the Balaton Highland may be classified as belonging to the lower part of the Upper Pannonian and occur together with Pectinaries aleurite and quartz sand. This would mean the beginning of travertine deposition in the Balaton Highland which may go back as far as the Csákvárium. In cannot be ruled out then that the oldest travertine niveaus in the Buda Mountains /Szabadság-hill, 474-49o m a.s.l.; FIG. 1/ and in the Gerecse Mountains could perhaps be also of the same age.

Looking at the problem from an other aspect, the basalts and basalt tufa surfaces of the Balaton Highland developed in 2-3 stages during the Upper Pannonian. On the Kemeneshát, on the other hand, younger basalt tufa was found underlain by the Rába fluvial gravel. In other instances the Rába gravel overlies the Upper Pannonian basalt tufa /Gérce basalt tufa ring, JÁMBOR, Á. - SOLTI, G. 1976/.

B é r b a l t a v á r i u m /KRETZOI, M. 1976/ - Stratotype: the vertebrate fauna of the sand-clay sequence with Unio wetzleri of the vineyard at Baltavár /Bélbaltavár/. - The Baltavárium represents the sediments of the fluvial system developed instead of the drying Pannonian inland sea, with the fauna assemblage of Margaritifera flabelliformis /"Unio wetzleri"/ with a lot of terrestrial elements /Tacheocampylaea doderleini,other Helicidae etc./. The absolute new feature of its sedimentation, its morphogenetic activity as well as its vertebrate fauna of Füvespuszta, led Lóczy, L. already in 1911 to assume aridization at that time. The results of the large-scale drilling activity initiated the investigation of the basin sediments of the Mediterranean Sea which revealed in the last years the same pieces of evidence for this drying period /termed "Messinian salinity crisis"/.

On the basis of the stratigraphic conditions outlined above, it appears that the rivers flowing from the marginal areas ot the basin, the Alpine and Danubian drainage networks deposited in several places mostly sandy deltaic deposits. The situation was similar to that experienced in the Csákvárium, at the end of the Lower Pannonian and the beginning of the Upper Pannonian. The alternation of regression and transregression had been accompanied then by the formation of sandy, gravelly deltaic deposits.

According to earlier investigations /PÉCSI, M. 1963/ the Pliocene pediment developed during the Bérbaltavárium; it seems probable that its development commenced prior to the Csákvárium substage and continued even during the Ruscinium /terrestrial Pliocene or "Levantinian"/. From the karst fissures infilled by terra rossa, which developed on the pediments of the Villány Mountainsthe Csarnótanum faunal assemblage had been recovered. Patches of red clay were also found in other places on pediments /e.g. below the gravels of Ezüsthegy on Kemeneshát overlying the Bérbaltavárium sand; in the foothills of the Mátra

Mountains on the top of the Upper Pannonian lignitic sandy clays; in the Central Gerecse and Eastern Bakony etc./.It seems reasonable to suppose that the slow development of the pediment surface lasted even during the Csarnótanum. In the Northern Gerecse, on the other hand, the lower lying pediments are covered by lacustrine travertines those containing "Unio wetzleri" fauna, and by a gravel sheet younger than the Pannonian. In the marginal areas of the mountains the /Late/ Pliocene pediments developed during a long interval of four or five million years /MÁRTON, P. - KRETZOI, M. - PÉCSI, M. - SCHWEITZER, F. - VÖRÖS, I. 1982. see in this volume/.

Though there is a sharp contrast between the faunas of the Hatvanium and Bérbaltavárium and this provides instances also to such sudden faunal changes, the transition between the Bérbaltavárium and the subsequent Ruscinium should have been much more gradual. This is suggested by the fauna of Balta known since Wenjukow /19o2/ and the fauna of Gödöllő described by Mottl /1939/ which show just this transition. Thus, it is probable that at the basis of Montpellierium a transitional stage, the Baltaium /BARBOT de MARNY, 1869/ should be incorporated. To solve this problem, however, no suitable data are available.

MONTPELLIERIUM /GAUDRY,A. 1878/

Stratotype: "Sables de Montpellier" /South France/. - Synonyms: Ruscinium, Levantinian,p.p. Barótian p.p., Upper Pliocene etc. - The Upper Pliocene contrasts with both the Middle Pliocene /Baltavárium/ below and the Lower Pleistocene /Villafranchian/ above in two aspects: first, its fauna is composed of new elements still existing in South-Asia or relating to them. Moreover, practically no fauna derives from the preceding Hipparion fauna, except for some in rather altered state. In addition to the abundant new Soricidae, the fauna is characterized by new monkeys /Macaca, Dolichopithecus/, flying squirrels /Pliopetaurista/, a populous assemblage of Muridae /Stephanomys, Rhagapodemus etc./, by the first true Canidae /Ruscinalopex/, by the Agriotheriidae /Agriotherium/, by large Viverridae, by the Grizoninae of recent South-American relations /Pannonictis/, by bears akin to the Malayan bear /Protarctos/, by new proboscids /Anancus, Mammuth/, by rhinos, swine of Indian relations, rusoid deers and by true Bovinae. The other feature is the massive forest formation substituting the zonal steppe conditions of the Hipparion faunas of the Bérbaltavárium reflected by the strong forest and gallery forest character /in the minor mammal fauna the predominance of mice, red squirrels, flying squirrels and dormouses/. Concerning the flora, only indirect data ara available /through the fauna/. In the fluviatile-lacustrine mollusc fauna the abundance of the so-called ornamental shells /Viviparus/ is conspicious. - Two substages can be distinguished: Ruscinium and Csarnótanum.

R u s c i n i u m /KRETZOI, M. 1962/. - Stratotype: Serrat d'en Vaquer, Roussillon. - Synonyms: Ruscinium s. str. the Mein's 1st phase. - Its main feature is the first phase of progress of the micro-fauna elements apart from the macro-elements of the immigrated fauna of the Montpellierium in which the hamster fauna predominates over the few ancient voles. Furthermore, some immigrants from East-Asia, e.g. the large Viverridae are restricted also to the Ruscinium. Out of their occurrence in the Carpathian Basin, Barót-Köpec and Ivanovce should be mentioned in the Southern and Western Carpathians, respectively. The Eastern European occurrences are mixed with Central-Asian elements /ostrich and camel/.

Pedimentation in the foreland and on the margins of the mountains continued throughout the whole Ruscinium along with the slow epeirogenic rising of the Pannonian Basin. The pediment extending from the Eastern-Alpine mountain front was overlain by Bérbaltavárium sand and covered probably as early as the end of the Ruscinium by an older gravel sheet. The gravel sheet of Ezüsthegy on the higher part of Kemeneshát, the truncated gravel sheets of Kandikóhegy in the Zala region, and the pink quartz gravels overlying the Ujhegy travertine /approx. 32o m a.s.l./ in the Gerecse Mountains, belong to this formation. On top of the travertine at Süttő /28o m a.s.l./ red clay and over it a thin layer of well-rounded quartz pebbles had been deposited. Based on their stratigraphic and morphological position the relative age of these gravels is considered to be Ruscinian-Csanótan, they were marked as terrace No. VIII. In the Gerecse and Buda Mountains the age of the travertines is not accurately fixed /e.g. Gerecse Öreghegy 32o m a.s.l.; Buda Mountais travertine No. 8/. They overlie the above-mentioned Upper Pliocene gravels or the Pannonian marine pebbles, or sometimes are found directly on top of the pediment.

C s a r n ó t a n u m /KRETZOI, M. 1959/. - Stratotype: the fauna of the karst fissure of the location Csarnóta-2. - In addition to the fauna elements deriving from the Ruscinium, the abundant mouse-fauna /Parapodemus, Apodemus, Rhagapodemus, Micromys/, the progressive modern Arvicolidae-ancestors /Dolomys, Proliomys, Cseria/ and the aberrant Cricetidae /Baranomys/ are characteristic. The older /Weze/ stage is characterized by the frequency of Trilophomys and Baranomys, the younger stage is characterized by the disappearance of Trilophomys and by the higher-grade evolution of the immigrated forms. - Characteristic fauna assemblages of the Csarnótanum are: Wölfersheim /BRD/, Odessa, the Catacombs etc.

During the Csarnótanum the older, mostly rock pediments /No.1/ of the mountain margins were preserved, or only slightly altered, in the period of red clay formation /PÉCSI, M. 1963/. The pediment surfaces developed on unconsolidated sediments continued to be lowered, and in the Alpine foreland in particular, the old gravel sheet kept on being deposited on them /FINK, J. 1963/. In the second part of the Csarnótanum the rivers /Rába, Mura/ on the western margin of the Pannonian Basin cut their channel into these surfaces and they formed the so-called terrace No. VIII. /KRETZOI, M. - PÉCSI, M. 1979/.

Its relative position and further evidence seems to indicate that the terrace marked No. VII belongs to the Csarnótanum stage of the Upper Pliocene. In our opinion the remnants of terraces standing out as isolated buttes from the old alluvial fan gravel sheet of Kemeneshát should also be classified into this stage. The terrace remnants of old alluvial fans on the Little Hungarian Plain and some of the Pliocene alluvial fans on the Pest Plain are in a very similar geomorphological and chronological position.

VILLAFRANCHIUM /PARETO, L. 1865/

The term Villafranchium /synonym: Perrierium, GAUDRY, A. 1878/ had been identified with the Lower Pleistocene for about a century, following the concepts of the author, in a broader sense than suggested by Movius at the London Congress held in 1948. Recently, however, due to the stratotype determination for the stage and to the identification of the neostratotype a new situation arose: the stratotype extends the stage limit downwards to the Upper Pliocene, distinguishing it as Lower Villafranchium from the traditional Villafranchium denominated now as Upper Villafranchium. When regarding the original intensions of the author and drawing the stage limit at the upper boundary of the Csarnótanum it can be achieved that the boundary between the Montpellierium /Csarnótanum/ and Villafranchium /Beremendium/ as well as the Plio-Pleistocene boundary are drawn between the substage characterized by typical South-Southeastern Asian fauna elements under zonally humid-forest ecological conditions and the new substage characterized by sharp North-American fauna elements of dry-warm steppe ecology.

Consequently, neglecting the right to identify a neostratotype, the classical Valdarno-fauna /Valdarno superiore/ is accepted as the stratotype of the Villafranchium. This fauna is characterized by large mammals, i.e. Equus /Allohippus/, Bos /Leptobos/ and by that of Canis immigrated suddenly from North-America together with the group of Equus. The fauna of small mammals is characterized by the steppe elements substituting the forest elements: mice practically disappear, the same fate is assigned to the Seiurida, Petauristida and Glirida fauna elements, while in addition to the predominance of Arvicolidae, the Cricetidae are represented also in large numbers in the fauna assemblages. Further, the disappearance of some forms of the Upper Pliocene small mammals should also be mentioned: the change of ear is represented first of all by the absence of some Soricida and ancient Arvicolida elements /Asoriculus, Blarinoides, and Promimomys, Cseria, Propliomys and Baranomys, respectively/.

The "geomorphological surfaces" /older terraces/ on the margin of the Gerecse Mountain are covered by thickly banded travertines. The travertine bands are intercalated with sandy, silty layers and redbrown fossil soils /SCHEUER, Gy. - SCHWEITZER, F. 1978/. The intercalated layers between three travertine niveaus No. 5, No. 6 and No. 7 showed a reverse magnetic polarity.

From the fossil red soil in the upper part of the travertine No. 6 overlying terrace No. VI. Schweitzer collected some vertebrate microfauna which was identified by Jánossy /1979/ as belonging to the upper part of the Villányium biozone, to the Kislángium. The gravel of terrace No. VI situated below is probably then Lower Villányium or Beremendium. It may also be supposed that the gravel terrace had formed at the beginning of the Kislángium in the Upper Villányium. The "gravel sheet of Kemeneshát with red or pink coloured gravel" can also be classified as belonging to this period.

The silty layers of the travertine overlying terrace No. V still show a reverse magnetic polarity hence the terrace must have formed in the Matuyama Reverse Epoch, and it is older than 7oo ooo years. On the basis of paleontological and other data, terrace No. V at Dunaalmás can be correlated with the end of the Kislángium, and the overlying travertine was probably formed in the Lower Biharium stage.

Below the old loess /Paks Loess Complex/ the so-called Dunaföldvár Complex is developed /PÉCSI, M. 1975/ on the Pannonian strata. Its lithological composition is non-loessic and consists of grey, clayey layers interbedded with some fluvial sand and alluvial soils. The presence of a series of red clay soils /Df_1-Df_6, KRETZOI, M. - PÉCSI, M. 1979/ characterize this terrestrial formation. At present we correlate the red soils Df_1-Df_4 with the Villányium. The Df_2-Df_3 fossil soils showed doninatly normal magnetic polarity /Gauss/, while the Df_4 soil had predominantly reverse magnetization. The Df_5 and Df_6 soils were again reverse magnetized, however, they probably belong to a different magnetic epoch /Gilbert/ and may be linked to the terra rossa formation in the Csarnótanum. A marked unconformity can be observed between the lowest stratum /Df_6/ of the Dunaföldvár Complex and the underlying Upper Pannonian /Baltavárium/ sands.

Within the Villafranchium two definite substages can be distinguished:

B e r e m e n d i u m /KRETZOI, M. 1969/. - Stratotype: the fauna of Beremend-5. - Characteristics: the survival of a lot of elements of Csarnótanum, first of all the presence of Dolomys preserved in the same frequency as the Mimomys genus. - In addition to the occurrences of Beremend, first of all the "older" Valdarno-faunas of the grey-clay formation of the lower part of Valdarno superiore, as well as some South-Polish and South-Ukrainian locations can be assigned to this substage.

V i l l á n y i u m /KRETZOI, M. 1941/. - Stratotype: Villány-3. - In addition to the predominating Mimomys species its fauna is characterized by varied Arvicolida fauna /Kislángia, Villányia, Lagurodon, Myodes etc./ and the first precursor of Arvicolidae of rootless teeth extending over the whole Holarctic from the Middle Pleistocene as microfauna element, i.e. by a species of Allophaiomys. In addition to these the Cricetidae and Citellidae are subordinate.In the fauna of large mammals the progress of eastern elements up to Transdanubia is characteristic /camels/. This is proved by the occurrence of Pachystruthio at Kisláng, the only known Struthio occurrence west of Eastern Europe. The preservation of the last Hipparion species up to the end of the substage in addition to the first true Equus species /Allohippus, Macrohippus, Asinus/ and to the Archidiskodon representing the elephants, are also characteristic. Out of the locations within the Carpathian Basin first of all the fauna at Kislang is to be emphasized, but the Villány-5 as the closing member showing cooling should also be mentioned. As "Valdarno faunas" these are widely extended both in Western and in Eastern Europe, thus due to their closing gravel sequences they provide good distinction from the Middle, and in general from the Upper Pleistocene.

BIHARIUM /KRETZOI, M. 1941/

Stratotype: Betfia-2. Synonyms: Lower Pleistocene p.p., Middle Pleistocene p.p. etc. - Within the alternation of warm-dry and cooling climatic conditions its fauna is characterized by the practical absence of "Tertiary" elements /only some surviving forms indicate the relationship with the Lower Pleistocene, e. g. Beremendium and the latest representatives of Mimomys and Pliomys, Trogontherium, Hypolagus, Macaca, Epimachairodus, Pchycrocuta, Xenocyon, Stephanorhinus etc./ as well as by the modern elements, e.g. Arvicolinae with rootless teeth, hampsters, shrews, Spalacidae of recent types, Mus, out of the ungulates the ancestor of all the species and subspecies lived here up to the end of the Pleistocene. So the genera Equus, Asinus, Coelodonta, Sus, Cervus, Megaloceros, Rangifer, Dama, Alces, Bos, Bison, Ovibos occur all in this substage, and in Europe here occurs also the man, i.e. the Homo /Pithecanthropus/ rectus,as well. These faunas are well-known from Spain to North China from the recent temperate zone, and their Mediterranean relations are also known /e.g. Tel Ubeidia etc./. It can be devided into two fairly well separable substages: Cromerium and Mosbachium.

C r o m e r i u m /MAYER, Ch. 1868/. - Conventional litho- and stratotype: Cromer Forest Bed sequence. - Disregarding from a shorter cooling period this is the warm /"interglacial" lower part of the substage /Lower Biharium/ which is separated from the Mosbachium by the latest occurrence of Mimomys, Beremendia. The end is characterized by a sudden cooling /Stadial: Mindel I or Elster I/. The Hungarian stratotype: Villány-8/9-12. Based on the predominance conditions of the Arvicolida species it can be divided into horizons. These are: the Betfia, Nagyharsány, Montepeglia and Templomhegy horizons and these allow intercontinental correlation with the Paleoarctis, especially the Betfia Horizon /Allophaiomys/ which can be followed up to North America.

M o s b a c h i u m /Atorum/. - Stratotype: Mosbach, obere Sande. - The small mammal fauna without Mimomys is characteristic of the Upper Biharium, but the large mammals of the Biharium, e.g. Epimachairodus, Trogontherium, Gulo schlosseri, "Leo" gombaszögensis, Pachycrocuta etc. can also be found. Its termination as well as the poverty in species accompanying the disappearance of the "Tertiary" forms immigrated into the Biharium, and the appearance of arctic forms /Dicrostonyx, Microtus gregalis etc./ are identified with the Mindel II /Elster II/ stadial.

Paleomagnetic samples collected from an exposure of terrace No. IV showed normal magnetic polarity. The travertine at Vértesszőlős overlying the terrace of the Tata River which is in about the same morphological position as the Danube terrace was examined by Osmond, J.K. /PÉCSI, M. - OSMOND, J.K. 1973/ and he determined its age by the Th/U method as more than 35o ooo years B.P. According to Pevzner, M.A. /PÉCSI, M. - PEVZNER, M.A.1974/ the loess interbeddings between the travertine bands had normal paleomagnetic polarity. Therefore terrace No. IV and the overlying travertine should belong to the Brunhes Epoch /not older than 7oo ooo years/. The terrace gravel probably represents the Tarkő phase of the Lower Biharium, while the travertine at Vértesszőlős is of the so-called "Vértesszőlős biozone" type. A similar level is represented by the travertine cover of the Várhegy of Budapest /JÁNOSSY, D. 1979/. The travertines on the Kiscell Plateau of Buda are somewhat younger, their Th/U age is 175 ooo years B.P.

In the classic loess profiles on the Great Hungarian Plain along the right bank of the Danube /Paks, Dunakömlőd, Dunaföldvár etc./ the old loess have been described as the "Paks Loess Complex" /PÉCSI, M. 1975; PÉCSI, M. - PEVZNER, M.A. 1974/. Most of the old loess series can be correlated with the Biharium, however, the upper part of the old loess is younger than the Upper Biharium, and in our opinion it was formed in M-R, R_1, R_2. The few vertebrate fossil faunas and paleomagnetic investigations both seem to support this assumption. /At Paks the whole sequence of the old loess, apart from the lowest 4-5 m thick loess layer and an intercalated red-brown fossil soil, shows normal magnetic polarity and thus belongs to the Brunhes Epoch. On the basis of paleomagnetic analyses carried out in several exposures of old loess we concluded that only the lowest strata and the intercalated fossil soil /marked PDK/ should be classified into the Matuyama Epoch. These lowest strata of loess are, however, younger than the Jaramillo Event /o.9o-o.95 m. y./. The latter event was identified in a stratum with normal magnetic polarity in the so-called pink sandy silt underlying the old loess /PÉCSI, M. - PEVZNER, M.A. 1974/. In the light of recent investigations we wish to revise the chronological classification of this pink sandy silt. Earlier it was classified as belonging to the Upper Villányium, but now we consider it to be formed in the Lower Biharium /see PÉCSI, M. 1982 in this volume/.

Two aspects support the assignment of the Middle and Upper Pleistocene of the former Quaternary division, or in old term of the Mindel-Riss, Riss phases or the Oldenburgium and the

Riss-Würm and Würm phases or the Utrechtium /classification after Lüttig/ to a uniform Upper Pleistocene: first the highly illogical disproportionality of the absolute time scale of the chronological classification identifying the Villányium and Biharium as Lower Pleistocene, the Oldenburgium as Middle Pleistocene and the Utrechtium as Upper Pleistocene /Lower Pleistocene 2 to 2.5 m. y., Middle Pleistocene o.25 m.y. and Upper Pleistocene o.15 m.y.!/. The other aspect is that disregarding of some characteristic forms the faunas show very good agreement, the afore-mentioned substage indicating forms /Hesperoloxodon antiquus, Stephanorhinus kirchbergensis/ are missing and they practically show the homogeneous faunal picture slightly influenced by fluctuations caused by climatic changes. This is also verified by the debates and uncertainties concerning fauna classification. All these justify to call the period Upper Pleistocene and to distinguish a lower /Solymárium = Oldenburgium/ and an upper /Thuringium = Utrechtium/ member only within this.

Solymárium /= Oldenburgium, LÜTTIG,G. 1958/. The biostratigraphic unit has not been accomplished so far. The subdivision into fauna units of Solymár and Steinheim remains open up to the suitable elaboration of the decisive faunas of Solymár, Steinheim and Hunas.

The age of terrace No. III that developed during this time can be estimated from the data obtained for the travertine cover on top of it. The Th/U age of the travertine is 19o ooo years /PÉCSI, M. - OSMOND, J.K. 1973/. The terrace gravel of terrace No. III could be classified into the Oldenburgium /Steinheimium/ substage, or into the Uppony phase, while the travertine and the fossils from the Várbarlang of Budapest /JÁNOSSY, D. 1979/ may be correlated with the Castellum phase.

Thuringium /= Utrechtium/. - Neither the litho- nor the biostratotype are indicated. - The faunal picture of the period strongly divided by climatic fluctuations is fairly well correlated both faunistically and by climate and archaelogical stratigrapy, disregarding certain phases /first of all the more temperate phase before the last temperature minimum /KRETZOI, M.-VÉRTES,L. 1965; KRETZOI, M. - PÉCSI, M. 1979/.

In contrast to the Solymárium, the Szántóium /the Riss-Würm + Würm/ is very well-known, its general geomorphology, terrace systems, glacial forms, sediments, particularly loess formation have been studied to such great depths that the richness of detail is overwhelming in certain cases.

Due to the abundance of well-established micro-stratigraphic data, a detailed paleontological-stratigraphic subdivision is beyond the scope of the present study of more general purpose. We wish to remark though that the terrestrial faunas, in particular the mammalian fossils are correlative with the palynological data. At the beginning of the Utrechtium /Süttő phase/they indicate a warm "interglacial" /one of the warmest phases of the Pleistocene/, the climate then gradually became cooler interrupted by recurrent warmer phases leading to the two /or three/ last glacial peaks /the last stadial had the coldest climate /KRETZOI, M. 1961c/. Paleontological and archaeological evidence led to a very detailed subdivision, but very few definite "markers" can be used directly in the field work. Sedimentation /loess-loam stratigraphy/ and terrace morphology, their profiling, mapping of distribution patterns seem to be the best guides in this respect.

The development of a terrace, the accumulation of terrace gravel and the consequent terrace formation occurred during a relatively shorter time in the upper reaches of the rivers /e.g. in the mountains/ than in the temporary reaches on the alluvial fans. A correlation between the development of young loesses overlying these terraces and the accumulation of terrace gravel in the mountain reaches of rivers proved that the accumulation of terrace gravel ended after the formation of the "Mende-Base Soil" which is situated at the bottom of the young loess sequence. The "Mende-Base" Soil Complex was formed during the last interglacial under the forest-steppe climate introducing the Würm glacial. The age of quartz grains collected from the lower part of the "Mende-Base Soil" and the underlying sand was determined as 125 ooo years by thermoluminescence analysis /BORSY, Z. - FÉLSZERFALVY, J.-SZABÓ, P.P. 1979/. The archaeological and paleontological data together with the charcoals collected from the forest-steppe soils /marked BA, $BD_{1,2}$ $MF_{1,2}$/ and the humic loess horizons /H_1, H_2/ interbedded in the young loess provide sufficient evidence about the stages and rate of subaerial resedimentation during the Utrechtium /see PÉCSI, M.1982 in this volume/.

Earlier we placed terrace No. II/b of the Danube into the R-W and W_1 phase on the basis of its geological and geomorphological position /PÉCSI, M. 1965, 1979/. It may be correlated with the Süttő-Varbó microfaunal horizons. The Th/U age of travertines covering the terraces was determined as 6o ooo years B.P. /Tata, Óbuda; PÉCSI, M. 1978/.

The formation of terrace No. II/a based on paleontological and geomorphological /cryoturbation phenomena/ evidence may be placed in W_3 /Ságvár phase/. The Early Holocene sand dunes developed on these terraces are 9 ooo years old. Terrace No. I is a postglacial flood-plain terrace. The radiocarbon age of the tree trunk collected from its alluvium is 11 ooo years. The geological-chronological subdivision of the Holocene, representing the last 1o ooo years and covering large areas on the geological maps of Hungary is a difficult task. Historical zoology adopting paleontological methods was able to establish 4-5 distinct faunal units in caves /KRETZOI, M. 1957; KORDOS,L. 1976/ but their application in the field is yet in progress.

Reliable chronological evidence is supplied by archaeology for the determination of the morphologically distinct Early and Late Holocene substages. The maps of archaeological sites /and several absolute chronological age determinations; BÁCSKAY, E. 198o/ indicate that on the Late Holocene surfaces even in areas reworked by lateral erosion, Neolithic settlements older than 7 ooo years B.P. existed. This would suggest that the surface developed quite early in the Holocene, so that we may question the age of terrace No. II/a /without loess cover/ which on the basis of our earlier evidence is still firmly placed to the very end of the Pleistocene.

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PLIOCENE-PLEISTOCENE PIEDMONT CORRELATIVE SEDIMENTS IN HUNGARY /BASED ON LITHOLOGICAL, GEOMORPHOLOGICAL, PALEONTOLOGICAL AND PALEOMAGNETIC ANALYSES OF THE EXPOSURES IN THE OPEN-CAST MINE AT GYÖNGYÖSVISONTA/

KRETZOI, M. - MÁRTON, P. - PÉCSI, M. - SCHWEITZER, F. - VÖRÖS, I.

The Mátra Mountains is the most characteristic member of the young Tertiary volcanic range of Northern Hungary. In the foothills of the mountains near Gyöngyösvisonta the "Gagarin" thermal power station with a capacity of 25o mW is supplied with fuel from Upper Pannonian lignites situated quite close to the surface.

The Pleistocene and Upper Pliocene sediments overlying the lignite seams vary in thickness from 2o to 5o m, and gradually thicken as one moves away from the mountains. In the course of prospecting numerous pilot boreholes have been drilled since the 195os. Open-cast mining activities started in the middle of the 196os and since then have been gradually extended /PHOTO 1/. Thus, during the last two decades there have been excellent possibilities to study the geological sequences, spatial distributions and genetic types of the superficial exposures as well as to carry out lithological and chronological classifications. To synthesize the research in the last few years a team was founded under the guidance of PÉCSI, M. and the results are published in this paper.

THE GEOMORPHOLOGY OF THE MÁTRA FOOTHILL

The summit range of the Mátra Mountains is of 9oo to 1 ooo m in height. On the southern slope an erosion surface developed of about 6oo m, during the Late Tertiary, bounded by a steep step and slope, i. e. the so-called mountain front. The streams having their origin in the mountain consisting of andesite lava and tufa reach the pediment of variable width /FIG. 1/. The pediment is also cut in Upper Pannonian sandy-clay sediments which down-

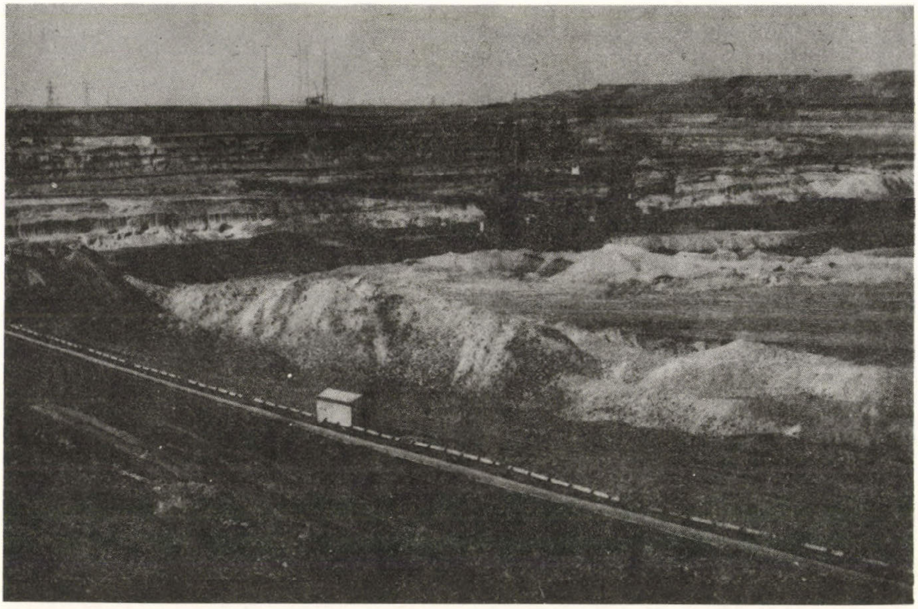

PHOTO 1 Exposures of the Gyöngyösvisonta open mine /POÓR, I. 1982/.

slope are overlain by a gradually thickening alluvial fan. In the area in question the alluvial fan extends down to about 13o m, i.e. down to valleys of the streams. The superficial exposures are situated in the lower part of the alluvial piedmont surface from 16o m above sea level /FIG. 1/.

As it was established earlier /PÉCSI, M. 1963, 1967, 197o/ the piedmont surfaces developed in the foreground of the Hungarian Mountain Range form a gently sloping primary form between 35o and 22o m above sea level, whereas in other localities it constitutes lower inter-valley ridges and foothill surfaces covered by piedmont alluvium inclining down to 16o m above sea level.

The higher foothill surfaces are dissected into inter-valley ridges and thin Quaternary alluviums are found on them. By contrast, the lower inter-valley ridges are overlain by a thicker sometimes several ten of metres of Quaternary-Upper Pliocene deposits.

It is assumed that the higher inter-valley ridges represent the remnants of the Late Pliocene pediment while the lower pediments covered by thicker deposits were formed during the Pleistocene /FIG. 2/.

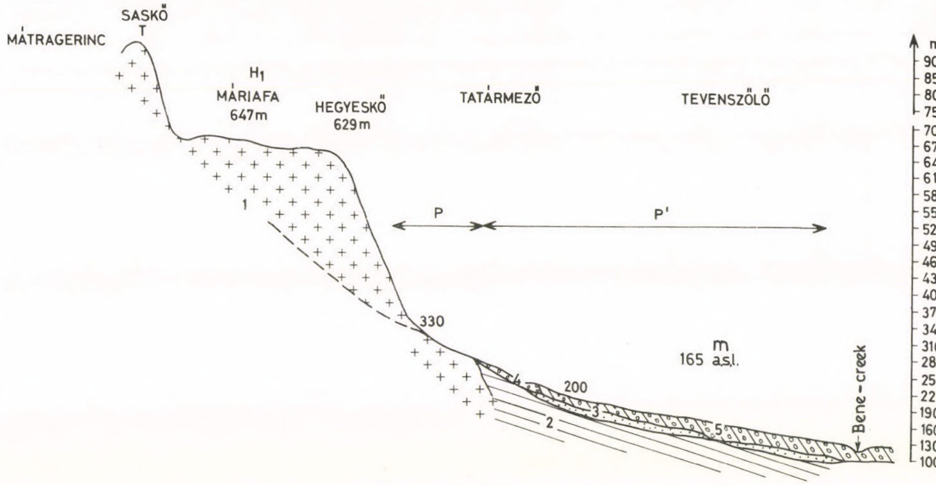

FIG. 1 Pediment and alluvial fan in the Mátra foothills in the Markaz-Gyöngyösvisonta environment /PÉCSI, M. 198o/
1: Miocene /Badenian/ andesite; 2: Upper Pannonian sand-clay formation with lignite beds; 3: Upper Pannonian sand; 4: coarser andesite boulder and gravel; 5: Upper Pliocene - Lower Pleistocene alluvial fan formation subdivided locally by lo fossil soils; P: rock pediment; P': piedmont surface.

THE LITHOLOGICAL SUBDIVISION OF THE EXPOSURES

In the so-called "Thorez" exposures 4o to 6o m of the Upper Pannonian lignite-bearing sequence could be studied, which in turn are overlain by a sedimentary sequence also about 4o m in thickness.

The overlaying sequence is alluvial fan material and varies in space, i.e. both perpendicularly and parallel to the slopes, and some of the strata are wedged. Locally these have been eroded and new sediments have been deposited on them. These features are related to the progress and regularities of alluvial fan formation.

The covering sequence can be dissected into fairly well separable parts:

1. The upper third of the alluvial sequence, down to a depth of 14.3 m, consists of yellowish clayey loess, grey sandy-clayey tufa detritus, and an assemblage of andesite gravels and sands, dark, brownish-black or brown meadow soils and red-brown forest soils. The sequence usually starts with 1 to 1.5 m of brownish-black clayey meadow soil which is mostly of brownish colour and locally overlies the red-brown fossil forest soil. This sometimes displays periglacial phenomena. The cracks filled with

FIG. 2 Geomorphological map of the environment of Gyöngyös-visonta /scale 1:25 ooo/
1: presumed Upper Pannonian marine terrace and its margin; 2: piedmont surface and its margin; 3: land step, derasion terrace; 4: pediment fragment divided into inter-valley ridges; 5: mountain crest; 6: derasion step; 7: terrace surface of smaller water-courses; 8: alluvial fan; 9: erosion valley; lo: derasion valley; 11: gullies; 12: slopes.

calcareous material and penetrating down to a depth of 1-2 metres. The andesite gravels and tufa sands intercalated between the fossil soils were accumulated during the Lower and Middle Pleistocene alluvial fan formation. Since the streams cut in the alluvial pediment are accompanied by two or three terraces, the geomorphological evidence indicates that the alluvial fan developed long before the Upper Pleistocene in the region of the open-cast mine.

2. The lower thicker part of the cover consists mostly of purplish-red cyclically stratified alluvium, together with some sands and greyish-purple compact clays. It is characteristic of the sequence that it is subdivided into 6 6o 8 purplish-red clayey weathered layers. These weathered layers, which can be called also fossil soils, were formed on sandy clay with tufa detritus. Between the purplish-red sequence and the upper yellowish loessic sand and grey clayey sequences a transitional sediment is found /between 14 and 21 m/, in which red-brown soils /F_5 - F_7/ as well as light-coloured sands and sands with tufa detritus are deposited to a thickness of several metres /FIG.3/.

3. The purplish-red soil sequence /F_8 to F_{15}/ is separated by a strong erosional unconformity of several metres of sand both up-[illegible]/between 21 and 23.5 m/ and downwards /between 33 and 34 m/. Out of the purplish-red soil sequence F_{1o} can be followed in a considerable part of the exposure, and all the other strata can therefore be related to this layer as an index horizon.

The purplish sequence overlies a thicker sandy band /H2/, at the boundary of which a strong unconformity is found which is underlain by a greyish purplish tufaceous sandy clay /samples loo-99: between 34 and 38.5 m/. In the middle part of the layer Mastodon borsoni was found. The layer is 4 to 5 m thick forming the base of the alluvial fan and is deposited on yellow, coarse slightly corss-bedded sands.

In the thick sand layer H_3 locally bright-coloured red clay lenses occur that formed on the sand surface. The sand /H_3/ is subdivided by clay lenses and often contains rounded clay-pebbles. Based on its composition, situation and stratification it is assigned to the Upper Pannonian /Unio wetzleri/ cross-bedded sand /Baltavárium/. This is supported by the other examples occurring in the Mátra foothills.

The sandy-clayey layer containing Mastodon-like remnants is locally absent and the purplish-red soil series directly overlies the sand H_3 or the lignite-bearing Upper Pannonian formation. The older strata of the alluvial fan sequence /the Mastodon-bearing layer and the sequence of purple soils/ unconformably overlie the slightly dipping lignite-bearing Upper Pannonian formation, and during their deposition some of the lignite seams were eroded. In the alluvial cover lignite detritus can also be observed.

4. In the Upper Pannonian formation three exploitable lignite seams, separated by sands and clays were deposited. In the lower and middle section of the profile sands predominate /FIG.3./. The Upper Pannonian lignite-bearing sequence is of reversed magnetism, except for a sandy-clay layer of several metres thickness underlying the lignite seam. The lowermost member of the alluvial cover /the Mastodon-containing deposit/ is of normal polarity.

THE DEVELOPMENT OF THE ALLUVIAL FAN IN THE FOOTHILL ZONE

Two problems emerge. Firstly in the region stratigraphic investigations /BARTA, F. et al. 1971; KRETZOI, M. 1969; PÁLFALVY, I. - RÁKOSI, L. 1979; JASKÓ, S. 1981/ based on guide-profile assigned the sequence including the lignite seams to the middle part of the Upper Pannonian /to the Sümegium, and to the horizon of Congeria balatonica, respectively/. Thus, from the stratigraphic point of view the sedimentary gaps and the time intervals separating the Upper Pannonian lignite-bearing sequence, the unconformably overlying coarse sands /Baltavárium/ and the Mastodon-containing and purplish-red alluvial sequences have to be established. Further, how can the paleomagnetic phases obtained from this sequence be fitted into the absolute chronological classification? By all means, it is to be emphasized that between the Mastodon-containing layer and the sand layer H3 considerable erosion can be assumed since the red clay formed on the sand H3 locally remained in places. It may also be pointed out that while from the geological point of view the unconformity is strong, temporally it may represent a relatively short period.

The second problem is a geomorphological one but is closely connected to the above, and concerns the age and length of time of the alluvial fan and the pediment development.

On the basis of the comprehensive sequence of the exposures at Gyöngyösvisonta, involving the analysis of their vertical and spatial arrangement some significant conclusions can be drawn:

- The streams changing in direction of flow on the piedmont surface deposited their alluvium in the neighbourhood of their flat beds simultaneously with erosional and accumulational character. Due to the repeated climate changes crumbling, weathering and soil formation took also place on the surface of this detritus. Over this soil or weathering coat eolian or solifluction sediments and in case of a change of channel proluvial alluvium could again accumulate. In the lower zone of the piedmont surface this process was cyclically repeated several times. Consequently, varied alluvial, proluvial, eluvial, colluvial and eolian sediments are deposited onto and beside each other, with necessarily repeating but shorter erosional gaps. In the higher part of the pediment, near the mountain front, coarser but thinner alluvium remained.

- It is a frequent phenomenon that on the gentle slopes of the pediment, and on the inter-valley ridges, derasional valleys or erosional trenches were formed which were flattened or filled due to the erosional processes. Such buried and superimposed erosional and derasional valleys can be observed in the profiles of the open-cast exposure at Gyöngyösvisonta both in the uppermost layers /PHOTO 2/ and in the sequence dissected by purplish-red soils. Occasionally, in the wide erosional-derasional valleys the number of buried soils and weathering horizons also increases.

- On the valley ridges and in the derasional valleys accompanying the pediments brown forest soils and Mediterranean red soils were formed during the warmer climatic periods. Occasionally, meadow soils were formed intermixed with rock detritus produced by solifluction activity during the cold periglacial stages. The soils with rock detritus and the clays mixed with the detritus were generated in this way, and frequently overlie in rhythmic fashion. On the slopes near the mountains the fossil soils and weathered layers of the sedimentary sequence were mixed usually with coarser rock detritus derived from cryofraction-solifluction process.

- In the investigated area in question, during the erosion-accumulation development of the alluvial fan sequence covering the lower pediment of the Mátra foothills, the Upper Pannonian strata were unevenly eroded and form an undulatory surface beneath the overlying sequence. Due to the Quaternary subsidence of the Great Plain the stream crossing the piedmont zone of the Mátra foothills became deeply incised and eroded their own sediments as well. These streams cut into this sequence as well as into the Upper Pannonian basement. Several streams together formed a submontane basin in the lower zone of the alluvial fan. Orographically, the surface is deepest along the recent valley of the Bene stream, where the Upper Pannonian formation in the region lies closest to the surface. By contrast, on the inter-valley ridges of the alluvial fan sediments of mostly double thickness are found on the Pannonian formation. The superficial sediments of the inter-valley ridges are, of course, much older, than those in the valleys /FIG. 2/.

VERTEBRATE FOSSILS AND THEIR STRATIGRAPHIC POSITION

When removing the Quaternary cover in the lignite mine of Gyöngyösvisonta vertebrate fauna was found several times which in addition to their paleontological significance may contribute greatly to the elucidation of the evolution of the region and the age of the sedimentary sequence.

The first finds were uncovered in 1965, during the construction of earthworks for a railway, from a depth of 32o to 34o cm, from the humus layer underlying the yellow loess /ROZSNYÓI, M. 1966/.

Further sampling was carried out in 1981, when research-workers from the Geographical Research Institute of the Hungarian Academy of Sciences collected vertebrate fauna from four different horizons in the open-cast mine /SCHWEITZER, F. and BALOGH, J./.

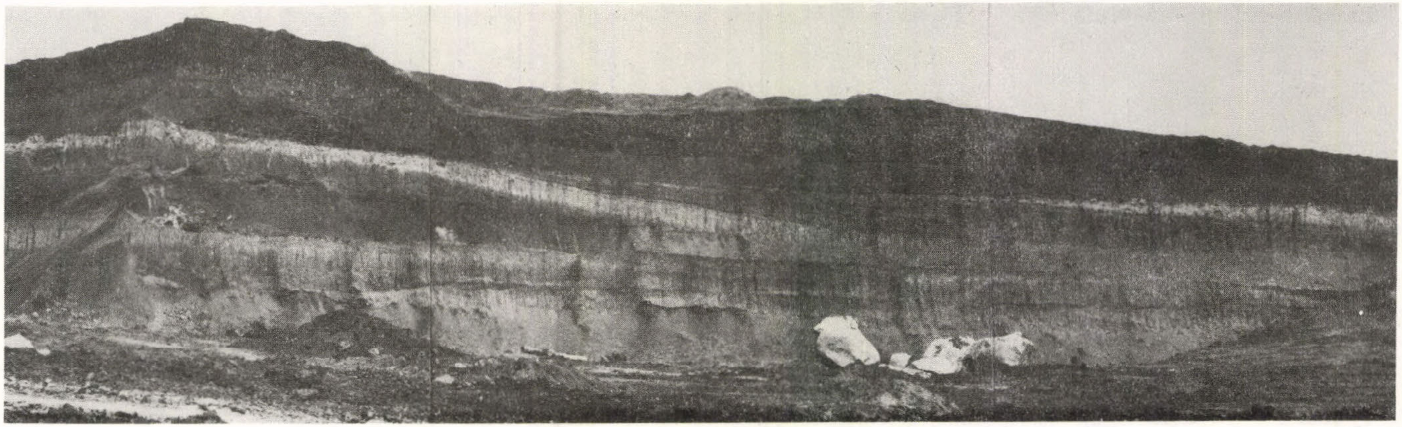

PHOTO 2 Upper part of the alluvial fan in the Gyöngyösvisonta open mine. Part of a buried derasional valley /SCHWEITZER, F. 1981/.

Concerning the profile in question /FIG. 3/ the first finds derive from a depth of 8 to 9 m, from the layer of andesite gravel and sand. The secondderives from a depth of 12 lo 13 m, where a proboscidean mandible was collected from the tufaceous clay middle section of the profile. Near to this, at a depth of 14 m, a mandible was found again in the lowermost part of the tufaceous sandy clay. Finally, at a depth of 34 m, in the middle of the greyish-purplish tufaceous sandy clay a proboscidean a pair of maxillaries and a proboscidean femur were found.

1/ Zygolophodon pavlovi Osborn

Stratigraphic position in the profile: the find derives from the lower part /34 m/ of the cover, specifically from the greyish-purplish tufaceous sandy clay.

The material: the alveolar part of the maxilla dext. and sin. with parts of the palatum and fragments of the M^2-M^3 dext. and M^2 and M^3 sin. respectively.

Description: the structure of the teeth shows fairly well the conical shape and distribution of zygodont characteristic of the "zygodont" mastodons. Its dental formula is 3 in M^2 and 4/x/ in M^3. The insection in the dental axis is well-developed, the separations of the jugal parts are sharp, their buccal part is divided into 3-5 cones, the masticatory surface is relatively large, while the lingual end-cones are weak. The dimension of the teeth are as follows:

	Length /l/	Width /w/ at the jugal parts				l/w
		1st	2nd	3rd	4th	
M^2 dext.	1o8	76	82	84	-	1.24
M^2 sin.	/1o5/	-	-	-	-	
M^3 dext.	142	85	89	81	64	1.59
M^3 sin.	14o	86	9o	81	65	1.56

Based on the morphological features of the teeth the find can be determined as Z. borsoni, although with some reservation /PHOTO 3a, 3b/. The features relating to Mammut americanum, or rather those relating to a transitional form prove rather the Zygolophodon. As regarding the assignment to species, the non-typical borsoni-like features of the morphological characteristics and its dimensions show that the M^2-M^3 of the small Podolian specimen defined by PAVLOVA,M.V./1894/ as Mastodon americanus Hays /ohioticus Cuvier/ /PAVLOVA, M.V. 1894/ is identical with our find. Thus, the remains at Gyöngyösvisonta are referable to this rare, taxonomically uncertain form which was distinguished by OSBORN in his monography on proboscideans /OSBORN, H.F. 1936/ as Mastodon pavlovi both from the species referred to Zygolophodon, Pliomastodom and Mammut. The last two species differ also in their advanced M^3 /4x 5 jugae/.

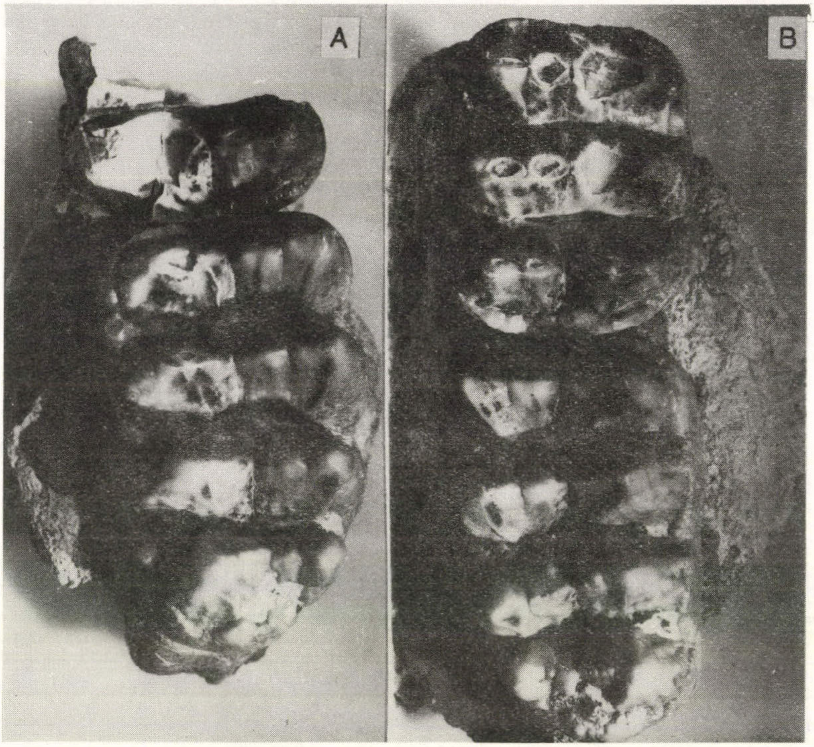

PHOTO 3A: Zygolophodon pavlovi Osborn, sinistral maxilla fragment, the aboral part of M^2 and the M^3. Depth: 34 m; M.: 1:1/2

B: Zygolophodon pavlovi Osborn, dextral maxilla fragment, M^{2-3}. Depth: 34 m; M.: 1:1/2 /VÖRÖS, I. 1982/

At that time PAVLOVA supposed her find to be of "Middle Pleistocene" age. later reclassified as be Lower Pleistocene /BORISSIAK, A.A. - BELIAEVA, E.I. 1956; PIDOPLICHKO, I.G. 1956/.

2/ A r c h i d i s k o d o n sp. i n d.

Stratigraphic position: from a depth of 34 m in the greyish, purplish tufaceous sandy clay, this fixes the age of Zygolophodon and the lower part of the cover as post-Pliocene, specifically Lower Pleistocene.

The material: femur dext., its proximal epiphysis is lacking /it is not coalesced with the deaphysis/.

The significance of this fossil in addition to the lack of specific determination is that is cannot be assigned to the mastodons /neither to Gomphotheriidaen or to Mammutidae/; the exclusive assignment to Elephantidae, however, supports the Lower Pleistocene age of the surrounding sediment.

Another femur fragment of the same taxonomic unit was found in the same sequence.

3/ A r c h i d i s k o d o n   m e r i d i o n a l i s   m e r i d i o n a l i s /Nesti/

Stratigraphic position: the find derives from the tufaceous, sand clay, from a depth of 13.5 to 14 m /FIG. 3/.

The material consists of the corpus mandibulae dext. and. sin. with the oral piece of M_1-M_2.

Description: the mandible was broken at the symphysis, the ramus mandibulae was split together with the talonids of M_2. The corpus mandibulae is low, relatively narrow, the lower edge is straight, characteristic of young animals, its height is 19o mm at the oral end of M_1 /PHOTO 4a, 4b/.

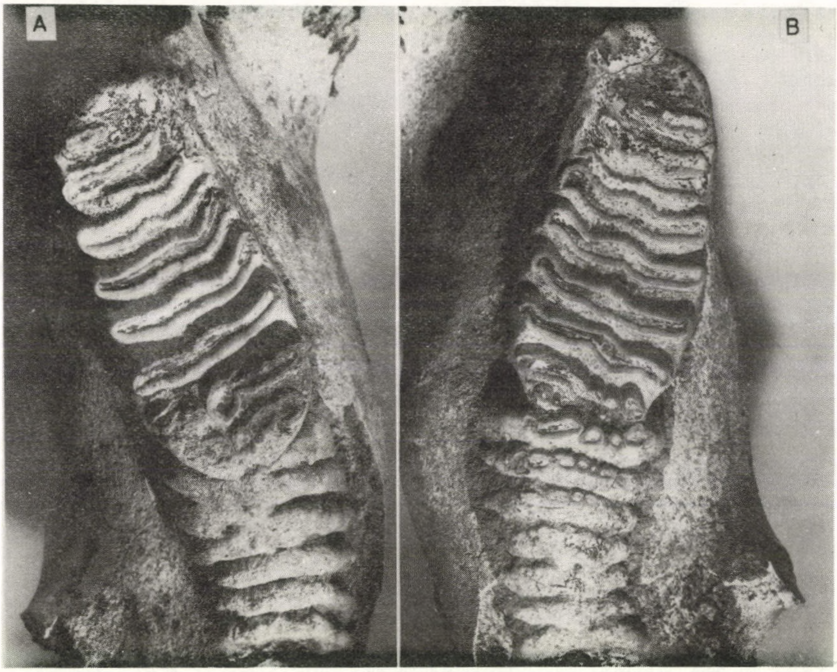

PHOTO 4A: Archidiskodon meridionalis meridionalis /Nesti/, sinistral corpus mandibulae with the oral piece of M_1-M_2. Depth: 14 m. M.: 1:1/2
B: Archidiskodon meridionalis meridionalis /Nesti/, dextral corpus mandibulae with the oral piece of M_1-M_2. Depth: 14 m. M.: 1:1/2 /VÖRÖS, I. 1982/.

The M_1-s are large-sized. Due to the successive eruption of the teeth dental wear the first lamellae of M_1 are worn to the root collar, while the 2nd and 3rd lamellae are worn down to the crown base /the lower edges of the lamellae are still preserved/.

Between the thick lamellae the wide interlamellar gap is found filled with cement. The lamellae of M_2 are pressed in and under the 9th lamellae of the aborally wedging M_1.

The aboral lamellae of M_1 were deformed due to the pressure of M_2. This deformation can be observed especially in the 8th and 9th lamellae of the M_1 sin. The lingual part of the lamellae is orally slightly inclined but the lateral enamel coat of the lamellae incline sidewards and backwards. In the medial part of the lamellae the aboral enamel coat is more wrinkled than the oral enamel coat.

Conjunction types of the lamellae: lateral lamellar - medial annular. The lamellae 1-6 of the sinsitral M_2 and those 1-7 of the dextral M_2 are already cemented. The sinistral M_2 could not be used for mastication, the lamellae 1-3 of the dextral M_2 are worn. On the basis of dental wear the age of the animal is about 15 to 2o years.

It is characteristic of the specific evolution of Elephantidae that the lamellae enamel coat of dentition become gradually thinner during the course of the Pleistocene. Consequently, the older a genùs or species within the genus, the thicker is the dental enamel, and inversely, the more evolved is a taxon /or genus/ or a species within the taxon /genus/, the thinner is the dental enamel /TABLES 2 and 3/.

Nevertheless, the specific trend in the evolution of dental enamel of Elephantidae is repeated during the evolution of individuals belonging to the species /!/, so that the mM 2-3 and M 1 members of the dentition of the animal show an ever more progressive, more evolved "evolution level" than the M 2s and 3s. The lamellae of mM 2-3 and M 1 as well as the enamel are thinner, and their index values are higher than those of M 2-3 belonging to the same individual.

Thus, an elephantid taxon or the evolution level within a taxon are most characteristically determined by the M 2-3 parameters.

The structure of dentition and the thickness of the enamel is more evolved than in the case of the older Archidiskodon meridionalis that occur predominantly at Aszód and Ercsi /SCHLESINGER, G. 1922; VÖRÖS, I. 198o/ or at Kisláng /KRETZOI, M. 1954/.

Based on the facts above and on TABLE 1 the find in question can be assigned to the typical meridionalis species of the Archidiskodom mega-species /DEPÉRET, Ch. - MAYET, L. 1923/, to the subspecies Archidiskodon meridionalis meridionalis /Nesti/. The Archidiskodon meridionalis meridionalis fossils can be assigned to the Kislángium of the Upper Villányium.

TABLE 1 Dental dimension of Elephantidae at Gyöngyösvisonta

	A r c h i d i s k o d o n					meridionalis		trogontherii		
	meridionalis		ürömensis							
	s.M_1	d.M_1	s.M_1	s.M_2	d.M_2	s.M_3	d.M_3	s.M_3	d.Me	d.M_2
	81				65			81	fragm.	
1.	167	16o	185	-	23o	39o	3oo	-	31o	2o2
2.	9	9	11	15	15	18	12	-	23	14
3.	5.5	5.5	7.5	6	6	5	5	7.5	8	7
4.	76	78	83	8o	85	127	125	76	76	9o
5.	-	-	115	-	-	14o	13o	125	11o	14o
6.	167	16o	155	22o	21o	29o	23o	162	146	13o
7.	9	9	11	15	14	16	1o	17	13	9
8.	12	12	8	7	7	1o	11	9	9	8
9.	3.o	3.1	2.5	3.o	3.o	3.o	3.1	2.o	2.1	2.4
1o.	18.5	17.8	16.8	-	15.3	21.6	25.o	-	13.4	14.4
11.	2.2o	2.o5	2.23	-	2.7o	2.4o	3.o7	-	4.o8	2.24

1: dental length /mm/; 2: number of lamellae /piece/; 3: dental lamellar index /number of lamellae in loo mm/; 4: dental width /mm/; 5: dental height /mm/; 6: length of masticatory surface /mm/; 7: number of lamellae constituting the masticatory surface; 8: lamellar thickness /mm/; 9: enamel thickness /mm/; lo: dental length /number of lamellae/; 11: dental length /dental width/.

s.: sin.; d.: dext.; 65: the find of 1965; 81: the find of 1981; fragm.: fragment.

Together with the Archidiskodom meridionalis fossils /?/ found at Ercsi, Budapest-Kőbánya and Kisláng /KRETZOI, M. 1954/, and from the basis of the gravel terraces containing the old meridionalis fossils at Aszód /SCHLESINGER, G. 1922/ Mastodon arvernesis Croizet et Jobert and/or Zygolophodon borsoni Hays fossils were found.

These Proboscides fossils are older and are probably indicative of the period from the Lower Villányium to the Early Upper Villányium.

TABLE 2 Trend of the thinning of the dental enamel of the Elephantitidae of Hungary

1	2	3	4	5	6	7
4.2	3					
4.1	3					
4.o	12					
3.9	6					
3.8	9					
3.7	-					
3.6	12					
3.5	4					
3.4	5					
3.3	2					
3.2	3					
3.1	-					M_1 /81/ Amm., M_3 /65/ Amü.
3.o	8	2				M_1 /81/ Amm., M_{2-3} /65/ Amü.
2.9	-					
2.8	-					
2.7	-					
2.6	-					
2.5	5		1			M_1 /65/ Amü.
2.4			1	1		M_2 /fragm.M./P./ trog.
2.3			1	1		
2.2			1	6		
2.1			2	-		M_3 /81/M./P./ trog.
2.o			7	18		M_3 /81/M./P./ trog.
1.9			-	-		
1.8			1		6	
1.7			-		6	
1.6			1		4	
1.6					6	
1.4					1o	
1.3					13	
1.2					3	
1.1					4	
1.o					4	

/65/ = 1965
/81/ = 1981
fragm. = fragment

1: enamel thickness; 2: Archidiskodon meridionalis meridionalis /Nesti/; 3: Archidiskodon meridionalis ürömensis Vörös; 4: Mammuthus /P./ trogontherii /Pohlig/; 5: Mam. prim. "alt"; 6: Mam. prim. "jung"; 7 - Gyöngyösvisonta.

TABLE 3 Lamellae frequency in the dentition of Elephantidae in Hungary

1	2	3	4	5	6
4	9				
4.5	1				
5	lo		2		M_{3-3} /65/ Amü.
5.5			1		M_{1-1} /81/ Amm.
6		1	3	4	M_{2-2} /65/ Amü.
6.5			2	2	
7			2	44	M_2 /fragm./M.P./ trog.
7.5			2	1	M_1 /65/ Amü., M_3 /81/M./P./ trog.
8.5			2	2	M_3 /81/M./P./ trog.
9				6o	
9.5				2	
lo				34	
lo.5				1	
11				16	
11.5				-	
12				2	
12.5				-	
13				5	

1: index = number of lamellae in loo mm; 2: Amm. = Archidiskodon meridionalis meridionalis /Nesti/; 3: Amü. = Archidiskodon meridionalis ürömensis Vörös; 4: M./P./trog. = Mammuthus /P./ trogontherii /Pohlig/; 5: Mam. prim; 6: Gyöngyösvisonta; /65/: the find of 1965; /81/: the find of 1981; fragm.: fragment.

4/ M a m m u t h u s /Parelephas/ t r o g o n t h e r i i /Pohlig/

Stratigraphic position: the fossil derives from the upper part of the tufaceous, sandy clay at a depth of 12 to 13 m. It is unrounded.

The material: dextral corpus mandibulae with an abrasion remnant of M_2 and M_3; sinistral corpus mandibulae with the "II. find"; costa fragment.

Description: both corpus mandibulae are incomplete, and the abrasion remnant of the sinistral M_2 is absent. The talonid of M_3 together with the ramus mandibulae are broken off. The abrasion remnant of the dextral M_2 consists of 5 lamellae, these being worn down to the crown base. The width of the M_2 abrasion remnant is 64 mm /PHOTO 5a, 5b/.

PHOTO 5A: Mammuthus /Parelephas/ trogontherii /Pohlig/, sinistral corpus mandibulae fragment, M_3. Depth: 12-13 m. M.: 1:1/2

B: Mammuthus /Parelephas/ trogontherii /Pohlig/, dextral corpus mandibulae fragment, the abrasion remnant of M_2 and the M_3. Depth: 12-13 m. M.: 1:1/2 /VÖRÖS, I. 1982/.

M_3s are long relatively narrow high teeth. The enemal contours of the masticatory surface of the lamellae are uniform. Conjunction types of the lamellae: lateral lamellar - medial annular. The walls of the lamellae are parallel, slightly widening in the medial part, where the enamel is slightly wrinkled. In the dextral M_3 masticatory surface developed only in the frontal third. The lower two thirds of the ten lamellae constituting the talonid of M_3 are posteriorly deformed. Thus, the dental talonid could fill the alveole of the ramus mandibulae.

In the related mandibulas the sinistral molars are more worn than the dextral ones. Based on wear and dentition the animal was about 45 to 5o years old. The fossils are suitable for the determination of the species.

Based on the dental structure and dimensions /TABLE 1/ it is assigned to the species Mammuthus /Parelephas/ trogontherii /Pohlig/ SOERGEL, W. 1912; DEPÉRET, Ch. - MAYET, L. 1923/. Because of a lack of faunal finds, the biostratigraphic position of the species M./P./ trogontherii is known only from a few localities in Hungary. Its biostratigraphic position is marked by the A. m. meridionalis /Upper Villányium, Kislángium/ lying in the deeper strata of the profile.

The fossil was buried in a sediment of normal magnetic polarization, probably during the lower third of the Brunhes epoch.

5/ B i s o n sp. /small/

Stratigraphic position: the fossil derives from the upper tufaceous sandy clay at a depth of 12 to 13 m.

The material: dext. M^2 fr.; caput humerii sin. fr. The protoconid of M^2 is unworn, and the caput humerii is not set with the diaphysis. Both fossils refer to an animal about three years old.

5/ E q u u s /Allohippus/ s ü s s e n b o r n e s i W ü s t

Stratigraphic position: the fossil derives from a layer of andesite gravels and sands at a depth of 9 m.

The material: dext. P^2.
Height of the dental crown: 55 mm; dental length: 46 mm; dental width: 33 mm.

The gigantic Allohippus assemblage indicates the Lower Biharium.

6/ A r c h i d i s k o d o n m e r i d i o n a l i s ü r ö m e n s i s V ö r ö s

Stratigraphic position: the fossil was found in the sequence in 1965 /FIG. 3/. The Arch. m. ürömensis was excavated from the black humus layer below the 32o to 34o cm thick layer of yellow loess /ROZSNYÓI, M. 1966/. The fossil is poorly preserved, the tubular bones are in a fragmental state and are found in the collection of Mátra Museum at Gyöngyös.

R e m n a n t s o f m a t u r e i n d i v i d u a l s

Cranials
- cranial fragments
- right and left tusks /length: 32oo mm; max. diam.:26o mm
  " 3ooo mm; " " 24o mm,
  typs incline slightly backwards and outwards/.

The dental dimensions are given in TABLE 1.

Postcranials

- vertebra thoracalis - lumbal fragments
- costae fragments
- scapula dext. dist. spec.

facies articularis, width	3oo mm	Mammuthus /1o/ 165-23o mm
facies articularis, height	17o mm	Mammuthus /11/ 1oo-135 mm

- pelvis fragments
- tubular bone fragments
- carpalia/tarsalia fragments.

R e m n a n t s o f a j u v e l i n e i n d i v i d u a l

- tusk /thin, strongly curved /length: 27oo mm; max. diam. 14o mm/
- M^1 sin The dental dimensions are given in TABLE 1.
- humerus sin. /prox. epiph. is lacking and it is noc ossified/. The length of diaphysis-dist. epiph.: 9oo mm, the width of dist. opiph. is about 24o mm.

Based on dental structure and size parameters /TABLE 1 and 2/ and on the size of tubular bone fragments, the fossil can be identified as an evolved form of Archidiskodon megaspecies, i. e. with the subspecies Archidiskodon meridionalis ürömensis Vörös /VÖRÖS, I. 198o/.

The megaspecies Archidiskodon produced large numbers of horizontally evolved forms in the southern regions of Eurasia during the Günz-Mindel interglacial and Arch. m. ürömensis is also a member of this assemblage.

The find Arch. m. ürömensis is assigned to the Templomhegy phase of the Lower Biharium.

STRATIGRAPHIC EVALUATION

Based on the paleontological evidence the younger sedimentary sequence overlying the lignite-bearing formation at Gyöngyösvisonta is of Sümegium age, being divided sedimentologically into two groups and can be subdivided and classified as a part of the terrestrial biochronology /PÉCSI, M. - KRETZOI, M. 1979/.

It is to be noted, however, that part of the taxons of the fossils are unsuitable for determination, being incomplete and represented by fragmental remains. Further, there are taxons which can be classified only according to their evolutionary phase and this can only provide reliable data in statistic quantities. Finally, it is to be emphasized that the first appearance of Elephantidae in Europe as drawing the lower boundary of the Pleistocene, is not evidenced according to recent considerations.

Taking all the facts into consideration the following can be stated:

1. The mastodon find being a rare representative of the group and showing a complicated picture of multi-furcating evolution, is of no stratigraphic value in itself: its assignment to the Upper Pliocene or Lower Pleistocene is a rather wide time interval. If, however, one also takes into account the Elephantidae-femurs, which are not derived from mastodon, according to size, this creates a new situation. Given our knowledge so far, the appearance of Elephantidae, in addition to that of Bos, Equus and Canis, places the conventional lower boundary of the Lower Pleistocene according to Haug. On this basis the horizon at a depth of around 34 m cannot be older than Lower Pleistocene. In this case, however, it is dangerous, to place the first European appearance of Elephantidae /which should follow in the Ruscinium-Csarnótanum/ in the Lowermost Pleistocene. Nevertheless, in this case the femurs of Elephantidas do not exclude the probable Ruscinium-Csarnótanum age of the complex in question either.

2. The paleontological age determination of the complex between 8 and 14 m represents a much more favourable case.

The Elephantidae maxilla pair found at about 14 m, i.e. at the base of the upper sedimentary complex is a characteristic representative of Archidiskodon meridionalis /Nesti/ whose age can be fixed as the upper part of the Villányium.

3. Nevertheless, the second pair of maxilla found at a depth between 12 and 13 m are from the Mammuthus /Parelephas/ trogontherii /Pohlig/ genus and species which do not appear earlier than the beginning of the Upper Biharium, i.e. it represents the upper horizon of the Biharium. This also shows that the temporal and spatial absence of the Lower Biharium in the profile should be expected.

From an horizon at a depth of 8 m of the same lithological complex an Equide upper molar was found. Since this fossil represents the primitive Allohippus genus which is practically absent from the Upper Biharium, this part of the profile contains a form which should be assigned to the Lower Biharium. This temporal transition suggests that the coarse sedimentary accumulation of this complex caused the intermixing of fossils from the two periods.

4. This assumption is supported by the fact that in 1966 a proboscidan maxilla representative of the terminal form of the A. meridionalis ürömensis Vörös subspecies of the Archidiskodon meridionalis /Nesti/ was found in the abandoned mines 3 to 4 m below the surface, this form overlaps the Biharium but does not reach the Upper Biharium, and is unambiguous evidence that the lower member of the Biharium not everywhere was in general eroded and remained only in isolated places in the mine area, e. g. in the locality of the proboscidean find at a depth of 3-4 m.

In other places the surface is eroded down to the Upper Villányium and is overlain directly by the Upper Biharium.

In summary the lower part of the terrestrial barren sequence overlying the lignite-bearing Upper Pannonian formation can be assigned to the interval between the Uppermost Pliocene and Lower Pleistocene, the base of the upper complex being placed at the end of the Villányium, and the middle sequence to the Lower Biharium. The upper part of the upper complex is Upper Biharium and/or younger, but can be assigned to a phase older than Utrechtian /Würm/.

PALEOMAGNETIC DATA /1981/ AND THE CHRONOLOGICAL BACKGROUND TO THEIR INTERPRETATION

The open-cast mining activities at Gyöngyösvisonta have uncovered at least four sedimentary sequences differing both in formation and age. Extending the paleomagnetic analyses to all of them, a sequence of 110 m in thickness was sampled. The sampling distance was 2 m in the lower lignitic sequence and 0.75 m in the top layers.

To isolate the stable long-life magnetic component, cleaning with alternating magnetic fields was used. This component can be identified as the polarity characteristic of the stratigraphic position of the formations. Disregarding the detailed magnetic data of each sample the comprehensive lithological-paleomagnetic profile of TABLE 4. shows the paleomagnetic polarities. N denotes recent magnetism, while R is the reversed polarity opposite to the recent one. When moving downwards in the profile, the first R-zone also contains samples of normal polarity; the R-polarity of the fourth zone is questionable since in this section the original, probably reversed, magnetism was subsequently strongly remagnetized and pure reversed polarity was found in none of the samples.

The task of the chronological interpretation of paleomagnetic data is to indicate how the paleomagnetic profile can be fitted and correlated with the known polarity time-scale /TABLE 4/. In case of continuous sedimentation up to the present the correlation is free from problems since the uppermost zone is the Brunhes Normal, and the Matuyama Reversed, the Jaramillo Normal, etc. subsequently follow down the profile.

The profile at Visonta, however, shows non-continuous sedimentation. Erosion produced clear unconformities and in certain periods the sedimentation gap should also be taken into account. In such cases when evaluating chronologically the paleomagnetic profile some reference, i. e. calibration points are required. Let us list them.

The lignite-bearing sequence is a wide-spread lithostratigraphically independent guide horizon. From the foothills of the Mátra and Bükk Mountains it uniformly slopes southwards to the

TABLE 4 Distribution of magnetic zones of normal and reversed polarity in the upper part of the Cenozoic /NESS et al. 196o/

Million years	Polarity	Polarity epoch		Polarity events
o.oo - o.72	N	Brunhes normal	1	
- o.91	R			
- o.97	N			Jaramillo
- 1.68	R			
- 1.87	N	Matuyama reversed	2	Olduvai
- 2.ol	R			
- 2.o4	N			Reunion I
- 2.12	R			
- 2.14	N			Reunion II
- 2.47	R			
- 2.91	N			
- 2.98	R			Kaena
- 3.o7	N	Gauss Normal	3	
- 3.17	R			Mammoth
- 3.4o	N			
- 3.85	R			
- 3.98	N			Cochiti
- 4.12	R			
- 4.2o	N	Gilbert reversed	4	Nunivak
- 4.41	R			
- 4.49	N			Sidufjall
- 4.59	R			
- 4.79	N			Thvera
- 5.41	R			
- 5.7o	N			
- 5.78	R		5	
- 5.97	N			
- 6.43	R			
- 6.55	N		6	
- 6.77	R			
- 6.86	N			
- 6.94	R			
- 7.34	N			
- 7.39	R		7	
- 7.44	N			
- 7.81	R			
- 8.18	N			
- 8.4o	R-8,49 m			
- 8.49	N			
- 8.8o	R		8	
- 8.87	N			
- 8.98	R			

TABLE 4 /cont./

Million years	Polarity	Polarity epoch	Polarity events
o.oo - 9.13	N		
- 9.17	R		
- 9.47	N		
- 9.48	R		9
- 9.75	N		
- 9.78	R		
- lo.o3	N		
- lo.o5	R		
- lo.3o	N		

Great Plain. It is found in the Hatvan-Vámosgyörk-Kálkápolna-Mezőkövesd region at a depth of loo m, in the Jászberény, Jászárokszállás, Erdőtelek, and Heves region at depths of 25o to 3oo m, in the Jászladány region at a depth of about 74o m. The lignite-bearing sequence was formed during the Upper Pannonian Congeria balatonica phase /JASKÓ, S. 1981/, the age of which is put at between 4 and 5 million years by the K/Ar data of the Transdanubian basalt flows at Pula and Kapolcs /BALOGH, K. et al. 1981/. Nevertheless, the same biostratigraphic horizon in the Great Plain is certainly older than 5.5 to 6 million years according to the magnetic stratigraphy of the cores from Dévaványa and Vésztő /COOKE, H.B.S. et al. 1979; La BREQUE, J. L. et al. 1977; NESS, G. et al. 198o/ and when taking into account of the fact that the formation of lignite along the margins preceded that of the basin, their age cannot be less than 6 to 7 million years.

In the Visonta profile the lowermost complete R, a relatively short N and an R-zone curtailed by erosion represent the lignite-bearing formation. This picture of polarity ought to be fitted into the polarity time scale to obtain the magnetic stratigraphic position of this part of the profile. Taking into account the restrictions above, one probable but not exclusive solution is to correlate it with the polarity epoch of No. 7-8 which suggest 6.8 and 8.4 million years as the age of the lignite. The upper age limit corresponds to the Sümegium phase determined from terrestrial stratigraphy of the lignite seam and to the dating of the Sümegium by KRETZOI, M.

According to KRETZOI, M. the proboscidean fossils found in the upper part of the profile at the Upper Villányium - Lower Biharium boundary indicate an age corresponding to the Oldovai geomagnetic event, i. e. 1.6 to 1.8 million years. The overlying vertebrate finds /PHOTO 6/ between 8 and 12 m can be assigned to the upper horizon of the Lower Biharium, to normal magnetic polarity of which relates only to one period, i. e. to the Brunhes Normal, if in this section of the profile a gap of one million year does not occur, which seems to be improbable. In the profile the R-zone between 14 and 24 m can be correlated with the lower part of the Matuyama. Downwards the magnetic stratigraphic correlations depends on the time interval of the erosion gap interrupting this R-zone. Again assuming that this is relatively short, the subsequent N-zone as well as that interpreted a reversed R-zone and the underlying N-zone between 36 and 39 m can be correlated with the Gauss epoch, so that the magnetism of the whole reddish-purplish soil sequence is probably Lower Pleistocene to Upper Pliocene in age /Lower Villányium to Upper Ruscinium/.

The magnetic stratigraphic classification of the formations between the lignite-bearing sequence and the purplish soils is as yet unsolved. The fossil assemblage of Zygolophodon maxilla and the Elephantida femurs lying at 34 m provide no clues either. Their joint occurrence indicates Lower Pleistocene but the paleontological evaluation does not exclude the Upper Pliocene /Ruscinium-Csarnótanum/, this being too large an interval to take as a calibration point. The stratigraphic position of the formations in question as well as the minimal magnetostratigraphic age decuded for the cover undoubtedly indicate formation before the Pleistocene.

These suggest a probable chronological interpretation of the 1981 paleomagnetic profile from Visonta, but other correlations in harmony with the stratigraphic and paleontological observations can also be envisaged. This is due to the relative temporal shortness and incompleteness of the profile and less importantly to the occasional uncertaintes of the individual magnetic zones.

THE INTERPRETATION OF THE GEOMORPHOLOGICAL, LITHOSTRATIGRAPHIC PALEONTOLOGICAL AND PALEOMAGNETIC DATA

After interpretation the lithological characteristics and formation of the alluvial fan cover /1 to 34 m/ it was pointed out that this formation was generated by an erosion-accumulation process during which soil formation and weathering took place at least 15 times, i.e. during the development of soils substantial sedimentation had ceased. Further, in 5 to 6 cases considerable down-wearing of sediments i. e. unconformities should be taken into account. These facts as well as the paleomagnetic sampling at one metre intervals should be taken into consideration.

- As to the geomorphological interpretation the profile's cover exposed an alluvial fan the surface of which is older than the two or three Pleistocene terraces of neighbouring streams, i.e. it is conventionally Middle Pleistocene or older. In the uppermost part of the alluvial fan, at depths of between 1 and 6 m, three fossil soils overlie each other; in the soil F_2 cryoturbation phenomena are also found. The paleontological finds from

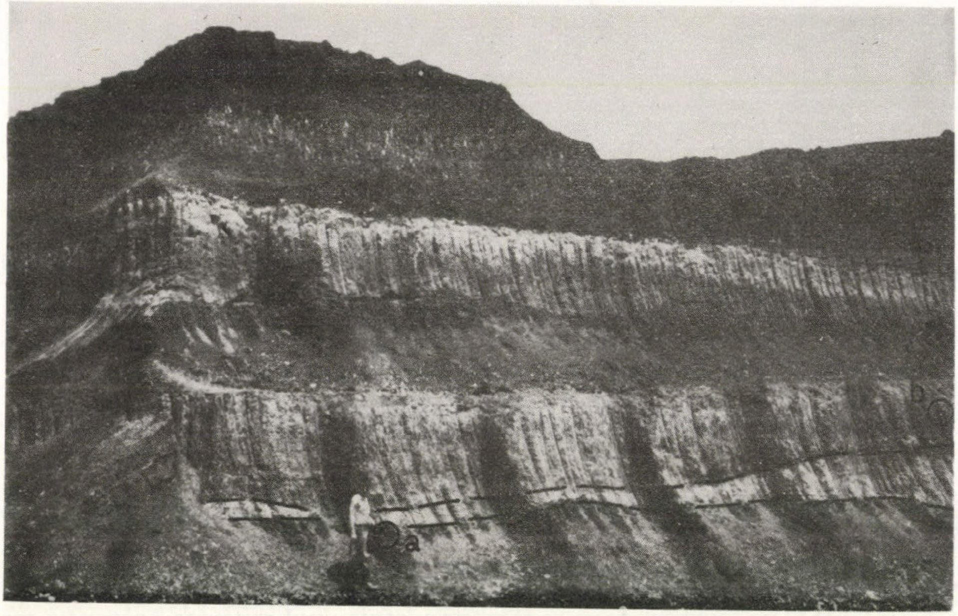

PHOTO 6 Location of the Archidiskodon meridionalis /Nesti/ /point a/, and the position of the Mammuthus /Parelelpas/ trogontherii /Pohlig/ /point b/ /PÉCSI, M./

the base of the old loess at between 6 and 9 m, as well as from the tufaceous sandy clay between 12 and 13 m are assigned in our interpretation to the Upper Biharium, i. e. to the Middle Pleistocene, the beginning of which is correlated with the beginning of the Brunhes Normal, i. e. o.73 million years. This is in agreement with the fact that the samples from this section /3 to 13 m/ are of normal polarity.

- The layer containing the A. m. meridionalis maxilla is separated from that above by an erosion gap /PHOTO 6/. According to the paleontological evaluation, this fossil can be assigned to the Upper Villányium. The boundary between the Upper Villányium and Lower Biharium is taken to have occurred at about 1.8 million years. The clayey layer of normal polarity at 14 m where the polarity change is between erosion gaps, may represent a part of the Olduvai event.

- The part of the Visonta open-cast mine studied in our profile represents a derasional valley 4o-5o m in width and containing 6-1o of fill. Based on previous A. meridionalis ürömensis finds /Lower Biharium/ at a depth of 3-4 m it can be concluded that the upper third of the alluvial fan generally belongs to the Lower Pleistocene. On the surface of the Lower Pleistocene alluvial fan derasional valleys were formed and in-filled during Middle Pleistocene /Upper Biharium/. According to previously paleomagnetic studies carried out in the three localities only the uppermost strata of the cover /between 1 and 3 m/ proved

PHOTO 7 Stratigraphic position of the Mastodon find /Zygolophodon/ and the probiscidean tusk and dental fragment.
P_2: Upper Pannonian sand
/PÉCSI, M./

to be of normal polarity. The strata of reversed polarity occurred mostly several metres below the recent surface /analysis of PEVZNER, M.A. and MÁRTON, P./.

- Lithostratigraphic and paleopedological analogies /e.g. Dunaföldvár, PÉCSI, M. et al. 1979/ suggest that the purplish-red soils /F_8 - F_{15}/ were formed during the Lower Villányium /Beremendium/, while the purplish soil fragment containing sediments at a depth of 36-39 m represents the Upper Csarnótanum. Paleomagnetic measurement show that the upper and lower parts of this sequence are of normal polarity, only the middle part is of reversed polarity. In the doubtful R-polarity zone two sand strata and erosional unconformities are found. Based on paleomagnetic, lithostratigraphic, paleopedological and paleontological data /PHOTO 7/ the sequence can be correlated with the Gauss magnetic stratigraphical epoch.

- On the Great Plain margins the lignite-bearing Upper Pannonian formation /FIG. 3/ is also an index horizon from the lithostratigraphic point of view and can be correlated with the lacustrine Congeria balatonica /BARTHA, F. 1971; JASKÓ, S. 1981/ and the Sümegium in terrestrial formations /KRETZOI, M. 1969/.

As mentioned previously the major part of this sequence /between 45 and 53 m N, between 53 and 95 m R/ can be probably correlated with the magnetic stratigraphical epochs7 and 8, respectively.

- The mainly coarse sand and clayey sand formations between the lignite-bearing Upper Pannonian sequence and the alluvial cover /38.5 - 43 m/ overlie each other with considerable erosional unconformities. This stratigraphic unconformity extends over the sand of Uno wetzleri /Baltavárium/ as well as the mastodon-bearing tufaceous purplish clay /Upper Pliocene, Ruscinium/. This phenomenon is characteristic of nearly the whole zone of the North Hungarian Mountain Range and of the marginal parts of the Great Plain /JASKÓ, S. 1981/. The strata gap progressively grows towards the margin, so that the lignite-bearing sequence, and deeper Pannonian horizons are absent. It is not impossible, therefore, to correlate the H_3 sand of the profile of R-N-R polarity with the Gilbert further with the 5th and 6th magnetic stratigraphic epochs.

In the open-cast mine of Gyöngyösvisonta the considerably eroded lignite-bearing sequence is about 5o m in thickness, although pilot bores locally show thicknesses of loo to 2oo m. During its formation the foothill and basin margin zones gradually subsided with repeated interruptions. The uplift and erosion of the lignite-bearing formation began first in the foothill zone at the boundary of the Gilbert and 5th paleomagnetic epoch /5.4 million years/, i. e. at the beginning of the Ruscinium. From among the subsequent phases of uplift the tectonic movements of the Upper Biharium are most significant as these produced the selective erosion and dissection of the older alluvial fan.

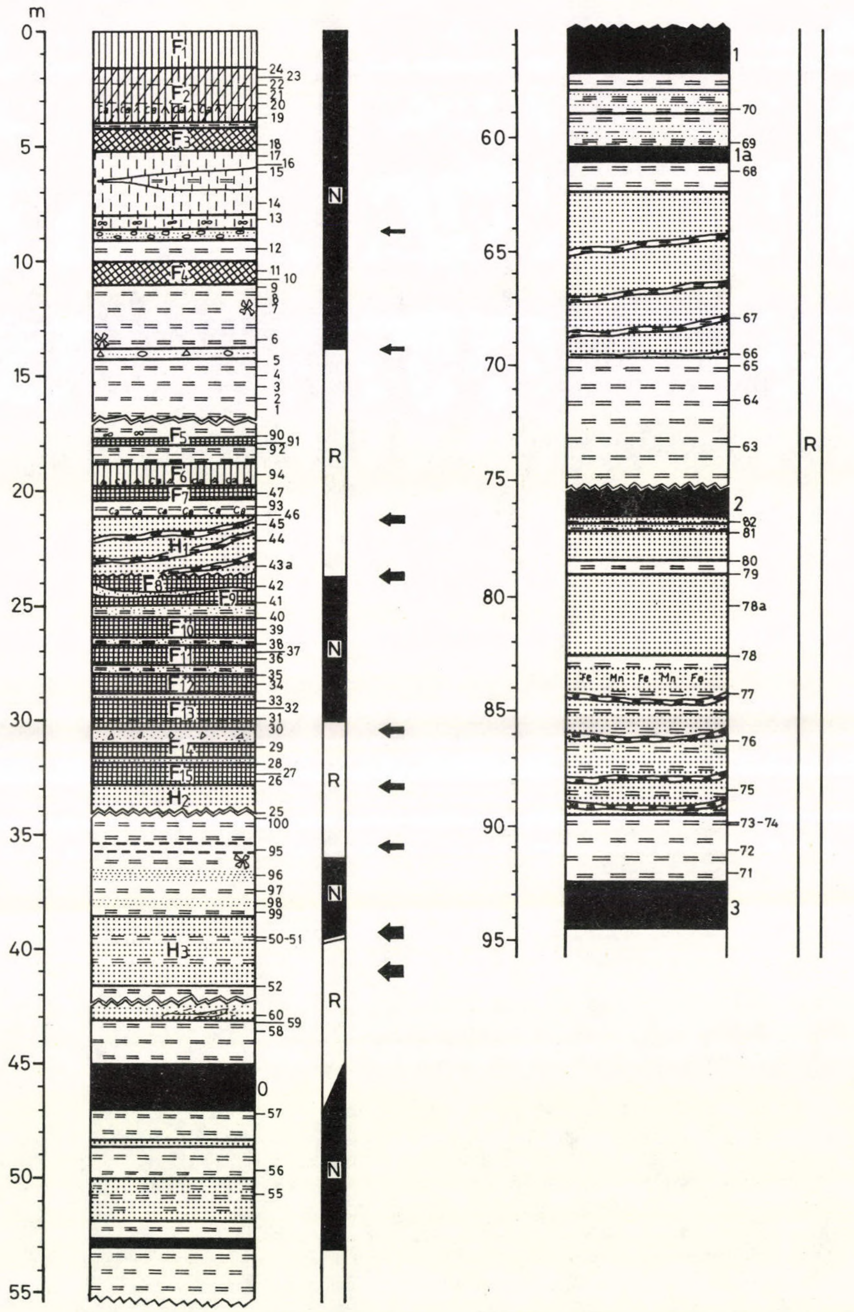

FIG. 3 Comprehensive profile of the Gyöngyösvisonta open lignite mine /Thorez Mine/. 1981. Surveying and determination of the profile were carried out by BALOGH, J. - MÁRTON, P. - SCHWEITZER, F. - SZOKOLAI, Gy. under the guidance of PÉCSI, M.

FIG. 3

Pleistocene

o.o - 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 tufa 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.o m	dark-grey purplish flood plain clay soil
11.o - 12.o m	$CaCO_3$ accumulation horizon
12.o - 13.8 m	grey clay with $CaCO_3$ concretions and tufa detritus /Mammuthus trogontherii and minor Bison sp. finds/
13.8 - 14.3 m	sand with andesite gravel /Archidiskodon meridionalis find/
14.3 - 15.3 m	clayey sand with tufa detritus
15.3 - 16.7 m	grey clay soil of flood plain
16.7 - 17.7 m	greyish-brown clay with tufa detritus
17.7 - 18.o m	purplish clay with tufa detritus
18.o - 18.8 m	greyish-brown clay with tufa detritus
18.8 - 2o.4 m	/reddish/ brown clay soil
2o.4 - 21.1 m	limy, sandy old loess
21.1 - 23.7 m	clayey sand /from 23.4 sand with tufa detritus/
23.7 - 25.o m	purplish aggregated clay /with yellowish-brown sandy tufaceous-detrital wedging/
25.o - 25.5 m	yellowish-brownish tufa detritus
25.5 - 26.4 m	purple clay soil
26.4 - 26.7 m	clayey sand with tufa detritus
26.7 - 27.6 m	greyish-purplish clay soil
27.6 - 28.o m	clayey sand with tufa detritus
28.o - 28.9 m	purplish clay with tufa detritus at the base
28.9 - 29.1 m	sand with tufa detritus
29.1 - 3o.4 m	purplish clay /from 29.9 m greyish-purplish clay/
3o.4 - 31.o m	yellowish-brown coarse sand with tufa detritus
31.o - 31.6 m	purplish clay
31.6 - 31.8 m	clay with tufa detritus
31.8 - 32.3 m	purple clay with tufa detritus
32.3 - 32.7 m	purple clay
32.7 - 34.o m	yellowish-brown sand with tufa detritus
34.o - 35.8 m	sandy clay with yellowish-grey purplish sand of tufa 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 tufa detritus
37.1 - 37.9 m	ferrous sandy clay
37.9 - 38.5 m	sandy clay with tufa detritus with purplish tufa detritus at the base

Pliocene

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.o m	grey clay
45.o - 47.o m	lignite
47.o - 48.3 m	grey clay
48.3 - 48.6 m	yellowish-grey sand
48.6 - 5o.o m	grey clay
5o.o - 51.8 m	yellowish sandy clay
51.8 - 52.7 m	grey clay
52.7 - 53.o m	lignite
53.o - 55.3 m	grey clay
55.3 - 57.2 m	lignite
57.2 - 58.o m	grey clay
58.o - 59.o m	greyish-yellowish muddy clay being more clayey at the base
59.o - 6o.5 m	grey muddy clay
6o.5 - 61.1 m	lignite
61.1 - 62.4 m	micaceous muddy clay
62.4 - 69.6 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

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PLIOCENE AND PLEISTOCENE FORMATIONS IN THE OPEN-CAST MINE IN THE MÁTRA FOOTHILLS

SZOKOLAI, Gy.

The Thorez Open Mine supplies the Gagarin Power Plant with fuel. Production amounts to 7.2 million tons of Upper Pannonian lignite annually, having an average calorific value of 6 28o to 6 3oo KJ/kg, and involves the removal of 45 to 5o million m^3 of overburden and the pumping away of 5o to 57 thousand m^3 of water per day.

The lignite occurrence in the foothills of the Mátra Mountains is relatively extensive and can be exploited by open cast methods. The floor of the Pleistocene-Pliocene sedimentary sequence consists mainly of Miocene andesitic volcanics. Towards the centre of the basin these are overlain by marine sediments /Tortonian = Badenian/ and/or brackish and terrestrial Sarmatian /Visonta-156/A/ formations. The Lower Pannonian is known only in the centre of the basin /Karácsond-1/, and only part of the Upper Pannonian /middle to upper/ sequence has been assessed. In the open-cast mine the upper part of the Upper Pannonian as well as its terrestrial Plio-Pleistocene cover can be studied over an extensive area.

THE STRATA SEQUENCE

In the area of the mine the Upper Pannonian sequence is represented by strongly limnitic shallow lacustrine formations /FIG. 1/ and is composed of the following:

- a quiet pelagic clay and aleurite,
- a fine sand deposited in a shallow lake and transported by alluvial action,
- lignite seems composed mainly of shallow marsh and bog forest formations,
- the reworked, terrestrial fluviatile formations of the flat bank with varied stratification, and with traces of the marginal zone of a drying bog.

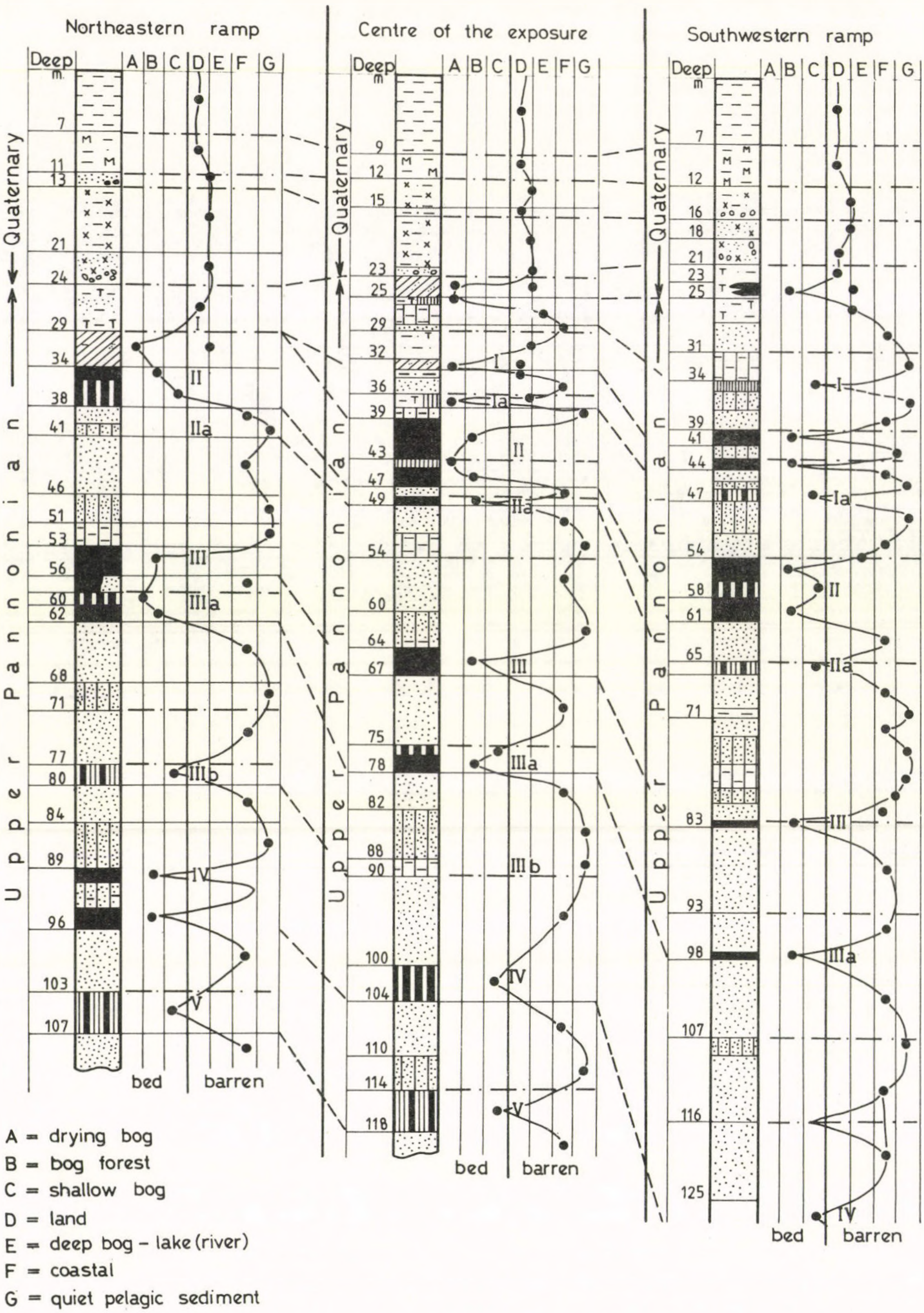

FIG. 1 Sedimentological sketch of the Thorez Open Mine

The following type sequences was established by pilot bores:

- seam No. IV /local numbering/ 2.5 to 7.o m,
- a sandy sequence representing two major or 4 to 5 secondary and less distinct sedimentary cycles /marked III/O/, locally with thicker lignite-bearing intercalations /trace bed No. III/ total 2o to 25. m,
- the seams of sequence No. III. which merge north-westwards, and are intercalated with 3 to 12 m of sand/K III /O/,
- a barren sequence consisting of several incomplete cycles of mainly sand but with silt and clay /II/O; 12 to 18 m/
- the seams of sequence No. II consisting of one initial separated /11 m in thickness/ and two interrelated banks of 5 to 8 m in thickness worthy of being mined,
- a mainly fine-sandy sequence averaging 1o m in thickness with the traces of the final I/a bed,
- a silty, sometimes clayey sequence of 2 to 5 m in thickness,
- seam No. I of marginal formation with maximum exploitable thickness of 2.5 m,
- a varied slightly cross-bedded sequence consisting mainly of fine sand /O/O/ of 8 to 12 m in thickness,
- seam No. O, also of marginal formation varying from O to 3 m in thickness,
- a clayey, silty closing strata with a thickness of 3 to 5 m except in the south-eastern part of the profiles,
- the mostly yellow-variegated fine-sandy, marly, sandstone lense bearing strata which occur above all the main seams directly underlying the closing strata can also be assigned to this sequence; these consist of the reworked material of the sequence on which they lie unconformably.

The formations of the Pannonian lignite-bearing sequence are derived mostly from the erosion of older loose sedimentary formations, whose mineral composition they largely reflect.

The Quaternary strata unconformably overlying the Upper Pannonian are of varied petrographic composition. The characteristic members which can be distinguished are as follows:

- a sequence consisting mainly of tufa sand dissected by coarse gravelly detrital intercalations,
- clay with tufa detritus of volcanic origin,
- a strongly calcareous "nyirok"-like clay sequence.

The mineral composition of the overlying sequence strongly differs from that of the lignite-bearing group and contains huge quantities of reworked and weathered volcanic tufa.

The complete Quaternary sequence averages 2o to 25 m in thickness, the stratigraphy of which is given this topic in the profile.

DEPOSITION FEATURES AND FACIES CHANGE IN

THE PANNONIAN SEQUENCE

In the outcrop the formations below seam No. III cannot be seen since here because this seam is unsuitable for exploitation.

In the northern part of the profile seam No. IV is covered by stratified mud, silty mud and clayey mud. This in turn is overlain by a more highly sorted fine sand with upward coarsening grain size, which in the southern part directly overlies the lignite seam /Cycles 3/1-3/2/. In the region of pure sand seam III/b is either very thin or entirely absent.

Seam III/b is followed by asymmetric cycles, the finer strata alternating two or three times with medium-grained sandy /3/3 to 3/5/.

Seam No. III is of bog-forest character showing ligneous and earth-coal features. The petrographic types which can be more or less parallelled by the bog zones are lenticularly stratified being directed towards the centre of the basin. Over the north-eastern boundary ramp of the mine the seam bifurcates and boreholes have revealed bog-forest formations, greenish-brown root and stem remnants as well as material with spherical jointing are found in the well-sorted K/III/O sand horizon. This sand is rather uniform /south-eastwards it is dissected by a clay-mud layer into cycles K 3/1-K 3/2, and moving further in that direction seam has become separated from the uppermost lignite seam showing deep-bog features: K 3/6/.

The seam sequence No. III is overlain by transgressive strata starting with coarse sand in the southern part of the profile. Across the north-eastern boundary ramp there is only one /boreholes Hu-lo9 and 187/, but within the ramp two cycles follow in the same sequence as between seams III and IV. /The particular investigations revealed three sand wedge sequences following on each other with slight linear stratification./ Internal unconformities in the form of sedimentation gaps, washouts and complete cycles are characteristic of the "Middle Member" of the Upper Pannonian, i. e. of the lignite-bearing group. The energy conditions are less favourable, the strata sequence consists of finer-grained and less sorted members. The sand between the side-seam and main seam /cycle 2/4/ is similar to K III/O, and differs also petrographically from the sand sequence.

Over the boundary ramp the seam sequence No. II is represented mainly by brownish-green variegated clays with plant remains. Dessication structures, small and large bentonitic lenses and the calcareous concretions that are present relate to terrestrial marginal formation. In the upper part of the seam, these formations alternate with clay containing lignite traces and of organic colour and extend southwards to borehole Hu-155. During the final phase of seam formation the bog forest was restricted to a narrow area, as is evidenced by the jointing of the upper banks in the south, while between the banks grey and brownish-grey mud and clay are intercalated.

It is interesting that sedimentation could proceed at a gradually accelerating rate. This is evidenced by the predominance of obliquely stratified silty-sandy strata /near-shore, probably deltaic formations/ as well as by the insignificance or absense of a clay substratum on which bog formation had been initiated. Thicker clay substrata of characteristic greenish-grey colour, with plant remains, and showing evidence of subaquatic slides, lime-spotting and drying structures /spherical-conchoidal jointing / are usually found as intercalations between the lignite seams. /South-east of the profile, in the open-cast mine K-II fossili ferous green clay is associated with seams I and III, and is presumed to be of tufa-like character./

In the northern-north-eastern part of the sequence poorly sorted yellow-variegated formations overlie seam No. II. In the excavation exposure the changing thickness and wedging of each member as well as the cross-bedding of the whole sequence can be observed. Seams are represented by ligneous clay, and those of higher quality are usually characterized by allochtonous features. Additionally shallow lacustrine leaf-imprinted, diatomaceous-calcareous clays and muds also occur. These features are displaced for several hundred metres in the direction of the deepening basin in the sequence of seams II-I-O, and their regression character is obvious. In other words, the Upper Pliocene appears there and in the form of a heteropic facies. The erosion of the lignite-bearing sequence had simultaneously started as is evidenced by the traces of redeposited, bentonitic clay-gravel.

Occasionally, the Quaternary cover is separated from the lignite-bearing sequence by appearance of gravelly "base"-horizons. Where there are absent, however, the separation is not always unambiguous, and can only be precisely established after petrographic examination. New data show that the erosion of the Miocene andesite tufas had already started during the Pannonian subsequent to the formation of seam No. II. /Thus between F-278 and K-5o/11 the boundary is marked higher than was previously accepted./

THE UPPER PLIOCENE - QUATERNARY COVER

The cover is of varied petrography. This variance depends mainly on the energy of the transporting medium, i. e. on relief energy conditions, as well as on the degree of weathering and the reworked state of the andesite tufa, i. e. on the sedimentation medium and climatic conditions, which underwent rhythmic changes

In the section representing the outcrop and its direct neighbourhood the two lower sections of the cover are characterized by purplish-brownish-red formations. Their volcanic origin can be recognized not only in the coarse fraction of the gravel detrital horizons but thoughout the whole of the deposit.The clay formations also contain between 3o and 6o per cent sand fraction. In this heterogeneously decomposed and redeposited material the strongly weathered argillaceous horizons are repeated several times at distances of from several decimetres up to 3 metres showing gradual transitions downwards and sharp boundaries upwards. The sequence is characterized by repeated transport of detritus under gradually decreasing energy conditions. The final clay horizons are of more fresh colour, and in the transitional zone small quantities of faded spotty greyish-green rock material is found.

In the lowermost section, in addition to the usual sandy composition very thin gravelly intercalations of wide extension are characteristic, but in the second section the gravel horizons are localized. In the closing members of this second section unsorted gravelly clays occur outside the area in question. At about the centre of the opencast mine exposure, i. e. southwards this section becomes thinner and more clayey, and its characteristic reddish material becomes subordinate. From the middle to the upper part of the second section channel cuts of varied extension are characteristic and can be traced along the outcrop in sections of 3o to 2oo m. These are filled with coarse cross-bedded sands dark brown to black yellow and green in colour due to subsequent mineral precipitation. These deposits can be associated with channel meanders, and occur twice as frequently in the outcrop as in the section. This is caused by the rough-and-ready processing of borehole data, as well as by the occasional lack of electric well logging.

Due to the restricted resolution of the strata the following is tentatively offered:

The lower section is found essentially in the northern and north-eastern part of the section and is composed of

- gravelly tufa sand and weakly decomposed redeposited andesite tufa being locally of fluvial detritus,
- clay and gravel-banded coarse and fine tufa sands /with fairly well recognizable tufa detritus/ - locally with admixed, redeposited Pannonian micaceous quartz sand,
- red-brown, sandy clay derived from tufa and containing andesite gravels, closed by an intensely weathered red-clay crust with a fossil soil horizon.

The second section is common in the recent exposure of the open cast mine.

- It is more complete in the north-eastern part where it overlies most of the lower section. Gravel intercalations indicating unconformities occur in the lower third of the section. Nort-east of the open-cast mine bentonitic-kaolinites /?/as well as dark-brown to dark-grey, ligneous strata are intercalated with this horizon /Ugra 6/. As a whole, this section is somewhat coarser in the north-eastern part but is dissected by at least 4-5 weathered or ground horizons. In the south-western part a more weathered clay with tufa detritus and tufa-sands predominates. It is difficult to separate it from the Pannonian in certain sections but in the south-eastern part where the Pannonian overlies seam "0" this is easier. The distinction is aggravated by the initial members smoothing the relief and containing redeposited Pannonian material.

- In the upper part of the section rhythmic,cross-bedded /fluviatile/ andesite sands, tufa-sand and gravel sand lenses are intercalated. The fluviatile sediments are unconformably overlain by tufa sand containing clays which are again dissected by red-clays. About one-third of the cover consists of a yellowish-greyish-brown sequence strongly differing in its appearance. The unconformity, however, is obvious where it is separated from the strata associated with the first and second phases by the gravel horizon or by tufaceous sand intercalations. The younger cover is redeposited weathered andesite tufa. Probably due to the repeated redeposition and to the climatic changes the tufaceous origin is overshadowed. The quantity of the obviously tufa detritus is small, i. e. it amounts to a maximum of lo per cent. Its internal structure, however, shows the same mosaic-like structure as the clay of the first and second phases.

The division of the cover in the profile is:

<u>Third section</u>:

- yellowish and greyish brown slightly cross-bedded sand, fine sand and mud occurring in several horizons, rarely with tufa gravel and andesite grit intercalations,
- the main mass of this section consists of yellowish and greyish brown clay and clays with tufa detritus. Here fossil soils and calcareous precipitations occur in several horizons. In other horizons thin /several cm/ grey, greenish-grey,brown, strongly mosaic-like strata are found without shearing stress,
- the final member of the section is a dark brown clay or greyish-brown clay without obvious traces of tufa origin. Its complete decomposition is evidenced by its plastic behaviour and its rich-clay character.

<u>Fourth section</u>:

- dark and light brown, sometimes yellow calcareous clay, which mechanically may be described as rich to medium-rich clay,
- rarely thin /1 to 1.5 m/ brownish-yellowish grey fine sand with clay is intercalated,
- the sequence is closed by a calcareous clay and brownish-black soil.

Fresh alluvium of muddy clay composition only occurs below the thin clay soil in a narrow strip in the Bene-valley along the south-western boundary ramp. Locally in the valley rounded gravel also occur. Here the tufagenic sequence discussed above is missing and the Late Holocene directly overlies the eroded Pannonian surface.

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MINERALOGICAL INVESTIGATION OF THE FOSSIL SOILS OF THE PLIO-PLEISTOCENE PIEDMONT SEDIMENTS

Mrs. PÉCSI, DONÁTH, É. - GEREI, L. - Mrs. REMÉNYI, M.

The results of an investigation into the fossil soils and their floor found in the open-cast lignite mine at Gyöngyösvisonta in NE-Hungary are presented in this paper. In the piedmont foreground of the Mátra Mountains /Miocene andesite stratovolcano/ the strata are part of an alluvial fan formed during the Middle Pleistocene and earlier. The floor containing the lignite beds is assigned to the middle part of the lagoonal coastal phase of the Upper Pannonian /BARTHA, F. et al. 1971.; JASKÓ, S. 1981./ and is unconformably overlain by the alluvial fan sequence.

Our aim was to draw conclusions about rock weathering and soil processes by an analysis of the mineral composition of an exposure characteristic of the terrestrial sequence overlying the lignite whose lithological and pedological characteristics have already been analyzed by PÉCSI, M. and SZEBÉNYI, E. /1979/.

The profile contains five fossil soils and three red clayey formations, in addition to the superficial brownish-black clayey hydromorphous soil /T; FIG. 1./.

The <u>first fossil soil</u> lies at a depth of 2 and 4 m, and is a brownish meadow soil /F_1/, the <u>second</u> is a red-brown forest soil found at depths of between 6 and 8 m /F_2/, the <u>third</u> is a dark red-brown forest soil found between lo and 11 m in depth /F_3/, and the <u>fourth</u> is a hydromorphous forest soil lying at a depth of 19 to 21 m /F_4/ overlain by warm-red clayey detrus. The horizon described as a red clay is marked F_5 and is found between 32.3 and 33.4 m.

The three upper soils /T, F_1, F_2/ were developed on yellow loessic clays /old loess/, the red-brown forest soil F_3 on gleyed clay, the hydromorphous forest soil /F_4/ on a purplishred tuffaceous clay, and soil F_5 on sandy sediments.

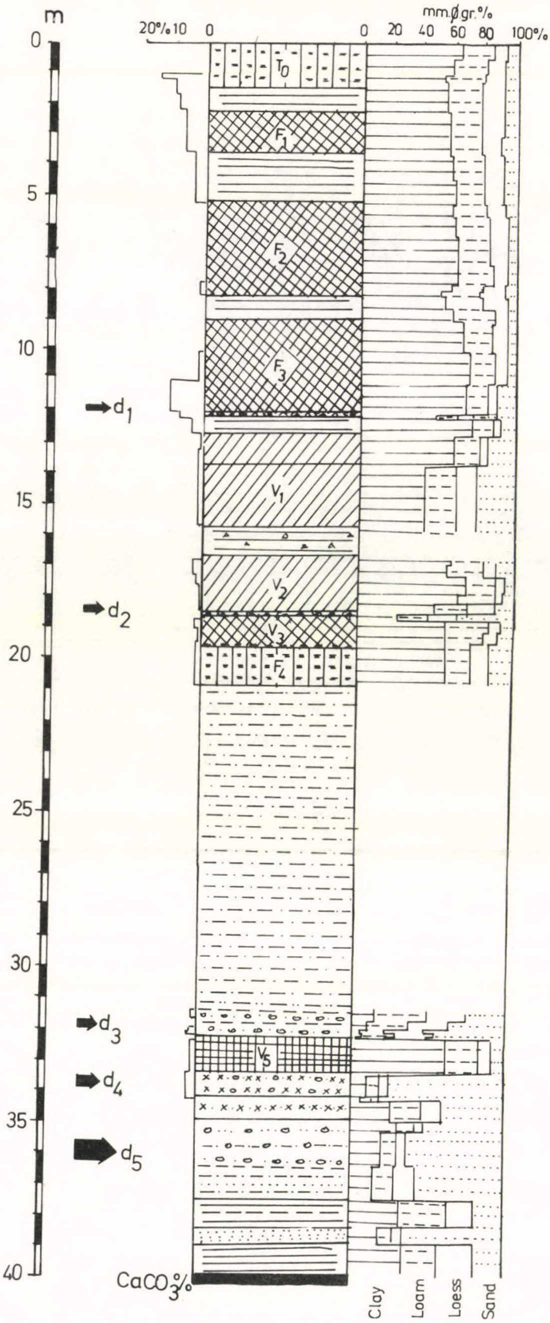

FIG. 1 The profile of Gyöngyösvisonta /After PÉCSI, M. - SZEBÉNYI, E.

The profiles were investigated by X-ray diffraction, derivatographic and sedimentological methods. The calcareous content is generally very low; below 12.2 m it is less than 4% in all samples or it is completely absent, and above 12 m it amounts between 7 and 5% with few exceptions, although in the fossil soils of the latter sequence in is frequently found in the form of calcareous concretions.

The high proportion of clay fraction /less than two microns/ is conspicuous, amounting to about 6o% from the surface down to 14 m but fluctuating at depth greater than 19 m. For example in the hydromorphous floodplain soil it is less than 6% at about 32.9 m while between 32.35 and 33.4 m it suddenly increases to about 6o%; in deeper parts it is about 2o% /TABLE 1/.

MINERAL COMPOSITION

In evaluating the mineralogical content, the works of BROWN, C. /1961/, GEREI, L. /1966/, GORBUNOV, N. /1974/, MIHEEV, V.I. 1957/, PÉCSI, M. /1977/, Mrs. PÉCSI, DONÁTH, É. /1979/, Mrs. REMÉNYI, M. /1976/, ROSS, G./1976/. VICZIÁN, I. /1975/ and ZUSSMANN /1972/ were taken into account.

The quantity of quartz varies widely, corresponding to the frequent changes in strata. In the upper part of the sequence between a depth of 0 and 12.7 m it varies from 21 to 37%; between 12.7 and 33.4 m it amounts to 16% in all samples, but thereafter to a depth of 39.9 m it increases to 42%, only to decrease again to 1o% at a depth of 4o.9 m, immediately above the lignite. The largest amounts of quartz are found in the grey clays /42%/, while the lowest values of 6% occurs in the red-clayey tufa detritus marked by d_2 in a depth of about 18 m /TABLE 1/. The amount of quartz is related primarily to the nature of the parent material; thus while the difference in quartz content between the soils and parent material is negligible that between different soils and different parent materials it is substantial.

Silica also occurs in the form of cristobalite. Below lo m cristobalite occurs in all samples, but in the upper ten metres it is only found in the brownish black hydromorphous soil of a depth of 0 to 1 m and in the red brown forest soil at a depth of 7.5 m. The presence of cristobalite seems to be related to the fact that during sedimentation, detritus derived from the weathering volcanic rocks was intermixed with the sediments.

The amount of calcite varies between 2 and 9% down to a depth of 5,2 m, but thereafter to a depth of 4o,9 m it is invariabily below 6% and is completely absent from four samples. These statements are also verified by the chemical determination of calcareous material. In soils T and F_1 considerable calcareous precipitation could be identified along vertical fractures.

The distribution of feldspars also strongly varies /between 0 and 22%/ with depth and sediment type. The less the amount of quartz, the higher is the feldspar content between depth of 8.6

TABLE 1 Mineralogical composition of section at Gyöngyösvisonta

Designation	Type, horizons, parent material	Depth	Quartz	Cristobalite	Felspar	Calcite	Micat hydromica	Montmorillonite	Kaolinite	Inter stratificated min.	Chlorite	Hydroxides	Organic material	Pyrite
		m	%	%	%	%	%	%	%	%	%	%	%	%
T	brownish-black	o,oo- o,5o	29	2	14	2	27	2o-o	2	-	-	2	o,6	1,4
	meadow soil	o,5o- 1,oo	3o	6	12	2	26	15-o	2	-	3	2	o,6	1,4
	yellow clayey loess	1,7o- 2,2o	25	-	8	9	28	23-o	-	5	-	2	-	-
F_1	clayey brown	2,2o- 3,oo	27	-	11	6	26	18-o	1,5	3	4	2	1,5	-
	meadow chernozem soil	3,oo- 3,6o	21	-	7	5	28	22-o	2	8	3	3	1	-
	yellow clayey loess	4,4o- 5,2o	37	-	6	3	26	16-o	-	6	6	-	-	-
F_2	red brown forest soil	5,2o- 7,2o	36,5	-	9	2	26	14-o	5	-	4	2	o,5	1
	red brown forest soil	7,2o- 7,8o	3o,5	3	4	-	31	16-o	8	-	4	2	o,5	1
	yellow clayey loess	8,2o- 8,6o	33	-	11	2	31	14-o	3	-	5	-	o,5	o,5
F_3	red brown forest soil	1o,oo-11,oo	26	2	4	4	34	2o-o	4	-	3	2	1,o	-
	gleyed clay /tuffaceous/	12,2o-12,7o	25	4	4	5	26	26-6	-	-	4	-	-	-
V_1	purplish red-brown clay	12,7o-13,7o	15,5	2	3	-	31	22-4	8	8	3	2	1,5	-
V_2	purplish red-brown clay	13,7o-14,7o	1o	5	3	-	31	24-4	8	9	3	2	1,o	-
V_3	purplish red-brown clay	16,7o-16,9o	13	6	4	2	24	2o-8	1o	6	2	3	o,5	1,5
d_2	red clay soil	18,1o-18,5o	6	5	2	2	37,5	2o-o	12	8	2	2	1,5	2,o
F_4	boggy forest soil	19,1o-2o,1o	11	6	6	3	25	16-5	1o	12	2	2	1,o	1,5
	boggy forest soil	2o,1o-2o,9o	7	5	3	2	31,5	2o-8	1o	7	3	2	1,o	o,5
	purplish red-brown clay	31,4o-31,7o	1o	6	3	2	39	16-3	8	7	2	2	1,o	1,o
F_5	red clay soil	32,35-33,4o	7	6	4	2	35,5	23-1	8	8	4	-	o,7	o,8
	purplish red	33,4o-34,2o	2o	9	14	4	33	9-o	5	3	3	-	-	-
	tuffaceous detrital sand	34,2o-34,3o	27	5	9	3	38	5-o	5	-	6	-	1	1
	grey loam	36,4o-37,5o	39	6	22	2	18	5-o	-	-	6	2	-	-
	grey clay	38,95-39,9o	42	6	6	2	23	14-o	4	-	-	2	o,5	o,5
	brown lignite in black clay	39,9o-4o,9o	1o	4	-	-	8	76-o	-	-	-	2	-	-

and 33.4 m, but thereafter the feldspars content decreases and finally disappears. The relatively small quantity of feldspars is evidenced by the weathering characteristics of the red clays in the purplish-reddish clayey sequences.

The amounts of mica and hydromica are generally high ranging from 18 to 39%, but about 25% in the most samples, although in the deepest sample at about 4o m derived from a brownish-black clay it is only 8%. The combined amount of mica and hydromica differs between the soils and the parent material. X-ray diffractometry shows that hydromica generally predominates.

Montmorillonite is found in all samples, generally lying between 14 and 26%. It was only 5.o to 9.o% in three samples at depths between 33.4 and 37.5 m, but in the lignitic black clay sample rose to about 7o%. The substantial presence of montmorillonite is also verified by the high T-values determined in the samples /3o to 5o mge/. Both the montmorillonite and hydromica indicate intense weathering processes.

Between a depth of 11 and 33.4 m, the presence of iron-bearing montmorillonite was established particularly in the red clay and gleyed hydromorphous forest soil. As to the macroscopic description. iron oxides are found in these red clays, while iron in reductive form occurs in the gleyed clay. With methods applied, however, only a few iron oxide-hydroxide minerals could be identified, because they either occur in microcrystalline probably amorphous, form or occur as part of the chemical structure of certain minerals.

Since during thermal analyses the characteristic endothermal maximum of montmorillonite usually occurring between 5oo and 7oo^{o} C was registered at temperatures 5o to 1oo^{o} C lower, the presence of iron built into the montmorillonite lattice is suggested. The formation of iron-bearing montmorillonites is probably related genetically to the formation of the red clays and gleyed forest soil.

The mixed-layer minerals, illite-chlorite and illite-montmorillonite are found at two depths levels /1.7 to 5.2 m and 12.7 to 34.2 m/, in amounts varying between 3 and 12%. These occur first of all in the brown clayey meadow soil and in the associated yellow loessic-clayey parent material, as well as in the gleyed forest soil and red clay soil. The occurrence of these clay minerals suggest considerable weathering leading to the formation of clays.

Kaolinite-type clay minerals also occur in certain soil and rock types of the profile but generally in considerably smaller quantities usually between 0 and 12%, than the montmorillonite-type clay minerals. They are most common in the red clay and gleyed forest soils at depth of 12.7 and 33.4 m. Chlorites are found in small amounts ranging from 0 to 6%.

The amounts of organic materials and pyrite were determined as 0 to 1,5%, and 0 to 2%, respectively. The small amount of organic material can be explained by the long time interval during which the processes of decomposition have been active /TABLE 1/.

SOIL TYPES AND FLOOR MATERIAL

The mineralogical investigation of certain characteristics fossil soil types and interbedded sedimentary rocks found in the lignite mine of the Gagarin power plant at Gyöngyösvisonta, not only revealed their sedimentological and pedological characteristics but also information concerning their genetic origin as well.

The sedimentary over-burden consists of two terrestrial alluvial fans of different genesis. The lower thicker fan, lying between 12.7 and 4o.9 m consists of purplish-red originally volcanic detritus on which had formed a red clayey, loam soil while the upper fan consists of piedmont alluvial material, clays, sands, andesite gravels, and tufa. Between the two lie dark interbedded clayey soils at depths of between 2.2 and 12.7 m.

11 samples were taken from the upper alluvial fan, 4 from the sedimentary material and 5 from the fossil soil material.

In the brownish-black meadow soil, T developed to a depth of 2,2 m on yellow clayey loess 2 to 6% of cristobalite was established, but was absent from the yellow clayey loess constituting the D-horizon of the soil. There are also great differences in the amounts of quartz, feldspar and mica between the soil horizons and the yellow clay,and this suggests that the soil did not form on the old loess. The soil and its floor thus bear no paragenetic relationship. Moreover the large amounts of mica-hydromica and montmorillonite indicate substantial weathering during soil formation process.

The clayey brown meadow chernozem soil F_1 developed on yellow clayey loess at a depth of between 2.2 and 5.2 m, consists of two horizons. No cristobalite was found in the soil and the amount of quartz falls far behind that of its floor /27, 21 and 37%, respectively in the three samples/. The large amount of mica-hydromica /26 to 28%/ and montmorillonite /16 to 22%/ as well as the presence of mixed clay minerals indicate more intensive weathering in soil F_1 than T.

The mineral composition of the two samples of F_1 are similar in many aspects, but differ from the parent material in terms of quartz, total clay mineral, oxi-hydroxide and organic material content. That the quartz content of the floor is about lo% higher can be partly interpreted as outwash, while the differences in the quantities of other minerals can be attributed to the intensity of the soil formation process.

The red-brown fossil forest soil, F_2 developed on yellow clayey loess at a depth of between 5.2 and 8.6 m contain a small amount of cristobalite /3%/ in one horizon only. Concerning the quantities of quartz, feldspar and calcite, no significant difference could be identified between the soil horizons and the floor, while the substantial quantities of mica-hydromica and montmorillonite indicate intense weathering. Rounded cavernulous of 5 to lo cm in diameter and elongated lime concretions occur particularly in the BC and C horizons. In Hungarian pedological literature this soil type is also called a brown forest chernozem soil /STEFANOVITS, P./.

Based on the mineral composition of the floor of the "red-brown forest soil" F_2 it appears that the high quartz content can be traced back to the source rock, since the amount of quartz is high in the clayey loess strata of the profile.

The pH-conditions during the formation of the soil are reflected in the considerable amounts of kaolinite present, while the changes in redox-conditions are indicated by the joint occurrence of oxi-hydroxides, organic material and pyrite. The presence of cristobalite suggests the admixture of volcanic detrital material to the soil.

The tuffaceous gleyed clay and the red-brown forest soil, F_3, developed on it is lying at a depth of lo to 12 m, contains cristobalite. Concerning th primary minerals no significant difference is found between the soil horizon and the gleyed clay - quartz 25.o and 26.o%, respectively, feldspar 4 and 4% respectively and calcite 4 and 5% respectively.

The presence of montmorillonite and mica-hydromica again indicate intense weathering, while montmorillonite with 6% iron in the tuffaceous gleyed clay suggest reduced prpcesses. At the base of this layer substantial groundwater seeping is found.

Soil F_3 and its floor can be distinguished from both the over- and the underlying soil types, particularly on the basis of their quartz, total clay mineral and cristobalite contents.The latter and the iron-bearing montmorillonite, however, make it more similar to the underlying soil types.

In the finer alluvium of the piedmont of the Mátra foreland found at a depth of between 12.7 and 19.1 m in the section at Gyöngyösvisonta, peculiar purplish red-brown clays, red clay soil and tuffaceous loams developed under sub-humid warm climatic conditions, which were later eroded and redeposited by piedmont streams. During certain phases these formations were wheathered in situ and underwent pedogenesis leading to the formation of the reddish clayey soil. In the Gyöngyösvisonta profile these reddish clayey formations are marked V_1, V_2, V_3 and red clay soil d_2. These formations also occur locally at the surface in the Mátra Foothills and Northern Central Mountains.

In all four samples of the purplish red-brown clays and red clay soil at a depth of 12.7 to 19.1 m cristobalite occurs. Since the amount of quartz varies between 6 and 15.5%, the quantity of cristobalite is also different in the samples /2,5 and 6%/, and calcite is found only in the lowermost samples. It can also be stated that the clay itself is stratified. Intense weathering is suggested by the accumulation of mica-hydromica /24 to 37,5%/, iron-bearing montmorillonite /4 to 8%/, kaolinite /8 to 12%/ and mixed-layer clay minerals /6 to 9%/ again suggest intense weathering. It is assumed that this soil is the eroded red clay soil interbedded with tufa gravels marked d_2 on the profile.

Cristobalite occurs in both samples of the boggy forest soil, F_4 at a depth of 19.4 to 2o.9 m, and there is no significant difference between the two horizons. The accumulation of mica-hydromica /25 to 31.5%/, montmorillonite /16 to 2o%/, iron-bearing montmorillonite /5 to 8%/, kaolinite /lo-lo%/ and mixed-layer minerals /12-7%/ once again points to intense weathering and reduction processes.

In the purplish red-brown clay detritus at a depth of 31.4 to 31.7 m cristobalite amounts to 6%. The proportion of primary minerals does not significantly differ from either that of the overlying boggy forest soil or that of the underlying red clay soil . The amounts are as follows: quartz lo%, calcite 2%, and feldspar 3%. The mica-hydromica content is the highest of any sample /39%/, while montmorillonite and kaolinite amount to 16% and 8% respectively, all pointing to weathering under semi-humid conditions. The presence of iron-bearing montmorillonite /3%/ and mixed layer minerals /73/ indicates reduction processes.

The cristobalite content /6%/ of the red clay soil, F_5, at a depth of 32.35 to 33.4 m is similar to that of the overlying horizons, while the proportions of quartz, feldspar and calcite are 7,4 and 2% respectively. The relatively high amounts of mica-hydromica /35.5%/, montmorillonite /23%/ and kaolinite /8%/ once more suggest intense weathering processes, while the 1% iron-bearing montmorillonite and 8% mixed-layer minerals indicate that reduction also took place.

Considerable amounts of cristobalite /5-9%/ occur in the purplish-red tuffaceous-detrital sand band /at a depth of 33.4 to 34.3o m/. Significant differences were also detected in the proportions of the primary minerals, e. g. quartz 2o-27% and feldspar 14-9%. Mica and hydromica amounted to 33-38%, while the montmorillonite content was only 9-5%. Iron-bearing montmorillonite was absent and while the proportions of mixed-layer minerals and kaolinite were o-3 and 5% respectively. During the formation of this horizon weathering and reduction processes probably predominanted but were less intense than in case of the overlying horizons.

From the point of view of mineral composition, while the fossil soils and their floors lying at depths between 12.o and

35.o m are similar, they differ from the other horizons. This can primarily attributed to the fact that the parent material is a tuffaceous-detrital clay.

The average cristobalite content is 5-6%, while the amounts of mica-hydromica is more than in the other horizons. Iron-bearing montmorillonite content fluctuates around 4%, the kaolinite content /about 5-lo%/ is high while mixed-layer minerals, oxihydroxides, pyrite and organic material are also present. Such an assemblage suggests intense weathering with reduction processes being locally predominant. In case of the red clays, however, there is the suggestion of oxidizing processes being present.

The Upper Pannonian greyish-yellow muds and grey clays lying between 36.4 and 39.9 m in the profile contain 6% cristobalite. The proportion of quartz reaches its maximum here /39-42%/, while calcite amounted to 2% in both samples. Feldspars content, however, is varied being 22% in one sample and 6% in the other. The two Upper Pannonian strata are separated by a band of yellow sand. Since there is some difference in the quantities of feldspar, quartz and mica-hydromica this might suggest that the two are different but the similar calcite and cristobalite content indicate a relationship. The relatively low percentage of mica-hydromica /18-23%/, montmorillonites /5-14%/ and kaolinite /o-4%/ as well as the lack of mixed-layer minerals point to a lack of weathering.

The results obtained from the Upper Pannonian strata suggest that conditions were different during their formation when compared to those enumerated above at depths less than 36.4 m.

The mineral composition of the brownish lignite in the black clay at a depth of 39.9 to 4o.9 m strongly differs from that of the other strata. This is indicated first of all by the extremely high montmorillonite content /76%/, and by the low proportions of mica-hydromica /8%/ and quartz /lo%/. In this horizon 4% of cristobalite was found.

CONCLUSION

According to the investigations discussed above it is obvious that the mineral composition of the sequence reflects the physical-chemical conditions of three different weathering and soil formation phases /Holocene, Pleistocene and Pliocene/.

1. The uppermost /recent/ soil is characterized by high feldspar content, the presence of pyrite, organic material and small amounts of kaolinite and 27% mica-hydromica. The cristobalite content of the soil suggests that they have been redeposited.

2. The lo m of thick clayey sediments underlying the first horizon as well as the fossil soils F_1-F_3 that developed on them, are characterized by smaller amount of feldspar, an increase in the kaolinite content, appearance of chlorite minerals and an increase in the mica-hydromica and montmorillonite ratio. All

these characteristics suggest less intense weathering than in the deeper- lying horizons, but at the same time indicate some admixture of more strongly weathered material.

3. The quartz and feldspar content of the sequence lying at a depth of between 12.7 to 34.3 m is roughly half of that of the overlying sequence, but the proportions of mica-hydromica, montmorillonite and kaolinite are considerably greater. Mixed-layer minerals and iron-bearing montmorillonites are found only in this horizon. Pyrite and organic material were detected nearly everywhere together with iron oxides-hydroxides. These facts would suggest that the sequence was formed during a sub-Mediterranean warm climatic phase and under alternating acidic and alkaline pH-conditions. The whole sequence was formed as a result of intense weathering processes during which there were frequent changes between oxidizing and reducing conditions.

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THE SCIENTIFIC AND PRACTICAL SIGNIFICANCE FOR INVESTIGATING THE QUATERNARY FLUVIATILE ALLUVIAL FANS OF THE FORELAND OF THE BÜKK AND MÁTRA MOUNTAINS

FRANYÓ, F.

The diversified Quaternary sequences comprising the denudation surfaces surrounding many of the large basins of the earth's surface together their varied but easily eroded, landforms are by no means able to give a continuous portrayal of the evolution of such areas during the last 2.4 million years. The interaction and intensity of the processes involved in morphogenesis are recorded primarily in the superimposed fluviatile sedimentary sequences of such basins. As proved by the results obtained, such investigations are well adapted to the study of the Great Hungarian Plain, a Pliocene-Pleistocene depression occupying the central part of the Carpathian basin, and almost completely enclosed. Quaternary fluviatile sedimentary sequences of varied lithology have accumulated here, and although the rate of deposition has varied through time, it seems to have been continuous.

Research into the geological events of the Quaternary has changed very much in philosophy and method during the last two decades both sedimentologically and palaeontologically, and now include deep drilling, detailed stratigraphic analysis of marine and lacustrine sediments, and palaeomagnetic investigations. As a result of the increase in information it had already became obvious, in the 1960's, that the earlier concept of Pleistocene phase of 600 000 to 800 000 years duration including glacials and interglacials represented only the upper one-third of the Quaternary.

Under what is now the Great Hungarian Plain 50 to 5000 m of Pliocene lacustrine sediments and 50 to 700 m of Quaternary fluviatile deposits accumulated. Lithologically, the Quaternary is composed of a range of fluviatile alluvial fans superimposed or juxtaposed one to another and showing a diversified granulometric composition and inricate lithology. Grain size varies widely from area to area: from pebbly sands on the margins, to fine-grained sediments in the central parts of the basin. Palaeomagnetic data obtained from a borehole of 1116 m depth at Dévaványa and another 1200 m at Vésztő have indicated that sedimentation was continuous during the Quaternary in the central part of the basin, the so-called Körös sub-basin, where a sequence recording the whole Pleistocene history of accumulation as well as the prevailing palaeogeographic and palaeoclimatological conditions can be found /RÓNAI A. - SZEMETHY A. 1979; RÓNAI, A. - COOKE, H.B.S. - HULL, J.M. 1979/. The stratigraphy of these deposits cannot, however, be correlated with the Quaternary chronology and climatic changes inferred from geomorphological and sedimentological results obtained for the glaciated areas of Western and Northern Europe. Very detailed sedimentological data files from more than thirty boreholes put down in various parts of the Great Hungarian Plain have enabled the identification of 9-1o major sedimentary cycles and 25 to 27 minor cycles. Whether coarse or fine-grained sedimentary suitesobtained, was controlled primarily by tectonic movements and only secondarily by climatic factors. As for the very complex spatial distribution of these complexes, this was determined by the alluvial fan accumulation mechanism of the rivers, involving changes in direction and deposition due to different rates of flow and transportation. The subsurface position of these alluvial fans does not always accord with the direction of present-day streams and occasionally indicates a mode of occurrence substantially different from that of their present-day counterparts, due,primarily to more recent tectonic deformation. The greatest change has taken place in the direction of flow of the Danube and Tisza, although their tributaries have also undergone, substantial changes of course.

Whether the pebbly-sandy sequences of the alluvial fans were deposited during the glacial or interglacial stages of the Quaternary has been a question of controversy for a long time. As evidenced by the data files of 32 cores put down during the last decade and a half to varying depths of between 1oo and 15oo m and subject to detailed palaeontological, mainly palynological analysis, the first third of the Quaternary period must have had a moderately warm climate, the middle third was moderately cool to cool, and only the last third was really cold. This upper part, in fact, corresponds with the glacial periods i. e. placed at 6oo ooo to 8oo ooo years by MILANKOVIC-BACSÁK. Coarse grained materials is also found relating to the moderately warm Early Pleistocene phase; the deposits associated with the middle, cool to temperate phase are of a relatively finer grain size, whereas the upper deposits corresponding to the glacial period again contain considerable coarse-grained strata.

The thickness of the deposits representing each of these phases is by and large, a function of the time-range involved. Many of the argillaceous sediments contain a great abundance of psychrophile pollen grains, but others testify to a temperate or warm climate. The mollusc fauna too shows a mixed spectrum, although these have been recovered in much smaller number and from fewer cores. The sands only contain the occasional mollusc and single vertebrate, and most of these appear to be allochtonous and are thus neither conclusive as to the timing of deposition, nor as to the climatic conditions involved. Rather unevenly distribued throughout the Quaternary sequence, are dark grey to black, humus-rich strata of o.2 to 1.o m in thickness, which represent contemporaneous soil and swamp horizons, mostly together with the B and C horizons, and which bear witness to the former vegetation cover and the existence of a humid climate. They also indicate that sedimentation was at times very slow and even interrupted for short intervals. Accordingly, a completely vegetation-free terrain and a very dry and cold, glacial climate cannot be assumed to have existing for very long even during the Late Pleistocene despite the fact that this part of the Carpathian basin belonged to the periglacial zone.

THE ALLUVIAL FANS OF THE MÁTRA AND BÜKK FORELANDS

To verify the previous discussion, we shall now present the evidence from some of the Quaternary alluvial fans that are to be found in the forelands of the Mátra and Bükk ranges bordering the north-west part of the Great Hungarian Plain /FIG. 1-4/. The rivers involved in their accumulation had a geologically and geomorphologically diversified catchment area of nearly 2o ooo km^2. In the west Tertiary volcanic rocks generally predominate, while in the east formations of Palaeozoic and Mesozoic age, Cretaceous-Paleogene flysh, Miocene volcanics and Tertiary sediments are to be found. The highest parts of the catchment area are more than 2ooo m above sea level, while the accumulation areas in the Great Plain are at altitudes varying between 85 and 12o m above sea level. Most of the catchment,

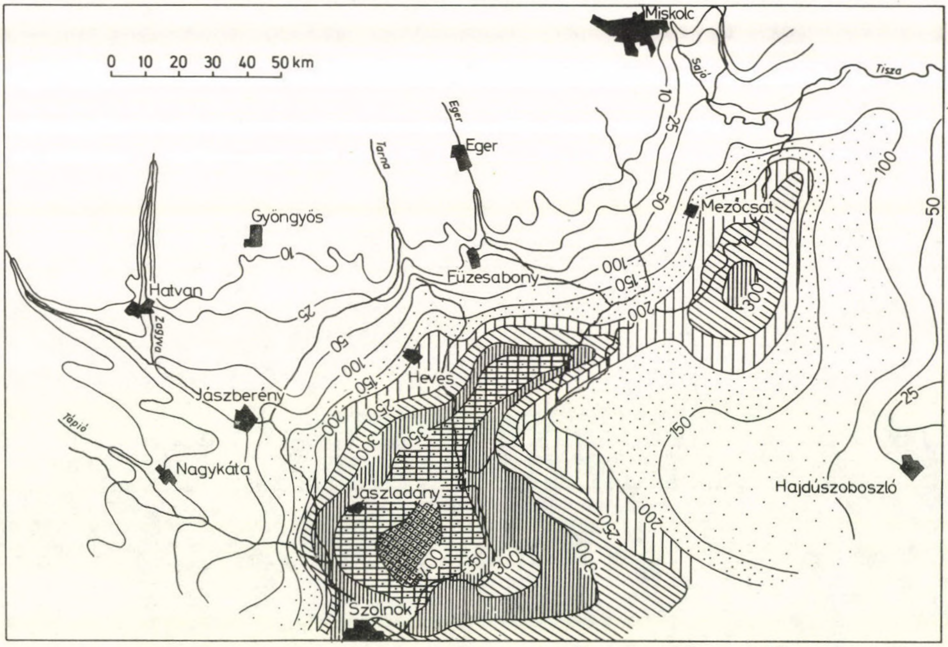

FIG. 1 Thickness of the Quaternary fluviatile sediments, in metre.

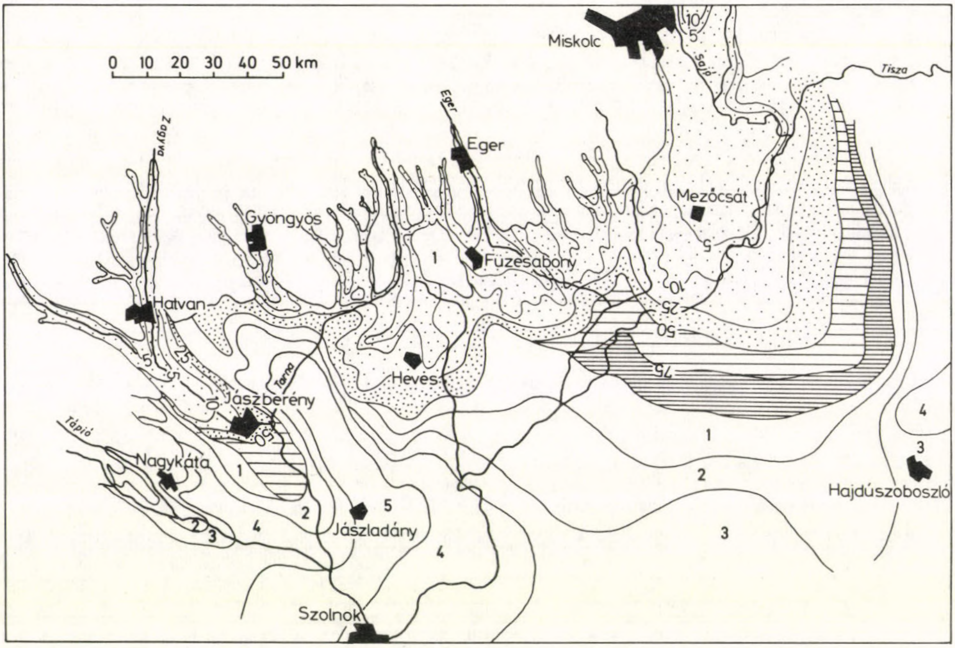

FIG. 2 Subsurface position of the pebbly layers of the Quaternary fluviatile alluvial fans, in metre, and extension of the sand zones of varying grain composition associated with them

1: zone of coarse-grained sand; 2: zone of medium-grained sand; 3: zone of medium- and fine-grained sand; 4: zone of fine-grained sand; 5: zone of very-fine-grained sand.

however, composed of hill and piedmont topography at heights ranging from 12o to 4oo m, and only a minor part lies at higher elevations. The longest rivers are the Hernád /24o km/, the Sajó /229 km/, the Zagyva /16o km/, the Tarna /1oo km/ and the Bódva /1oo km/, associated with which are the largest alluvial fans and the greatest proportion of coarse-grained detrital material. The detritus decreases in grain size as one proceeds towards the basin centre and, at distances greater than 3o km from the mountain foreland, their fans tend to merge with one another and also with similarly fine-grained fans laid down by other rivers. The minor streams emerging from the hill and mountain margins have also built small independent alluvial fans /FIG. 2/.

The main river of the study area is the Tisza which incised itself into the earlier-formed alluvial fans during the late Pleistocene and was emplaced in its present position as a result of tectonic movement /FIG. 1-4/. The present river system is different from its predecessors. During the Quaternary, in corre-

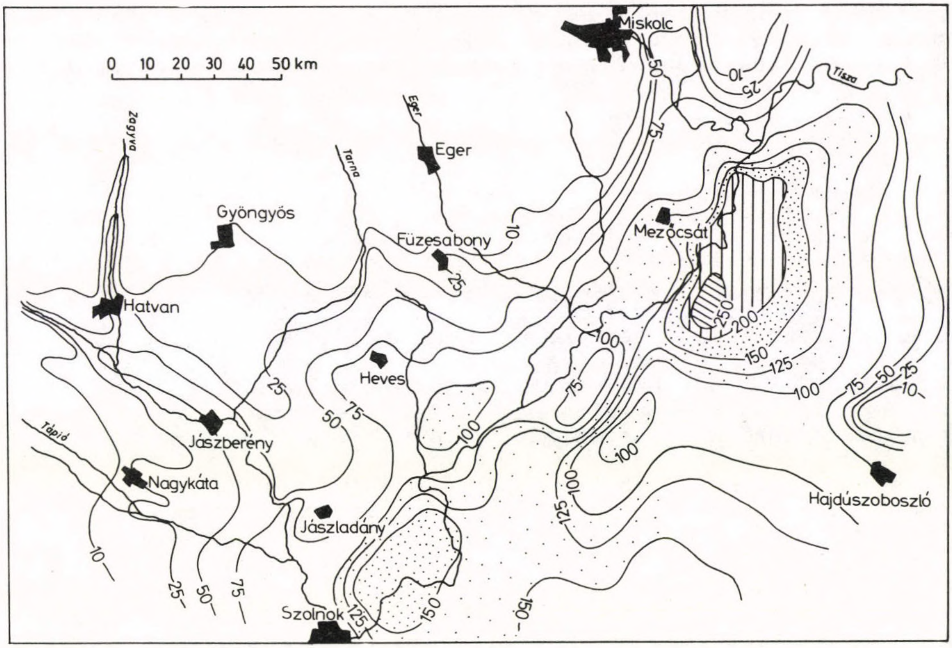

FIG. 3 Joint thickness of the pebble and sand layers of the Quaternary fluviatile complex, in metre.

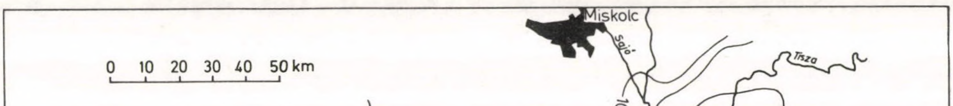

FIG. 4 Thickness of the fine-grained sediments /clays, silts/ of the Quaternary fluviatile complex, in metre.

spondence with the subsidence and accumulation of the various subbasins, the rivers often changed their courses and extended well beyond the present line of the Tisza where they accumulated their alluvial fans. This has been verified by the lithological and water yield records of hundreds of artesian wells and by the analysis of drill cores /FRANYÓ F. 1979/.

The position of the alluvial fans within the study area, the thickness, stratigraphy and lithology, of the sediments involved, and their zonality in terms of decreasing grain size are demonstrated by a great number of borehole data. In compiling figures 1 to 4, the author has used information from 2oo exposures, 28oo survey boreholes /1o m/, 19oo soil mechanical boreholes and 1ooo water-prospecting wells which partly or completely reveal the Quaternary sequence. In addition, the results from 15oo boreholes drilled during prospecting lignite for deposits on the margins of the Mátra and Bükk ranges have been taken into consideration.

Along the margins of the mountains in the river valleys and also over much of the basin centre, fluviatile deposits are generally of relatively coarse grain size and are thus readily distinguishable from the finest grained Upper Pliocene and Upper Pannonian sediments. In the basin centre, where the fluviatile sediments get finer and were invariably deposited under water, the distinction between the two is more difficult. Here the fluvial sediments are more akin to an inland sea or lacustrine sequence.

In the western part of the study area the largest alluvial fan is that formed by the river Zagyva, situated south and south-east of the town of Hatvan in a broad structural depression trending from north-west to south east and contiguous with the valley of the river Galga. Large contributions to its accumulation were also provided by the rivers Galga and Tápió in the west. Some of the pebble material of the alluvial fan was derived from the redeposition of the Miocene gravel sheets found at higher elevations.

This fan is separated from the fans of the Tarna and its tributaries, whose Pleistocene evolution is readily depicted by the subsurface distribution of pebbly-sands, by a fine grained accumulation zone of similar trend and breadth /FIG. 2-3/. After expanding towards the south-east and then towards the south during the first half of the Pleistocene, the alluvial fan was tectonically displaced towards the south-west and west during the latest phases of the Quaternary so that the thickness of coarse-grained sediments in this subarea is much lower. Accordingly the pebble zones are found progressively deeper levels as one proceeds south-east, are accompanied by coarse, medium and fine grained sand zones, while the argillaceous sediments become increasingly thicker /FIG. 4/.

Towards the north-east minor alluvial fans emerge at the foot of the Mátra and Bükk ranges /FIG. 2, 3, 4/. Older alluvium associated with these cores, however, even be found to the east of Tisza where it coalesces with the large fan complex of the Sajó and Hernád rivers /FIG. 1-4/, and forms one of the most uniform fluviatile alluvial fans of the Great Hungarian Plain. Its associated pebbles and sands form a continuous horizon over a large area being traceable for 6o to 65 km towards the basin centre and locally reach a thickness of as much as 2oo to 25o m. The coarsest material occurs in the mountain valley floors and on the margin of the Great Hungarian Plain, where pebbles exceeding lo cm in diameter can be found. Farther south grain size drops rapidly, the pebble content declines and sands become dominant in the sedimentary sequence.

The alluvial fans just listed are well individualized in terms of lithology, though they merge and overlap in the basin centre, as evidenced by the mineralogical analysis of borehole data. Mostly fine-grained deposits of rather mixed mineralogical-petrographic composition originating from diversified sources accumulated to a thickness of 4oo to 6oo m in the central part of the Great Hungarian Plain.

At present there is a pause in the evolution of the alluvial fans and the deposition of coarse-grained materials both on the Great Plain and on the floors of the valleys that penetrate into the mountains. With only 55o to 1ooo mm of precipitation annually erosion is insufficient for both large-scale fluvial activity and for the transport of large amounts of coarse-grained detritus, even though, the mountain areas and river valleys contain much coarse material in the form of old pebble, gravels, talus and scree. Extending into the mountains, the valley floors which are 1 to 5 km wide are overlain by lo to 4o m of Late Pleistocene and Early Holocene pebbles on which are found by 1 to 6 m of fine grained Holocene flood-plain alluvium. Consequently, in recent times the rivers have not been able to transport coarse-grained material in any considerable quantity. It follows from the above, that the large volume of coarse and fine grained alluvial deposits /FIG. 1-4/ was accumulated by rivers with a much greater discharge than now. Most of the detrital material produced in the mountains during the cold-dry glacial phases was transported towards, the basin interior during the humid interglacials, when precipitation seems to have been 2 to 2.5 greater than now i.e. 13oo to 18oo mm per year. In the study area the ratio of coarse to fine grained sediment is between 1:3 and 1:4, whereas in the case of the present rivers entering the Great Hungarian Plain to corresponding value lies between 1:1oo and 1:6oo. That in the central parts and depressions of the Great Plain the ratio of the coarse to fine grained sediments is 1:5 to 1:1o to 1:2o cannot, of course, be left out of consideration. These figures, however, are still far from the values that can now be measured in the present river alluvium. During the Pleistocene most of the suspended load carried by the rivers was not deposited in the basin, but was removed altogether from the area via Iron Gate.

The approximately 2ooo km^3 of Quaternary fluviatile sediment accumulated in the basin /FIG. 1-4/ are assumed to have been derived from source area covering 2o ooo km^2. Given this the deposits are equivalent to the erosion of a loo m thick layer which over the 2.4 million years of the Quaternary, imply an average rate of removal of o.o42 mm of material per year from the catchment area. This value, however, is too low for two reasons: firstly the alluvial fans extend well beyond the limits analyzed in this paper and form part of the sedimentary fill of the basin interior, and secondly, as already mentioned, much of the material has been removed beyond the Carpathian basin. Given the present state of knowledge, a rate of erosion some 2 to 2.5 greater than this value can be assumed, i. e. it was somewhere between o.o8 and o.1 mm/year. Accordingly, the removal of about 2oo to 25o m of sediment from across the whole catchment area should be reckoned with during the Quaternary. The onetime rivers responsible for the construction of the huge alluvial fans seem to have had a discharge 2 to 3 times greater than the present figure, during the humid interglacial and interstadial periods and during the longer middle and lower icefree periods of the Quaternary. Accordingly the coarse to fine ratio was also substantially different from the present-day value and may have been 1:5o or so. The broad terraced river valleys bear convincing witness to the high rates of discharge and to the more intense erosional action of the rivers during the Pleistocene period.

Lying near the surface on the Great Plain margin and on the broad valley floors extending into the mountains, the pebble materials represent the most recent, Late Pleistocene to Holocene stage of alluvial fan development. These strata are less thick and less extensive than their older counterparts which extend farther into the basin and lie deeper underground /FIG. 2-4/. This is the consequence of multi-phase movements and the rhytmic sequence of deposition. During the earlier stages of the Pleistocene especially the relative relief between denudational and depositional areas was greater; when neither the source areas were eroded nor the basins filled with sediment to the extent they are now. The degree of tectonic movement involved is indicated by the different hypsometric position of the Pannonian sequence in various parts of the basin. At present these formations lie at 3oo to 35o m above sea level along the hill and mountain margins, whereas in the centre of the basin they are found as much as 11oo-135o m below the surface. In other words, the difference in altitude between sediments forming the same stratigraphic horizon is 14oo to 17oo m. To this an additional increment of 25o-3oo m or so due to uplift must be added, so that a total of nearly 2ooo m of vertical movement since the end of the Late Pannonian /Rhodanian and Romanian phases, about 5 million years/ may be assumed in the Carpathian basin.

On the basis of a multidisciplinary analysis of drill cores in the Great Plain during the last decade and a half. RÓNAI, A. calculated an average rate of accumulation of o.17 to o.2 mm/year, i. e. 1 m of sediment would have taken 5ooo-56oo years to accumulate during the Pleistocene. These calculations are fully supported by the results obtained from the cores at Dévaványa and Vésztő, both of which were put down between 1976 and 1979 and tested palaeomagnetically at intervals of one metre. Both boreholes were in mainly fine-grained sediments. The Brunhes-Matuyama boundary was reached at depths of 12o and 135 m respectively corresponding to rates of accumulation of 575o and 511o years for every metre. Let us emphasize that the sequence is continuous and every magnetic inversion and deviation is represented in temporal sequence and proportion.

THE ECONOMIC SIGNIFICANCE OF THE STUDY OF ALLUVIAL FANS

The investigation of the sedimentary sequences of alluvial fans is important both scientifically and from the economic point of view in that their underground water and sand and gravel content are coming under increasing use. Both activities have provoked problems of environmental control which still remain to be solved.

HYDROGEOLOGICAL SIGNIFICANCE

The vast thickness of coarse-grained sediments contain considerable quantities of good quality water which are transmitted to the fine-grained aquifers of the basin interior. To satisfy the ever increasing demands of the population and industry, regional waterworks of high capacity supplying clean water should be built. Consequently, it has become worth while to transport water over quite large distances, from water bearing alluvial fan regions to water deficient areas. The near-surface water reserves of the pebbly-sand can also be used by agriculture, primarily for irrigation. It was in these areas that the so-called tube-well type of irrigation was developed 2o to 25 years ago, first by private farmers but later even by the large-scale collectives. Using wells of 2o to 5o m in depth and a low drawdown /1-3 m/ one can attain water yields as high as 6oo to 1ooo litres/min. The water drawn off is quickly recharged and the hydrostatic level rapidly restored. The valley floors of the major streams emerging from the mountains are locally lined with coarse sands and gravels up to the thickness of 1o to 4o m and are locally several km wide. During summer periods of low precipitation and a low rate of surface flow, these waters drain underground into the alluvial fans along the Great Plain margin and into the most distant central aquifers, the whole process being controlled by slope conditions. The recharge of underground water through the fractured volcanic rocks, the karstic limestone, the piedmont debris sheets and the loose sediments of the lowland and hilly regions is considerable. In these areas, and also throughout the Great Plain, it is the Quaternary sequence that contains the largest quantity of and best quality water. Most of the artesian wells supplying the towns and communities tap their strata.

The most important water-bearing complex is the Sajó-Hernád alluvial fan on the eastern margin of the Great Plain /FIG. 1-4/.

The fan associated with the river Zagyva containing 2o m to 6o m of coarse-grained sediment in the western part of the region and that relating to the river Tarna in which the thickness of the continuously exploitable layers varies between 5o and loo m are smaller, and represent bases for local water supply only.

SAND AND GRAVEL EXTRACTION

The coarse-grained sediments are first-class building materials and are utilized at an ever increasing rate and ever widening variety. Good quality gravels occur in the marginal parts of the alluvial fans of the Great Plain and beneath the broad valley floors extending into the mountains at depths of between 1 and 5 m, and mechanized extraction is quite economic. Because the groundwater table is between 1 and 3 m below the surface the silt fraction that would reduce the quality is largely washed out.The grain and petrographic composition of the gravels and sands are here the most favourable of all and by sorting and mixing grain sizes to satisfy any special requirement can be obtained.

The gravels of best quality can be found in the alluvial fan of the Sajó-Hernád rivers, where both coarse-grained pebbles and fine-grained sands are present. Lithologically, the material consists for the most part of quartz. The near-surface alluvial complex of the rivers Tarna and Zagyva is of less importance, though mechanized extraction is also being carried out here as well. The bulk of the alluvium is coarse to medium grained sand while the greater part of the pebbles is small-grained and their ratio to the rest of the material is relatively low. The proportion of quartz is also comparatively lower, and is derived mostly from volcanic rocks. The minor streams accumulated small alluvial fans along the mountain margins of heterogeneous grain composition and including a good deal of clay. The only applications are for road construction and the making of concrete. The coarse-grained material for these fans and also from the terraces is widely quarried by the local population.

An ever growing need has made it imperative for the geologist to have a detailed knowledge of the subsurface extent, quality and quantity of these important construction raw materials so as to ensure their exploitation in the greatest number of localities. This can be justified from the economic point of view, for the gravels and sands are commodities of comparatively low commercial value compared with their volume and mass, and to transport them great distances would not be economic.

ENVIRONMENTAL CONTROL

Lying immediately below the surface or just a few metres underground and composed of water-saturated, loose, coarse grained sediments, the alluvial fans and the streams traversing them are sites where the location of industrial plants yielding a great deal of waste and refuse dumps for chemicals is prohibited. Gravel and sand pits produced by extraction over large areas down to depth of several metres and filled with water, could if filled with municipal or industrial waste or slag, become sources of grave damage to the environment. Unfortunately, this is already the case in many places including the municipal areas of large settlements. In fact, the groundwater table is quite high in these areas, vertical fluctuations are considerable and some pollution has occurred. Because of the rapid groundwater flow this could become widespread and water quality would be so reduced as to become unsuitable for either public or industrial and agricultural use. To store large amounts of organic or artificial fertilizers in such areas is not advisable either, and even the location of large livestock-holding units there is unwise.

To reclaim exhausted quarry workings for agriculture would be too expensive, and as an alternative so it would seem advisable to develop them into recreation areas of fish-ponds, for as has been demonstrated parts of the country this can be done at relatively low cost.

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BIOSTRATIGRAPHIC CLASSIFICATION OF PLEISTOCENE FORMATIONS IN HUNGARY ON THE BASIS OF THEIR MOLLUSC FAUNA

KROLOPP,E.

About 8o% of the surface of Hungary is covered by Quaternary formations. In the basins, first of all in the Great Plain their thickness amounts to several hundred metres. Most of the formations consists of Pleistocene sediments.

Beyond the results of the palynological investigations /JÁRAI - KOMLÓDI 1966,1969; LŐRINCZ 1972/ mainly concentrated on the evolution of vegetation and climate and the stratigraphic observations concerning the ostracod fauna /SZÉLES 1972/, the biostratigraphic classification of the Pleistocene sediments of Hungary was carried out first of all on the basis of the vertebrate fossils /KRETZOI 1953, 1956,1961, 1969; JÁNOSSY 1969,1973,1979 /. The insufficiency of the high precision biochronological classification of Pleistocene elaborated on the basis of small mammals of rapid generation is the fact that it is based on finds in special sedimentary facies of restricted extension. Thus, in field works this method cannot be always used which is mainly due to the scarcity of vertebrate fossils in extended basin sediments.

The classification based on the Quaternary malacological data provides the possibility for the biostratigraphic classification of the sedimentary sequences /TABLE 1/. Mollusc shells are fairly suitable to fossilization, thus molluscs are frequent in the Pleistocene sediments, occasionally in large masses. Since the molluscs live in the most different aquatic and terrestrial biotops, their fossils can be found in all Pleistocene sediments, with a few exceptions only.

In addition, the elaboration of the malacostratigraphic classification proved to be feasible by the malacological material of about 5o localities and 3o boreholes and by their investigation also by means of quantitative methods as far as possible. These investigations were supplemented by the processing and revision of the Quaternary malacological material in the documentation collection of the Hungarian Geological Survey.

TABLE 1.

CORRELATION OF THE HUNGARIAN GEO- AND BIOCHRONOLOGICAL PLEISTOCENE CLASSIFICATIONS

Chrono-stratigraphy		malacological subdivision		mammal-stratigraphic phases		Alpine subdivision	
Pleistocene	Upper Pleistocene /?/	Bithynia leachi - Trichia hispida biozone	Semilimax kotulae subzone	Utrechtian	Palánkium	Würm	W_3
			Catinella arenaria subzone		Pilisszántóium		
			Succinea oblonga subzone		———		W_{2-3}
			Helicopsis striata subzone		Istállóskőium		W_2
					Tokodium		W_{1-2}
			Clausilia pumila subzone		Subalyukium		W_1
		4. Helicigona banatica - Phenacolimax annularis			Varbóium	Riss - Würm	
					Süttőium		
		3. Helicigona vertesi biozone			?	Riss	
					Solymárium	Mindel - Riss	
					Castellum		
	Middle Pleistocene /Biharium/			Oldenburgian	Upponyium	Mindel	
					Vértesszőlősium		
		2. Perforatella bidentata biozone			Tarkőium		
		1. Viviparus böckhi biozone	Gastrocopta sacraecoronae subzone	Lower Biharium	Templomhegyium	Günz - Mindel	
					Nagyharsányhegyium		
			Neumayria crassitesta subzone		Betfiánum		
	Lower Pleistocene /Villányium/		Gastrocopta serotina subzone	Upper Villányium	Kislángium	Günz and Pregünz	
				Lower Villányium	Beremendium		

My research has increased to 196 the number of Pleistocene mollusc species in Hungary. When taking into account the potentialities of the recent fauna and area this number of taxons is approximately complete, no significant modification can be expected. Out of the 196 species 153 /78%/ still exist. The number of extinct species is 22, while 21 species do not exist in the area in question. The biostratigraphic classification is based first of all on the temporal distribution of these two groups /22% of the fauna/. A finer classification was carried out applying the quantitative sampling method according to changes in dominance values. Through the quantitative malacofaunistic investigation of the sequences of each localities we succeeded in recognizing ecological successions based on the change of specimens which were caused first of all by the alteration of the environment, i.e. climate, thus they bear biochronological significance.

Based on the analysis of the evolution of the Pleistocene malacofauna and of the launs of "stratotype localities" 5 biozones and further 8 subzones were distinguished. In a temporal sequence these are as follow:

1. biozone[x] /Viviparus böckhi zone/
   a/ subzone /Gastrocopta serotine subzone/
   b/ subzone /Neumayris crassitesta subzone/
   c/ subzone /Gastrocopta sacraecoronaae subzone/

2. biozone /Perforatella bidentata zone/

3. bizone /Helicigona vertesi zone/

4. biozone /Helicigona banatica - Phenacolimax annularis zone/

5. biozone /Bithynia leachi - Trichis hispide zone/
   a/ subzone /Clausilis pumila subzone/
   b/ subzone /Helicopsis striata subzone/
   c/ subzone /Succinea oblonga subzone/
   d/ subzone /Catinella arenaria subzone/
   e/ subzone /Semilimax kotulae subzone/

A correspondence of the bio- and subzones with the most frequent geo- and biochronological classifications of Hungary was established as seen in the Table.

[+] Biozones correspond to the Oppel-zone.

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CHRONOSTRATIGRAPHIC EVALUATION OF QUATERNARY AND PLIOCENE TERRESTRIAL STRATA BY PALEOBIOGEOCHEMICAL METHODS

SZŐŐR,Gy. - KORDOS,L.

Following a comparative examination of recent model material /SZŐŐR,Gy. 1971, MÁNDI,B. et al.1975/ the authors have recently completed a paleobiogeochemical evaluation of Quaternary and Pliocene inland fossilized vertebrates from Hungary /SZŐŐR,Gy. 1975,1979/ which has clarified the formation, accumulation and diagenesis of sediments and the related fossilization process.

It has been established that during the earliest, so-called syn-diagenetic stage of sediment burial the changing geochemical processes occurrency within the microfacies and the climate -induced variations of microbiological decomposition can produce highly different and even extreme stages of fossilization. However, during continuous sedimentation, these differences are evened out with the passage of time or, referring to the macro-facies, they become uniform.

At this stage the gradual and regular process of transformation by collagenic autohydrolysis, carbonation of apatite structure and impregnation of bone caverns with clay minerals can only be influenced by incidental catastrophic exogenous factors, such as the activity of thermal springs and effect of anthropogenic hearths. Recognition of this regularity provided the possibility for elaborating a complex thermoanalytical method /derivatography/, from which two parameters, closely associated with the passage of geological time can be determined.

The one parameter is the total bound organic-matter content of the fossil /A+B%/: the other is the so-called fossilization coefficient /F_K/. The latter is the ratio of derivatographically determined organic matter and incorporated darbonate CO_2 or clay mineral and structural water. /Derivatographic measurements were controlled by neutron activation analysis./ Firstly, sample material from sources that had been exactly determined from the point of view of paleontology and sedimentation geology were examined KRETZOI,M.1953, KORDOS,L.1977/. Relying on the biostratigraphic order determined by CHALINE et al./1974/, the absolute dates obtained by the isotope method were correlated with our thermoanalytical parameters, and three functional correlations obtained by computer were analysed.

From among the exponential, logarithmic and powered regression models the latter two are suitable for absolute dating.

The most important correlations are:

for the Holocene /5 ooo--1o ooo B.P. years/

$$T_{abs} = 10^2 . e - \frac{/A+B/-33.86}{2.60} \quad \pm 500 \text{ B.P.years}$$

for the Pleistocene 1o ooo--1 ooo ooo B.P. years

$$T_{abs} = 10^3 \; / \frac{28.483}{A+B} /^{5.3124} \quad \pm 1000 \text{ B.P. years}$$

Taking into consideration the fossilization coefficients of the analysed bone samples, we have established three correlations for the Holocene period and one for each of the Upper-, Middle- and Lower Pleistocene periods. The derivatographic measurements for the organic matter in the bones samples is supplemented by the fine-structure analysis of bone-tissue slides.

Sample material from several sources of unknown age was evaluated with the new dating method and our measurements compared with the values from C^{14} dating.

SUMMARY

Our results can supplement biostratigraphic research work evaluating the changes in vertebrate succession, and can complete the biochronological classification by providing absolute indices. The importance of the procedure is even greater when only undetermined sporadic finds are obtained from sediments.

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GEOMORPHOLOGICAL POSITION AND CHRONOLOGICAL CLASSIFICATION OF HUNGARIAN TRAVERTINES

PÉCSI, M. - SCHEUER, Gy. - SCHWEITZER, F.

An analysis of Hungarian travertines based on their orographic position during formation, on an evaluation of their lithological character and on the study of karst-hydrological processes, provides both the possibility of establishing their chronological position a more detailed method of their morphogenetic reconstruction. FIGURES 1-5 show different types of travertines according to the hydrodynamic and morphological position of karst springs.

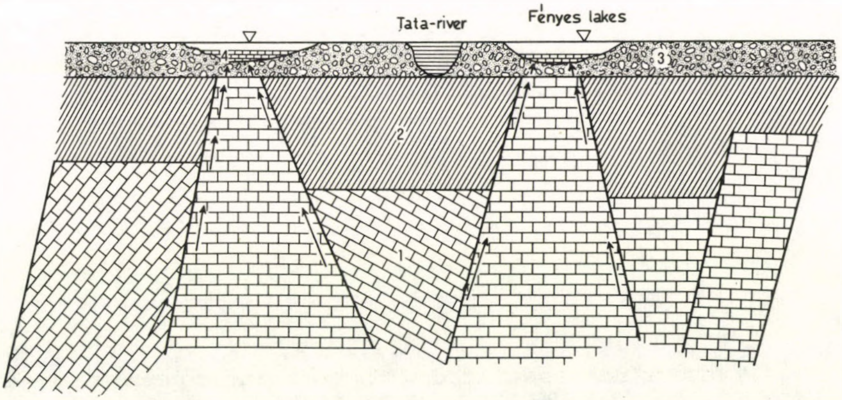

FIG. 1 Flood-plain-lacustrine-marshy travertine formation associated with spring issuing from covered horst through fluviatile sediments /SCHEUER, Gy. - SCHWEITZER, F./
1: permeable Triassic sediments; 2: impermeable tertiary sediments;3:recent sediments of the Által-ér; 4: travertine;

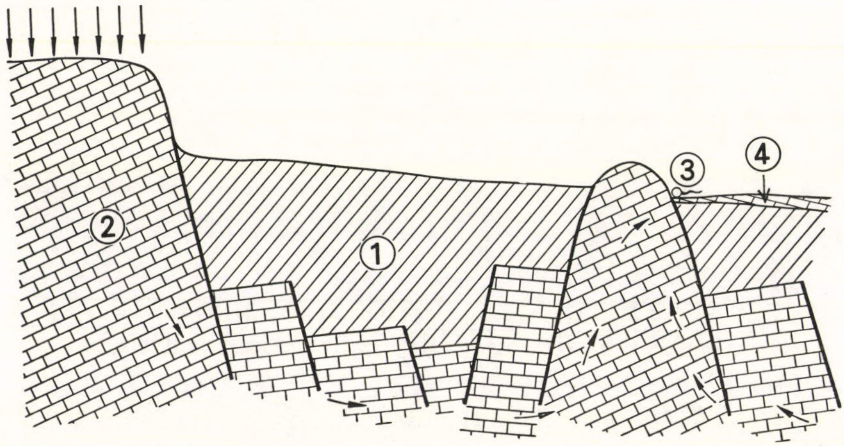

FIG. 2 Travertine associated with springs issuing from horst side on to flood plain
1: impermeable Tertiary sediments; 2: permeable Triassic sediments; 3: karst spring; 4: travertine.

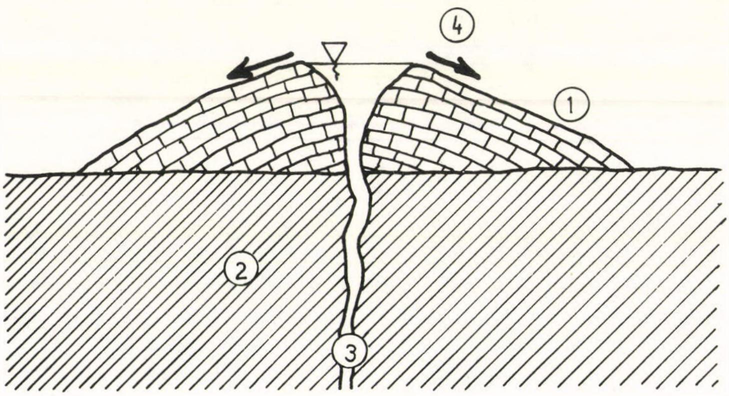

FIG. 3 Travertine associated with a spring cone /after SCHEUER, Gy. - SCHWEITZER, F./
1: travertine; 2: floor; 3: spring conduit; 4: spring crater.

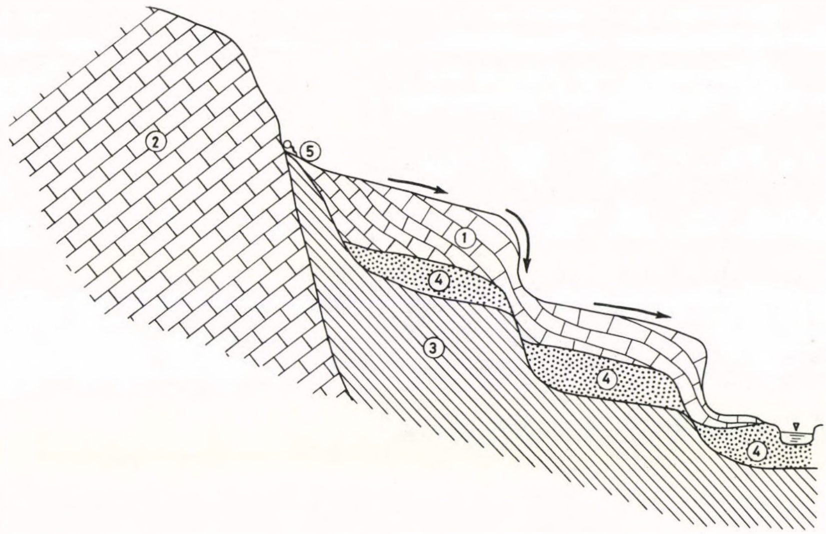

FIG. 4 Travertine of valley-side type /after SCHEUER, Gy. - SCHWEITZER, F./
1: travertine; 2: water holding limestone or dolomite; 3: impermeable rock; 4: fluviatile sediments, occasionally slope deposits; 5: karst spring.

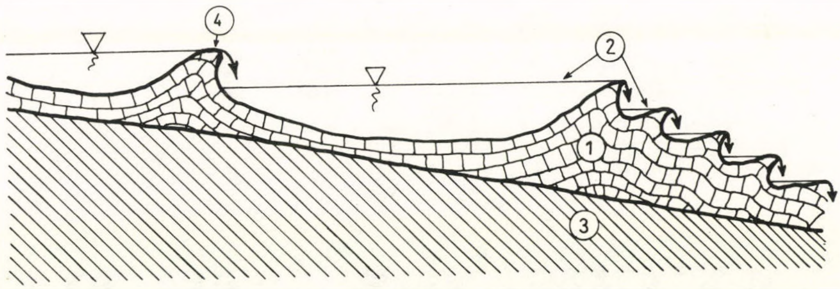

FIG. 5 Travertine with tetarate dams /after SCHEUER, Gy. - SCHWEITZER, F./
1: travertine; 2: tetarate lakes; 3: floor; 4: tetarate dam.

Concerning the different types travertines sequence several new findings have come to light, i. e. the interpretation of travertine blocks formed in spring funnels, the distinction between 3o to 4o m thick travertine sequences with tetarate dams and the classification of terrestrial sediments and fossil soils according to their genesis and chronology /PHOTO 1, 2, 3/.

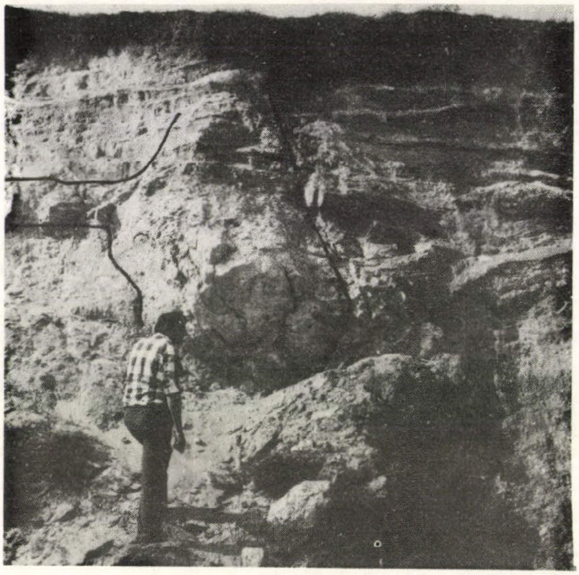

PHOTO 1
Travertine hot spring crater in Upper Pannonian delta gravel. Travertine horizon T_9. Gerecse Mountains.

PHOTO 2 Tetarate travertine in the Danube terrace No. VI. at Dunaalmás, 215 m a.s.l. Travertine horizon T_6. Gerecse Mountains.

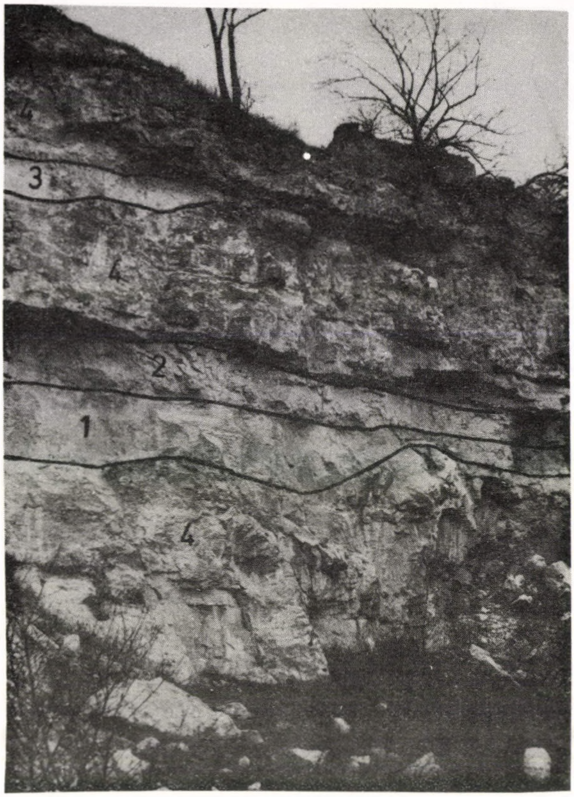

PHOTO 3
Profile of the tetarate basin developed on the Danube terrace No. VII. at Dunaalmás, 24o m a. s.l. Travertine horizon T_7. Gerecse Mountains. 1: red-brown fossil soil /with fauna of Kislángium age/; 2: fine sandy loess; 3: lime mud; 4: travertine.

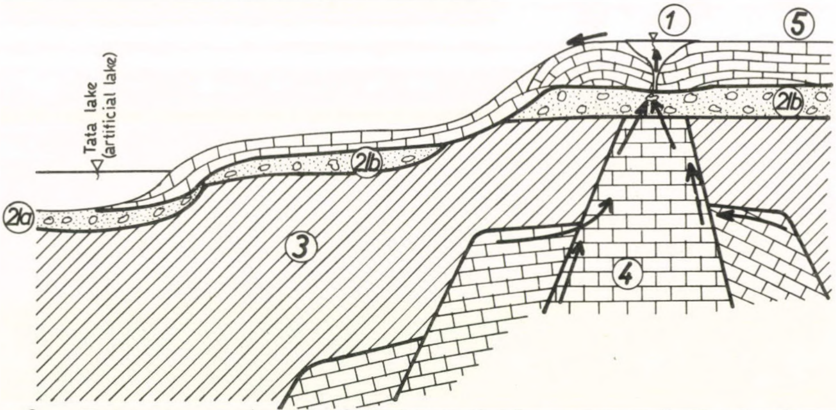

FIG. 6 Terrace springs of Tata and the geomorphological position of the travertine /after SCHEUER, Gy. - SCHWEITZER, F./
1: spring lake and spring crater; 2/a: recent sediment of the Által-ér; 2/b: younger terraces of the Által-ér; 3: impermeable Tertiary rocks; 4: permeable Triassic rocks; 5: travertine;
⟶ direction of water flow.

The previous view that the formation of travertines took place mostly at the erosion base level and that travertine sequences generated in this way preserved a definite geomorphological position characterizing their evolution, has proved to be an extreme over-simplification and should be revised. As exemplified in figures 4 and 5 certain cases travertine occurrences and sequences can be generated above the base level of erosion and moreover on slopes as well. Certain karst springs can be active in the same morphological position for a considerable time, during which the relative height of the immediate erosion base may change considerably due for example to valley incision or the formation of lower terraces. The displacement of the base level, however, to lower levels need, not necessarily produce a corresponding lowering of karst spring levels /FIG. 6/.

Thus, there are cases travertines are simultaneously formed in different morphological positions e. g. on slopes or on terraces from karst springs above the erosion base. In the case of tetarate limestones, sequences of 2o to 4o m in thickness can also develop on terraces, pediments and marine terraces above the base level of erosion. The formation of this type of travertine continues, until a change in karst-hydrodynamic conditions produces a rearrangement of the associated springs /FIG. 7/.

The general tendency can be established, however, that the formation of travertines and the occurrence of karst springs has more or less been dictated by the morphology and gradual subsidence of the erosion base since the Upper Pliocene both in the foothills and in the valleys /FIG. 8/.

This can be verified by the fact that in the Buda and Gerecse Mountains the oldest travertines have been formed on Upper Pannonian marine terraces with spring activity on the Upper Pliocene pediments generating travertine occurrences at a height of 27o to 3oo m above sea level. The travertine occurrences at lower levels are associated with Quaternary valley formation and with the evolution of the Danube valley and its tributaries /FIG. 9; PHOTO 4/.

On the margins of the Mesozoic horsts of the Danube gorge, where the river cuts through the Hungarian Uplands, travertines of different age are found at lo to 12 different levels on the terraces and pediments. Using these formations a fair reconstruction of the morphological evolution during the Quaternary can be carried out /FIGS. 9, lo/.

The travertine levels, which overlies each other in a step-like fashion can be devided into two groups[x]. First are the

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[x] The horizons of travertines were numbered from the lowest point /Budapest, Rómaifürdő, lo7 m a.s.l./ up to the highest /Buda Mountains, Szabadsághegy-Normafa, 493 m a.s.l./, so their symbols are T_1 - T_{12}.

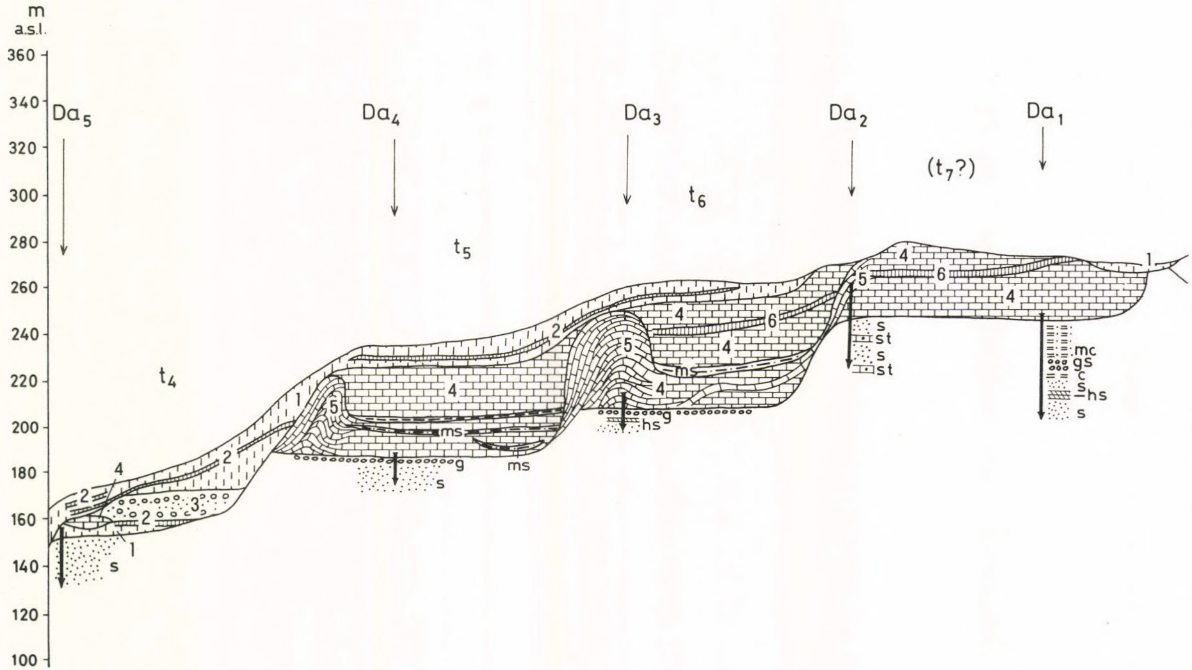

FIG. 7 Profile of Danube terraces V-VII and the overlying travertine sequences based on superficial exposures and boreholes /after PÉCSI, M. - SCHEUER, Gy. - SCHWEITZER, F. 198o/.

1: loess, slope loess; 2: fossil soils in loess; 3: terrace gravel; 4: travertine; 5: tetarate dams; 6: fossil soil in travertine; Da_1-Da_5: borehole locations; t_4-t_7: terraces; c: clay; mc: muddy clay; ms: muddy sand; s: sand; gs: gravelly sand; hs: hydromorphous soil; st: sand-stone; g: gravel.

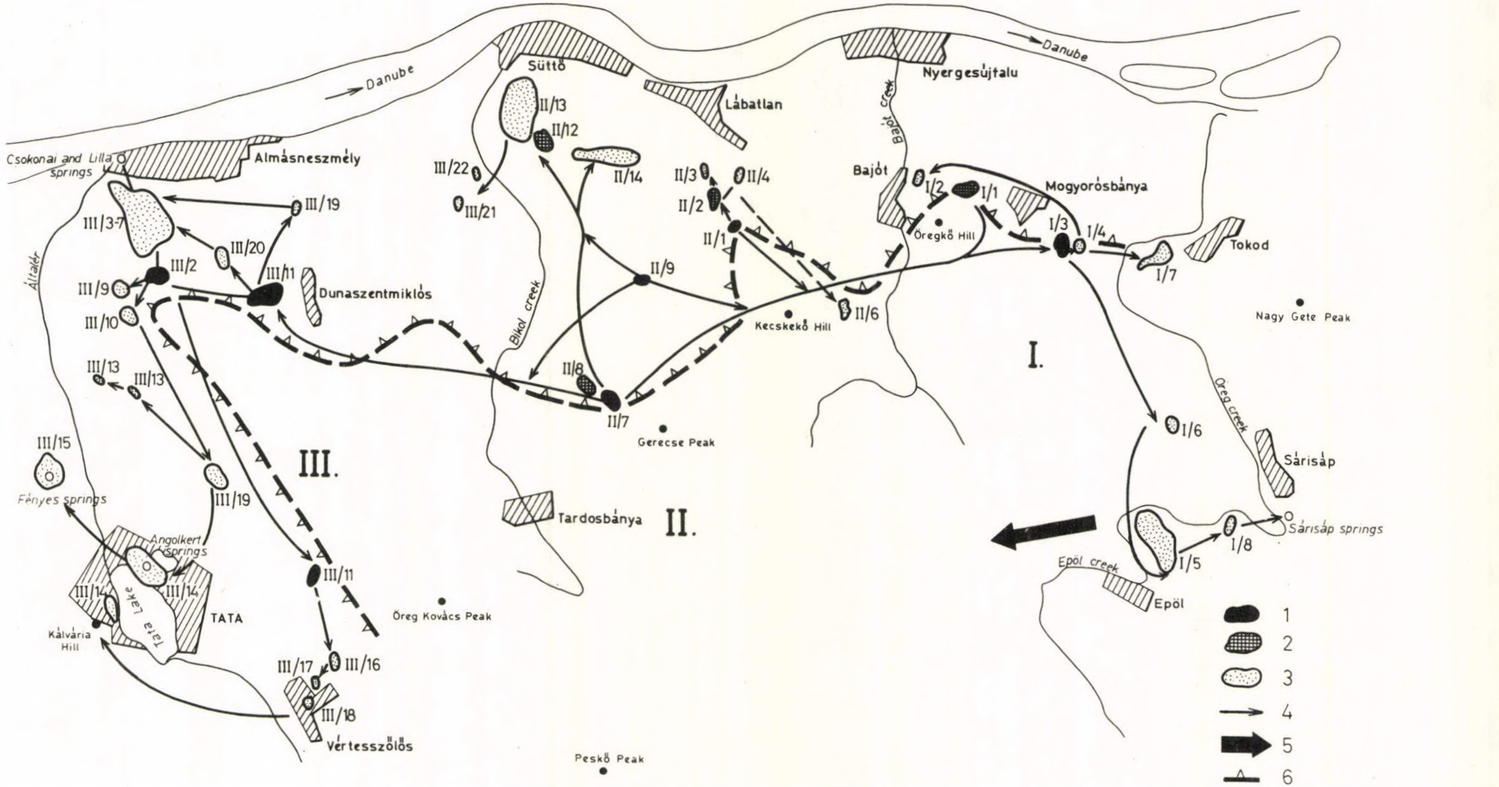

FIG. 8 Principle travertine occurrences in the Gerecse Mountains
1: Upper Pannonian springs and travertines; 2: Upper Pliocene springs and travertines; 3: Quaternary springs and travertines; 4: direction of spring displacement; 5: direction of Late Pleistocene spring displacement; 6: presumed Upper Pannonian shore-line; I: Eastern Gerecse; II: Central Gerecse; III: Western Gerecse.

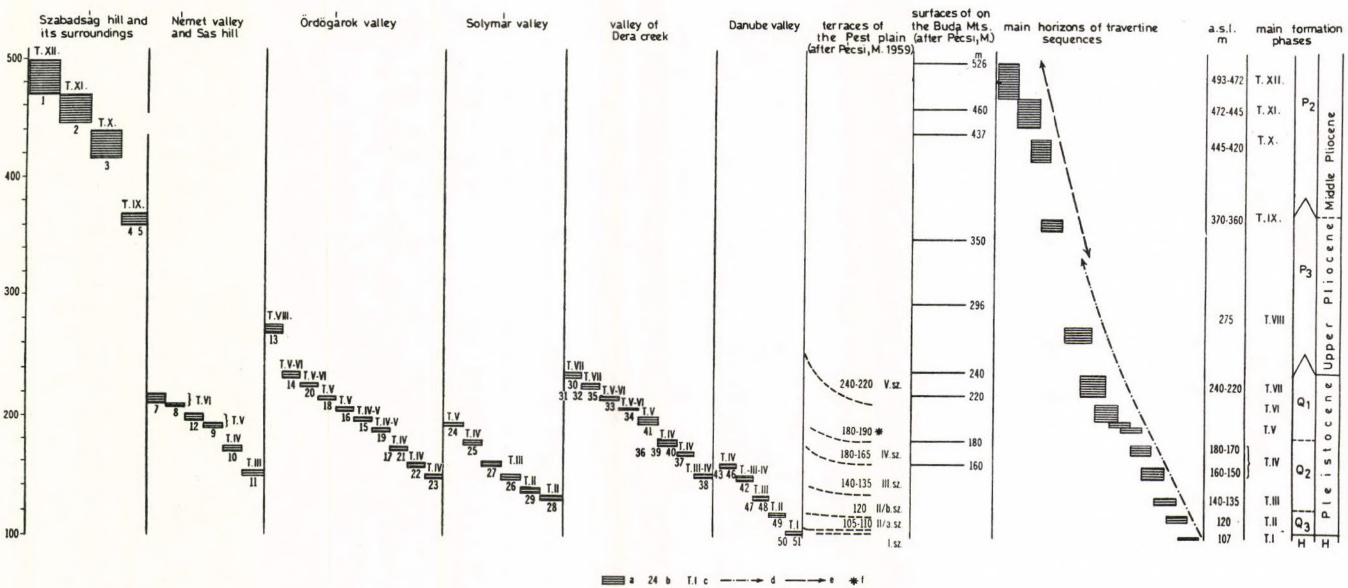

FIG. 9 Travertine horizons and main formation phases in the valleys of the Buda Mountains /after SCHEUER, Gy. - SCHWEITZER, F. 1973/

a: travertine horizons; b: locations of occurrences; c: T I - T XII: main travertine formation phases; d: travertine horizons associated with the Danube-valley occurring on the eastern margin of the Buda Mountains and formed during the development of valley systems; e: travertine horizons associated with tectonic movements /mainly uplifted/ and related valley formations in the János and Szabadság hill region; f: local terrace occurs in Pest-plain between alluvial fan terraces IV and V.

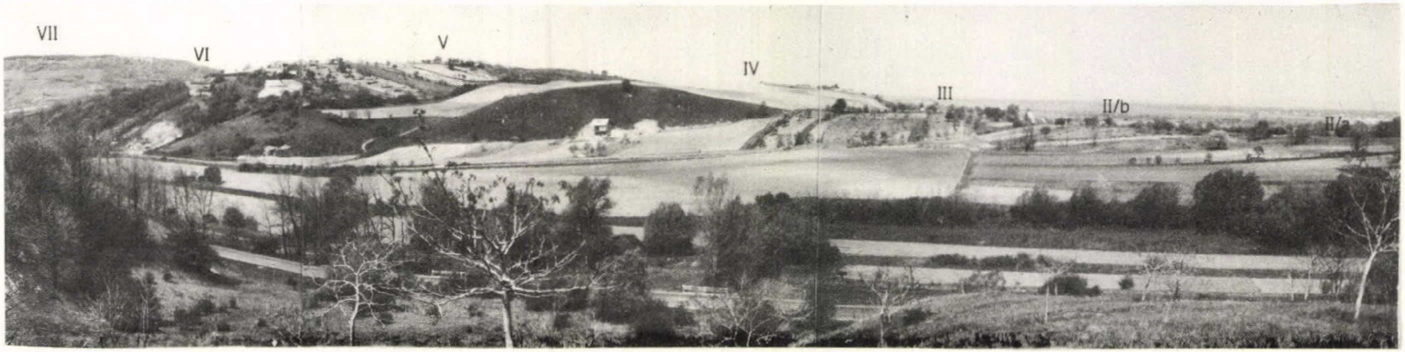

PHOTO 4 Danube terrace horizons in the Eastern Gerecse Mountains

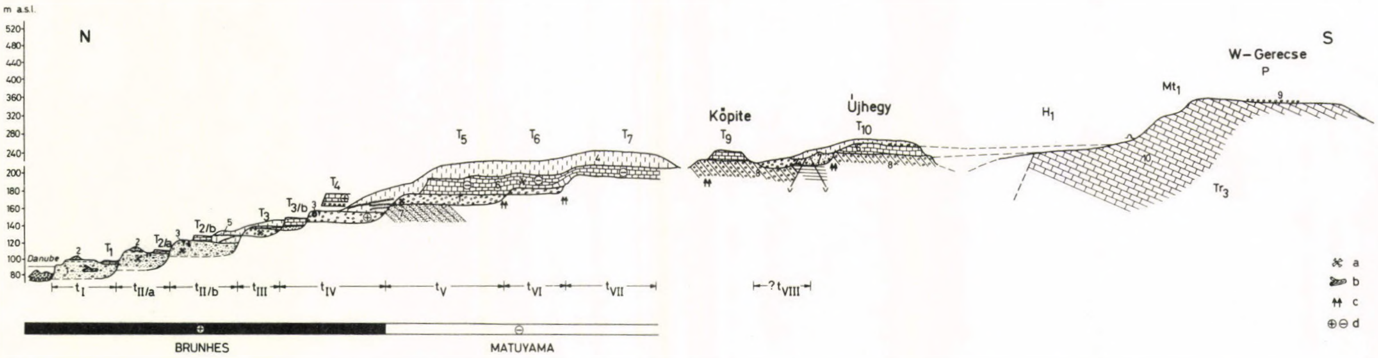

FIG. lo Geomorphological horizons of the Western Gerecse Mountains /after Pécsi, M. - SCHEUER, Gy. - SCHWEITZER, F. - PEVZNER, M.A./

l: fluviatile terrace gravel and sand; t_I - t_{VII}: terraces,chronological sequence given in Plate l. Terrace gravel t_{VIII} is presumed to overlie the Upper Pannonian delta gravels by an erosional unconformity, destroying the uppermost Pannonian cross-bedded sands; 2: blown sand; 3: remnants of Pleistocene cryoturbation; 4: loess, slope loess; 5: fossil soils in loess; 6: travertine horizons; T_l - T_{lo}: travertine horizons of different age, chronological sequence given in Plate l. 7: Upper Pannonian cross-bedded sands and gravel with rounded travertine blocks in lower parts; 7a: Upper Pannonian cross-bedded sand /?/ Bérbaltavárium?; 8: Upper Pannonian clays; 9: Miocene /?/ terrestrial gravels; lo: Upper Triassic limestone; H_l: Upper Pliocene pediment remnant with Upper Pannonian wave-cut platform No. 2. preserved on its margin; M_{tl}: Upper Pannonian marine terrace; P: pre-Tertiary - Tertiary planation surface with Miocene terrestrial gravel occurrences; a: fauna location; b: fossilized tree-trunk; c: traces of hot-spring funnels in travertines and gravels; d: paleomagnetic polarity.

members of the lower series deposited close to each other on the valley-side terrace between lo7 and 24o m a.s.l. /horizons T_1 - T_7/. Second are the members of the higher series deposited on older geomorphological levels /T_8 - T_{12}/ which succeed each other with considerable local height difference and are lithologically different from the lower series.

Correlations between the lower travertine series and the terraces of the Danube and its tributaries.

Travertine T_1 can be associated with the first floor-free/II/a/ terrace /PHOTO 5./, travertine T_2 with the second flood-free terrace /II/b/ /PHOTO 6/, and so on up to horizon T_5, which is deposited directly on to terrace No. V north of Budapest. The travertine horizons T_5, T_6 and T_7 are best represented in the Gerecse Mountains, where they lie on terraces V, VI, VII of the Danube and occasionally on those of its tributaries /PHOTOS 7, 8/.

The absolute age of selected travertines deposited on the terraces was determined by means of the Th/U method /PÉCSI, M. - OSMOND, J.K. 1973/, and gave ages of 7o ooo years for travertine T_2 /Óbuda terrace II/b/, 19o ooo years for travertine T_3 /Kiscell Plateau/ and more than 35o ooo years for the travertine T_4 /Vértesszőllős - Buda Castle Hill/.

According to the paleomagnetic data from the loess strata intercalated in the travertine T_4, is younger less than 7oo ooo years of normal, while the T_5 horizon is older than 7oo ooo years and of reversed magnetic polarity.

The fauna found in the travertines of the Buda Castle Hill /T_4/ and at Üröm-hill /T_5/ can be referred to the Middle Pleistocene and Upper phases of the Lower Pleistocene /JÁNOSSY, D. et al. 1976; KROLOPP, A. 1966/.

In the Gerecse Mountains travertines T_6 - T_7 proved to be of Upper Villányium - Lower Pleistocene /Kislángium age/ bared on microfauna collected by SCHWEITZER, F. and determined by JÁNOSSY, D. /1978/.

Travertines T_9 and T_8 are deposited on the lower /27o-25o m/ and higher /36o-3oo m/ pediments abutting the valley sides of Szabadság and Széchenyi Hills. Preceding their formation, the Buda Mountains rose considerably at the beginning of the Upper Pliocene, causing a lowering of the karst water table and the generation of new karst springs along the bank line of the lower pediment.

The oldest travertines of the Buda Mountains /T_9 - T_{12}/ are deposited on sands and gravels of Upper Pannonian age, the T_{1o} is a greyish lacustrine-marshy formation, whose micro- and macrofauna as well as position suggest it to belong to the "Sümegium" of the Upper Pannonian. Travertine T_{11} is deposited on the highest Pannonian marine terrace at a height of 44o-45o m above

PHOTO 5 Recent travertine horizon T_1 developed on terrace No. II/a. Tata.

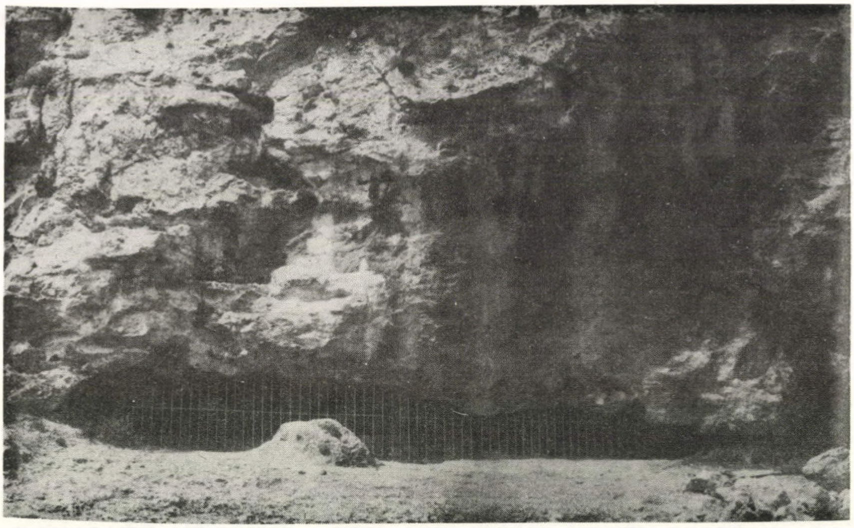

PHOTO 6 Travertine horizon T_2 developed on the terrace No. II/b. at Tata, with location of the paleolithic Tata-culture.

PHOTO 7 Lacustrine-marshy travertine deposited on the Danube terrace No. V in the horizon of the erosion base in 18o m a.s.l. at Dunaalmás. Travertine horizon T_5. Gerecse Mountains.

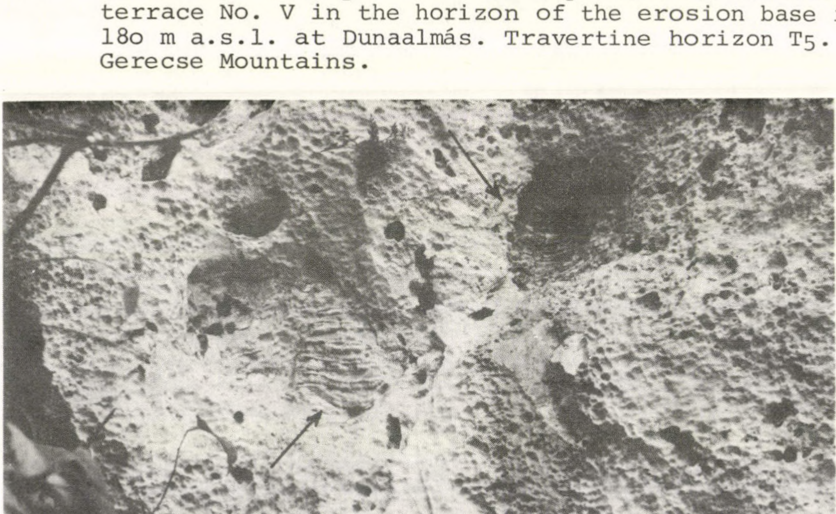

PHOTO 8 Dental fragments of Elephas meridionalis in the travertine deposited at 22o m a.s.l. Gerecse Mountains. /Photos were made by the authors/.

sea level. It is suggested that at the time of the formation of travertines T_{11} and T_{12} the Buda Mountains had risen somewhat above the level of the Pannonian inland sea and that the marine terrace may be associated with hot karstic springs action.

In the Buda Mountains the travertines suggest the existence of 12 geomorphological stages, which are indicative of the degree of tectonic uplift that has taken place since the Middle Pliocene /Upper Pannonian/. Based on the position of the various travertines, we would estimate 7o to 8o m of uplift took place during the Middle Pliocene, 8o to 1oo m during the Upper Pliocene and 13o to 14o m during the Quaternary, within which 6 to 8 m can be assigned to the recent /FIG. 9/.

Since the travertines are used on a large scale by the building industry our surveys have yielded some qualitative and quantitative estimations of their potential use. It was the need for this information, which in fact provided the possibility of reviewing the topic in detail.

PLATE 1

Relationships between Plio-Pleistocene travertines and geomorphological horizons in the Hungarian Mountains Range.

/1/ Pliocene-Pannonian marine terraces and travertine horizons:
- Early Upper Pannonian travertine /T_{12}/, Szabadság-hill horizon at 5oo m; Balaton Highland: Kapolcs Travertine;
- Middle and Late Upper Pannonian /Sümegium and Bélbaltavárium/ travertines on marine terraces /T_{11} and T_{1o}/; Bakony Mountains: Nagyvázsony, Várpalota. Buda Mountains: Szabadság-hill.

/2/ Upper Pliocene travertine and pediment.
- Travertine formation characterized by Unio Wetzleri during the main phase of the formation of the Pliocene pediment /Bérbaltavárium/; in the Gerecse Mountains: T_9.
- Further pediment development during the Csarnótanum,formation of red clay and travertine /Buda and Gerecse Mountains, T_8/.

/3/ Quaternary travertines and fluvial terraces .
- terrace VII is overlain by travertine containing fauna of Upper Villányium age /T_7/.
- terrace VI /Lower Villányium/, travertine T_6 /from the Upper Villányium - Kislángium phase/;
- terrace V /Lower Biharium/, travertine T_5 /Lower Biharium, with reversed magnetic polarity, about 8oo-9oo thousand years/;
- the travertine lying on terrace IV /T_4 at Vértesszőllős/ is more than 35o ooo years old; the terrace and the travertine are of normal magnetic polarity;
- the travertine lying on terrace III. /R1 and R1-R2/ is 19o ooo years old /marked by T_3/;

- the travertine /T_2/ lying on terrace II/b /R-W and W_1/ is 6o ooo - loo ooo years old;
- the cover overlying travertine /T_{2a}/ on terrace II/a is of Upper Würmian age;
- flood plain I and the spring limestone /Holocene/ are younger than 11 ooo years.

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HYDRATION RATES OF THE CARPATHIAN OBSIDIANS FROM ARCHAEOLOGICAL LITHIC ASSEMBLAGES

Mrs.TAKÁCS,BIRÓ,K.

Obsidian has been the subject of varied archaeological, technological and chronological studies in Quaternary research /TAYLOR,R.E.1976/. It is of primary importance in enabling the archaeologist to trace ancient trade routes and intercultural connections on the basis of raw material characterization. In addition, however, it possesses special qualities which offer possibilities in archaeological and geochronological age determination /FRIEDMAN,I. - SMITH,R.L.196o, FRIEDMAN,I. - OBRADOVICH,J.1981/.

OBSIDIAN HYDRATION DATING /OHD/

Obsidian is a volcanic glass which generally contains large amounts of SiO_2 and very little water / $\leq 1\%$ /. Because its amorphous structure is unstable at normal soil and surface temperature it undergoes crystallization over the course of time. Crystallization starts at phase boundaries; these are freshly broken surfaces or fractures where the material comes in contact with its immediate surroundings. It is here that the glass absorbs the water from the environment. Diffusion of the water advances perpendicular to the phase boundary in the direction of the interior of the glass. At high temperatures, or under conditions of high pressure the water diffusion front intrudes into the glass at a speed higher than that of the crystallization. Under normal surface conditions, however, water diffusion and crystallization occur simultaneously /PESTY,L.1981/.

This phenomenon was discovered around the mid-fifties /ROSA,C.S. - SMITH,R.L.1955/ and has since been adopted for archeological age determination /FRIEDMAN,I. - SMITH,R.L.196o/.

Obsidian hydration can be directly observed in petrological thin sections. Hydration rind can be seen around the edge of the implement in the form of a slightly diffractive band which may be seen with linear polarized light /1 N/ as well. There are significant sources of error which occur when measuring the hydration rind in a polarization microscope, however. The errors may be due to sample preparation, scale reading and the limits of the resolving power of the light microscope. More accurate measurement techniques have also been attempted. These include the transmission electronmicroscopic carbon replica method /GIBBON,D.L. - MICHELS,J.W.1967/ and nuclear profiling measurement techniques /TSONG,I.S.T. et al. 1978,LANFORD 1978/. This latter method is suitable for determining the growth rate of obsidian hydration each year under natural circumstances or the measurement of artificially grown hydration layers. In this way, the role of certain variables influencing the obsidian hydration rate may be clarified /LAURSEN,T. - LANFORD,W.A.1978/.

Among the most important factors influencing obsidian hydration are pressure, temperature and the quality of the raw material. On the other hand, the water content and the pH values in the surrounding environment do not seem to influence the rate of hydration. The role of high pressure and temperatures on the hydration of volcanic glasses has been the subject of many studies of geochemical interest. Recently, PESTY, L. has had outstanding results in this field /PESTY,L.197o, PESTY,L.1981/. Under natural archaeological conditions, however, the role of pressure is negligible, while temperature becomes a decisive factor in the evaluation of hydration rind thickness both regionally and locally. Regional dependence can be attributed to differences in the mean annual temperature of areas. The dependence on temperature is not, on the other hand, linear. Thus, the so-called "effective hydration temperature", determining the hydration rate proper, must be calculated on the basis of the thickness of the soil cover lying above the obsidian, because the hydration rate of surface finds exposed to large temperature variation is always higher /FRIEDMAN,I. - LONG,W.1976/.

Variations in the chemical composition of obsidian types also results in different hydration rates. The dependence of the hydration rate on the chemical composition may be a function of higher silicon content, alkaline-calcalkaline character, or even the geological age and crystallite density of the obsidian /ERICSON, J.E. - BERGER,R. 1976/. In case of obsidian specimens coming from the same geological source this factor is negligible.

In order to determine absolute age using OHD, the main conditions are accuracy of measurement and that of the hydration rates calculated on the basis of the measurements. Obsidian hydration rate can be determined with the measurement of hydration layers of obsidian implements of known age, using the following general equation which has been worked out experimentally:

$\underline{x = kt^n}$, where x = the thickness of the hydration layer
t = the time elapsed since the last surface

break

k = obsidian hydration constant

n = the slope of the function, which has been determined experimentally by seriation /MICHELS,J.W.1971/. The limit of scale reading accuracy /o,3 um/ in this case will make a standard error of 75o years in case of an 5ooo years old specimen and ± lo5o years using a sample of lo ooo years. Sample preparation problems added this error can easily reach o,5-1 m, resulting an inaccuracy of ± 2ooo /in a 5ooo years old specimen/ and ± 3ooo /in a lo ooo years old specimen/, applying petrographical thin sections and polarization microscope. The simplicity and relative cheapness of this method, however, made possible routine applications of OHD. This was above all true from the material from the Americas, chiefly the USA, where historical chronology has modest traditions. Factors influencing hydration rates were mainly discovered during the course of thin section technique measurements. Such data served as the basis of the first hydration constant calculations. By 1971, more than lo ooo obsidian hydration dates had been evaluated. Even today, light optical measurement is the most common means of measuring hydration thickness. A more accurate measurement of the hydration layer is also carried out using the different "profiling" techniques detecting the concentration changes of ions moving in the hydration zone as a cause of water diffusion, in function of depth from the surface. Thus as we know more about the obsidian hydration phenomenon the accuracy of OHD might increase.

APPLICATION OF OHD TO THE CARPATHIAN OBSIDIANS

Practically speaking, OHD has not been used to study European obsidian industries. One of the chief reasons for this fact may be that after the mesolithic period the very fine Mediterranean historical chronology offers possibility for a more exact dating even using traditional typology. The mesolithic is the terminus post quem for the appearance of obsidian in the Mediterranean archaeological sites /AMMERMAN,A.J.1979, DURRANI et al. 1971/. I should note that OHD may play a positive role here too, by checking C^{14} dates and "short" and "long" chronologies.

Obsidian sources of the Carpathian Basin have supplied the inhabitants of this territory with high quality raw materials since at least the Middle Paleolithic /T.BIRÓ K. in press/. Dating in such a long time-span /5o ooo - 4ooo BP/ is an unique opportunity. Palaeolithic obsidian implements are very scarce in the USA /ERICSON,J.E. - BERGER,R., 1974/. Upper Palaeolithic sequence has been set up in Japan /KATSUI,Y. - KONDO,Y.1965/. Beside these two instances only scattered palaeolithic obsidian hydration dates are known to exist. There is a great opportunity offered by the OHD of Armenian and East-African artefacts. The archaeometric study of these geological sources, however, is not on a level adequate for a hydration study yet. This is because proper source characterization is the first condition of hydration dating.

Source characterization of the Carpathian obsidians has been carried out since the end of the 7o-ies /WILLIAMS,O. - NANDRIS, J.1977, T.BIRÓ,K.1981/. Shortly afterwards it was possible to measure hydration layers of our archaeological obsidian samples. Proceding trials for the measurement of this layer had failed to preserve the hydration layer in the course of sample preparation /LINDNER 1964--65/. The first series of thin-section measurements contained serious sources of error that could have caused an inaccuracy of 5o% of the measured value. For this reason a new, more accurate measurement technique was developed /T.BIRÓ,K. - POZSGAI,I.1982/. This method can provide much better reading accuracy, and besides archeological dating, it can solve source characterization and geological age determination on the same sample, simultaneously or with minor readjustment of the specimen.

Scanning electron microscope was used for the study of a polished, slightly etched section of the obsidian implement, cut perpendicular to the hydration layer. SEM allows the hydration layer thickness to be read at about an order of magnitude better than the light optical polarization microscope. At the same time, SEM makes possible the electron microprobe analysis of the sample. By the help of this latter we may successfully determine the geological source of the specimen and can detect chemical differences between the interior of the obsidian and the phase identified as the hydration layer /FIG.1./

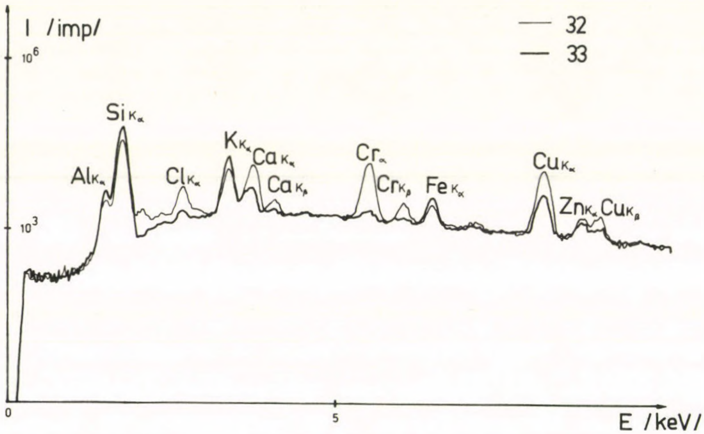

FIG.1.: X-ray spectra of Carpathian II obsidian - 33 = interior 32 = hydration rind

Our results agree well with other measurements - concerned with the movement of ions in hydrated glass, carried out using other methods /TSONG et al. 1978/. This is an essential proof for us that our observation agrees the hydration layer proper. The interpretation of the SEM image is not simple in any case. Backscattered and secondary electrons used for the SEM image may reflect only morphological differences. The hydration rind observed can be explained by the selective etching efficiency of the lo% HF acid. This results in a well-defined trough in place of the hydration layer. Where thin hydration layers occur the different hardness of the hydration rind and the interior of the glass in itself enough to cause morphological differences due to different degree of abrasion during the course of polishing /PHOTO 1/.

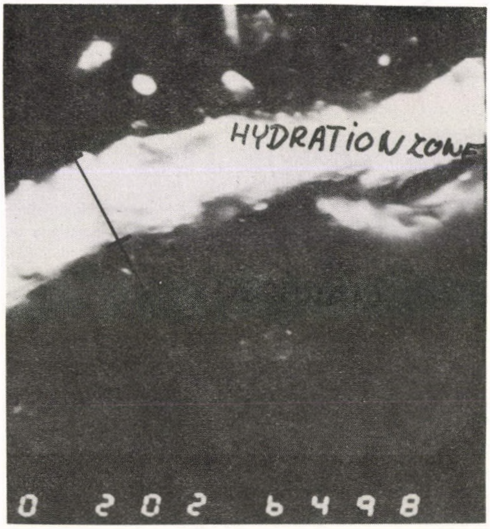

PHOTO 1:
Scanning electron microscopic image of the hydration rind /2ooox/

For a more certain evaluation of SEM images, several specimens of hydrated and freshly broken surfaces were compared, prepared in different ways. The points where the measurements were taken were later checked using opaque illuminated reflexion microscope with polarized light. Measurements were taken at places where the hydration rind was continuous and possibly unhurt, perpendicular to the plane of the hydration rind. Measurements were taken at several places and in different enlargements the average and standard deviation were derived from the measured thickness values. The obsidian specimens examined were grouped according to raw material type /Carpathian I - II/ and site type /open air sites and caves sites/, to eliminate the role of temperature and chemical composition change factors. Thus the relation of the hydration rind thickness values and the known age of the samples were possible to correlate.

For the first series of examination I used a small sample of specimens selected by VÉRTES,L. in the early sixties as well as some flakes from the HNM collection on which I had previously performed thin section hydration measurements /FIG.2./ All the samples come from relatively old excavations making the evaluation more difficult, especially in the case of multilayered cave site materials. Acceptable absolute chronological datum of the samples obtained by ^{14}C dating of the cultural layer has been worked out for Ságvár /Gravettian, open air site/. Dealing with copper age and neolitic samples ^{14}C periods

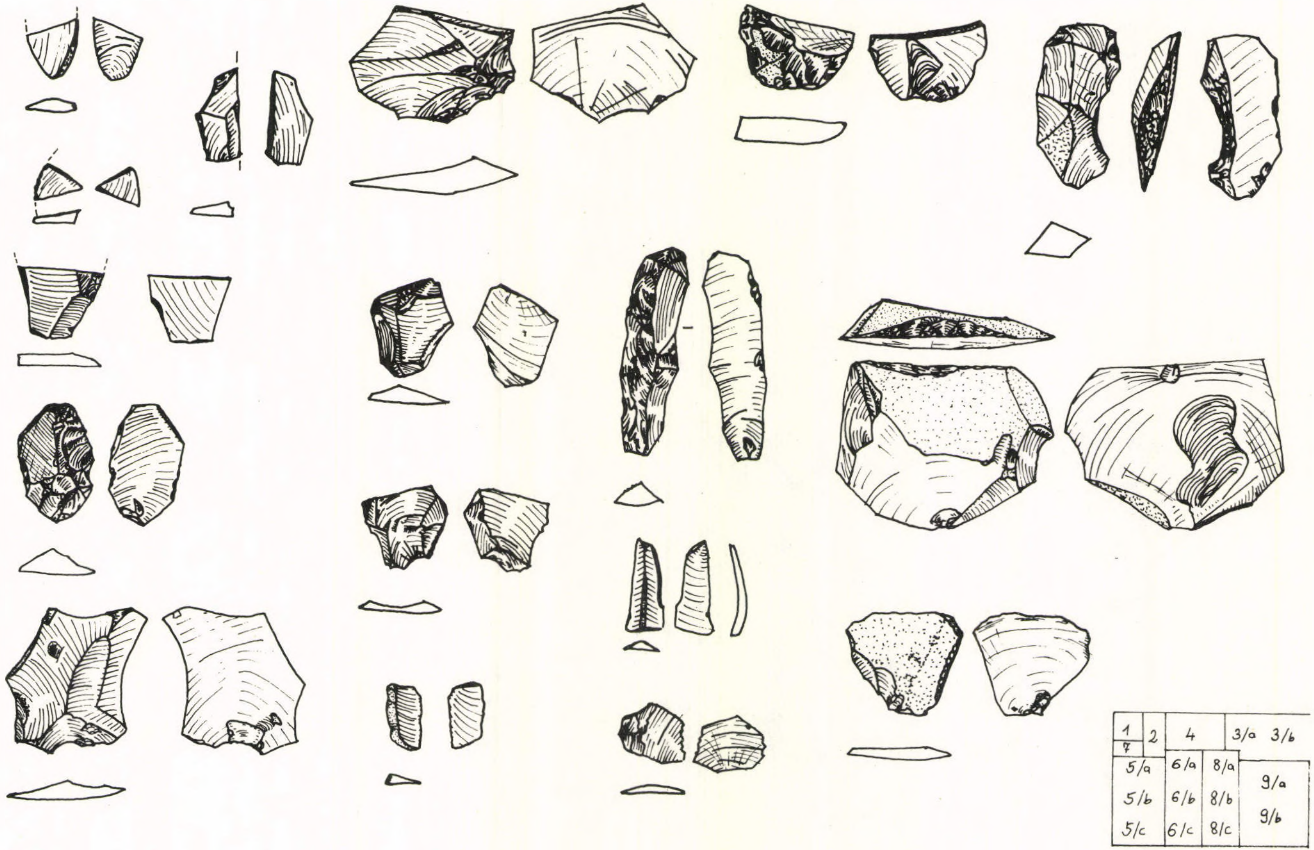

FIG.2: Flakes and blades used for OHD

and historical chronological dates were equally considered.The obsidian blade from the epipalaeolithic Petényi cave was found among circumstances of good stratigraphical control and has been placed chronologically after the late palaeolithic - early epipalaeolithic site of Szekszárd-Palánk with a ^{14}C date of 1o,4oo /VÉRTES,L.1965/. The age of the Pilisszántó sample can be roughly estimated on the basis of the typological features of the Gravettian assemblages known from here coming from several surface collections and excavations, and from stratigraphical examinations of loess /GÁBORI,M. - GÁBORI,V.1957/. The evaluation of multilayered cave site material is uncertain as yet, due to mixing of the characterless waste material during and after excavation, solifluction and cleaning by acids, all of which can bias the sample.

From the modest material at my disposal I can establish acceptable hydration rates only for the Carpathian I type obsidian from openair sites as yet /FIG.3/. On the basis of the Zengővárkony /8 a,b/ Ságvár /6 a,b,c/ and Pilismarót /7/ samples taking n=o,512 expotential coefficient generally accepted in technical literature we get for k hydration constant o,o5 that fits well among hydration constants known for other obsidian types /MICHELS,J.W.1971, etc./. For determining the standard error of the SEM reading method, further samples and measurements are needed.

SUMMARY

The main advantage of OHD lies in ability to immediately date the archaeological specimen and event, associated with the production or use of the implement. The present level of accuracy renders it suitable for relative chronological application.Its main use in Central Europe may be the archaeological dating of otherwise objectively undatable lithic assemblages like surface or mixed collections. With the examination of samples coming from new excavation and from known ages OHD can be developed as an effective means for determining absolute age of archaeological assemblages in the Carpathian Basin.

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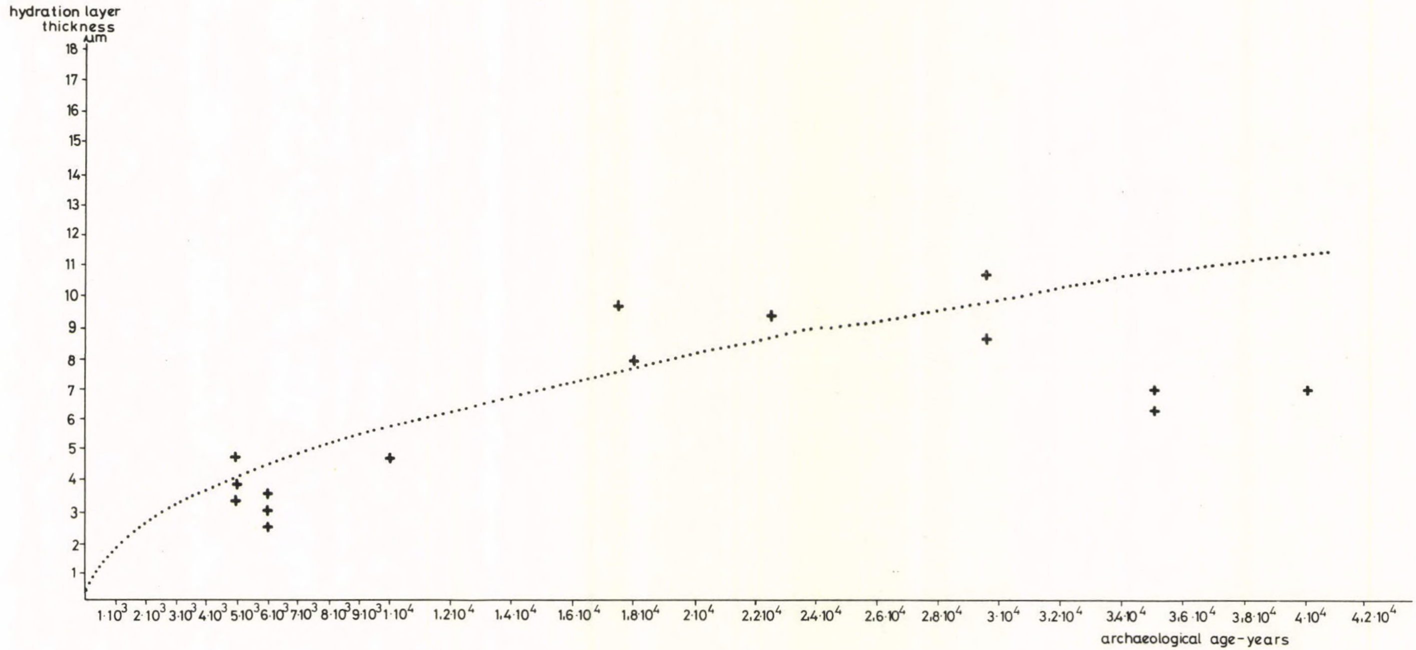


FIG.3: Hydration rate of the Carpathian obsidians

THE MOST TYPICAL LOESS PROFILES IN HUNGARY

PÉCSI, M.

REGIONAL DISTRIBUTION OF THE MAIN LOESS VARIANTS

Due to Hungary's situation in the Carpathian Basin, several variants of loess and loess-like deposits /loess formation/ can be found.

1. The so-called "infusion loess" /alluvial loess/ is the most widespread on the Great Hungarian Plain, covering mainly the alluvial fan surfaces only a few metres above the flood-plains of the rivers without valleys /MAP 1, FIG.1/.

The present-day surface soils are meadow chernozems, different types of meadow soils, alluvial and salt affected soils. Below the profile of steppe, or meadow type soils, the 1--2 m thick "yellow earth" exhibits loess-like characteristics. In some places it is only o.5 m thick, while in other areas it may reach a thickness of 3 m.

The genetic interpretation of the loess-like deposits on the Great Hungarian Plain was a subject of discussion and of frequent debate among Hungarian specialists during the past hundred years. Recently the study of several loess profiles on the Great Hungarian Plain including the one at the Hódmezővásárhely brickyard /MÁRTON,P. - PÉCSI,M. - SZEBÉNYI,E. - WAGNER,M.198o/ enabled us to arrive at the conclusion that the widespread "infusion" loess blanket on the plain may be classified in terms of deposition as loess silt: as a result of meadow or chernozem soil formation it has acquired a loess structure by diagenesis to a depth of 1,5--2 m.

The lithological composition of infusion loesses is diverse, they are compact and loamy at certain spots or loose and sandy at other places, though their calcium carbonate contents are usually significant /1o--2o%/. The interstratified and buried floodplain soils /FIG.1/ are loamy with less calcium carbonate /5--1o%/.

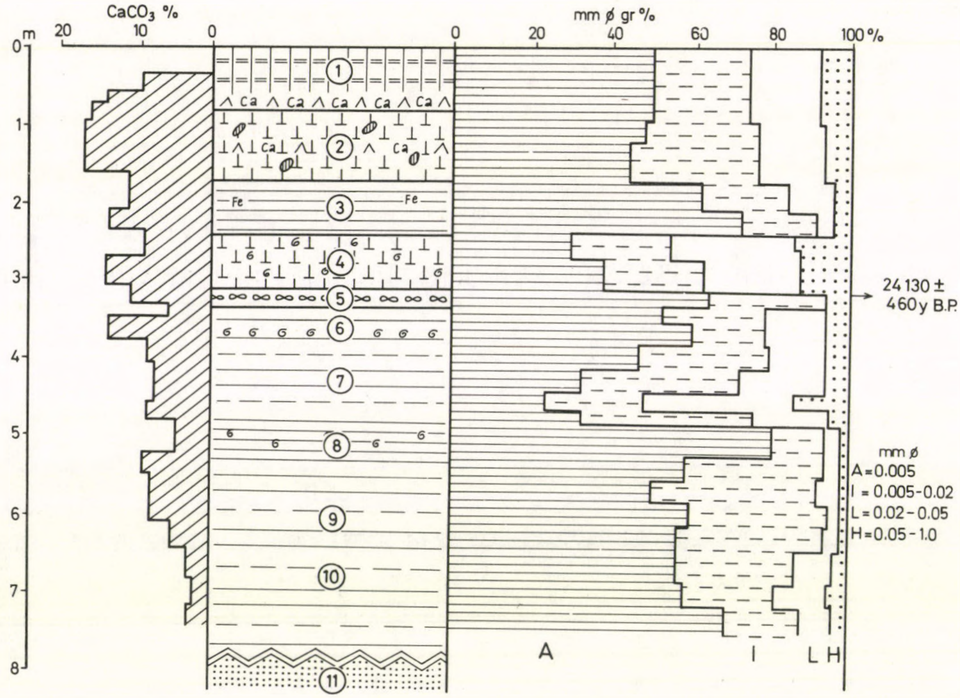


FIG.1: Lithological profile of infusion loess /lowland loess at Hódmezővásárhely /PÉCSI,M. - SZEBÉNYI,E./

1 = dark coloured, compact meadow soil very rich in humus aggregates, plant remains, Fe aggregates, shell fragments with small $CaCO_3$ concentrations at the bottom; 2 = yellow, brownish yellow, silty clay with an "infusion loess" structure, small carbonate concentration, many shell fragments at the bottom; 3 = light and dark coloured ochre-grey, gleyed clay, shell fragments, carbonate concentrations, Fe and Mn nodules; 4 - variegated silty clay, intensive Fe precipitation at the bottom, very many molluscs in structure similar to "infusion loess"; 5 - caliche horizon in gleyed silt; 6 - grey stratified silty clay; at 3.oo m there is a horizon with Mn precipitation - above which there are many marsh molluscs /predominantly Stagnicola palustris/ /Molluscs for radiocarbon analysis were collected from this layer/; 7 - rhythmically alternating thin layers /few cms/ of silt clay and fine sand; the finely stratified layers are near horizontal, without interruptions; 8 = grey, compact gleyed clay with molluscs; 9 = variegated gleyed clay, Fe and calcium-carbonate concentrations, Fe and Mn nodules, shell fragments; lo = stratified variegated clay with silt layers that contain mica, Fe concentrations and Mn nodules; 1 - greyish-yellow medium-grained alluvial sand with mica. Cyclic changes in stratification characterize the whole profile.

On the basis of the radiocarbon dates determined in the Helsinki University Laboratory and supposing that the rate of sedimentation had been around 2ooo m per year we may conclude that the deposition of infusion loesses probably occurred 18--24 ooo years B.P. The radiocarbon age of molluscs collected from the silt layers situated at 2--4 m in some brickyard exposures.[+] The latter data and the mollusc and vertebrate fauna remnants found earlier /HORUSITZKY,M.19o3--19o6/ indicate that the "infusion loess" /"lowland loess"/ was formed during the maximum of the last glacial /Würm/. Fluvial sand or sandy silt embedded regionally in its direct base.

2. Unlike the above cited thin "lowland loesses" there is a rather thick loess blanket in <u>hilly regions</u> and foothills heavily dissected by valleys. Numerous lithogenetic variants of this so called hilly loess are known. The different variants are well subdivided not only horizontally but also vertically within a section. Loess, loess-like deposits, stratified sandy loesses, sands and fossil soils are alternating. Approaching the marginal region of the Carpathian Basin, brown loess-like loam is found to be more and more dominant, mainly to the west /the foreland of the Eastern Alps/ /MAP 1/.

On hilly regions /Transdanubian Hills/, and especially on the hillslopes and in smaller valleys the so called "<u>valley loess</u>" is characteristic. They are stratified parallel to slope and are recently named "<u>derasional loess</u>". They typically occur on the slopes of derasional valleys /dells, balkas/, or they fill up and cover former derasional valleys or even smaller erosional ones. Despite the occurrence of several fossil soils, the sequences of the exposures have very different subdivisions depending mostly on the topographical configuration.This explains the difficulty in allocating typical loess exposures. The 5--2o m thick sequence of the hilly loesses belongs to the so called young loess series.

Loess formation on foothills is usually not older than the last glacial /FIG.2 the Veszprém exposure/, sporadically it is formed of 1o--2o m thick, quite young, stratified, sandy, detrital derasional loess /FIG.3/.

The sporadically preserved old loess section can be studied only at a few exposures, because the Transdanubian Hills are covered by the young loess blanket to a thickness of 5--25 m /FIG.4/.

+

Hel - 12o3 Hódmezővásárhely 24 13o±36o y.B.P. δ ^{13}C-8.o per cent O
Hel - 12o4 Törökszentmiklós 2o 1oo±33o y.B.P. ^{13}C-9.5 per cent O
Hel - 12o4 Mohács 21 52o±35o y.B.P. ^{13}C-8.5 per cent O
Hel - 12o6 Tiszaföldvár 17 1oo±24o y.B.P. ^{13}C-6.3 per cent O

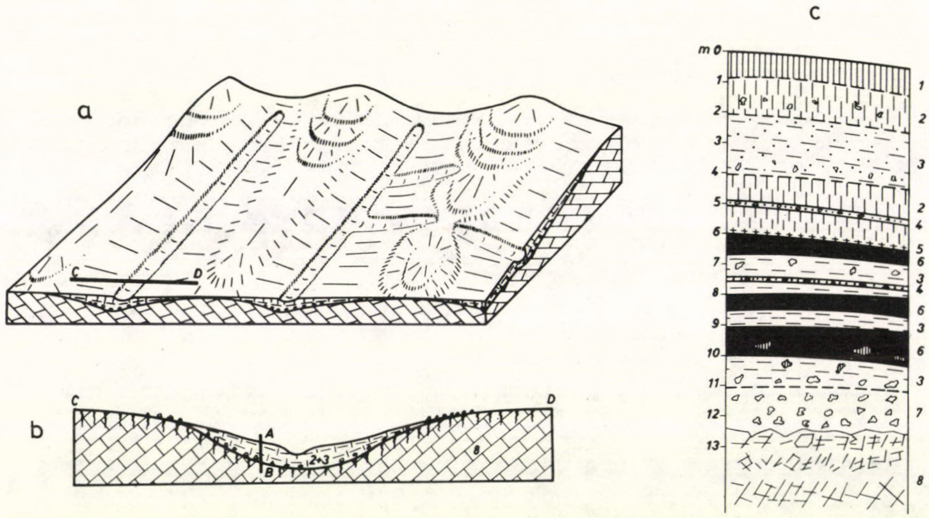


FIG.2: Young loess in derasional valley one type of "valley loess" or "derasional loess" /near Veszprém/

a = Pediment on dolomite transformed by cryoplanation, dissected by derasional valleys;
b = cross section of a derasional valley /dell/ filled up by slope loess , dolomite debris /derasional loess/;

c = lithological profile of derasional valley loess;

1 = chernozem; 2 - slope loess with dolomite debris; 3 - rhythmically stratified sandy slope loess; 4 = weak unconformity indicated by dolomite debris in loess; 5 = slope loess with numerous charcoal fragments Pinus sp., Pinus silvestris, Larix-Picea and Pinus Cembra; 6 - fossil soils /F_1,F_2,F_3/ chernozem-like soils, F_3 partly reworked, fossil soil F_2 with many charcoal fragments of the ^{14}C date: 26 35o±31o years, Lab.H.V.1777. 7 = dolomite series; 8 = dolomite, intensely altered and comminuted near its top.

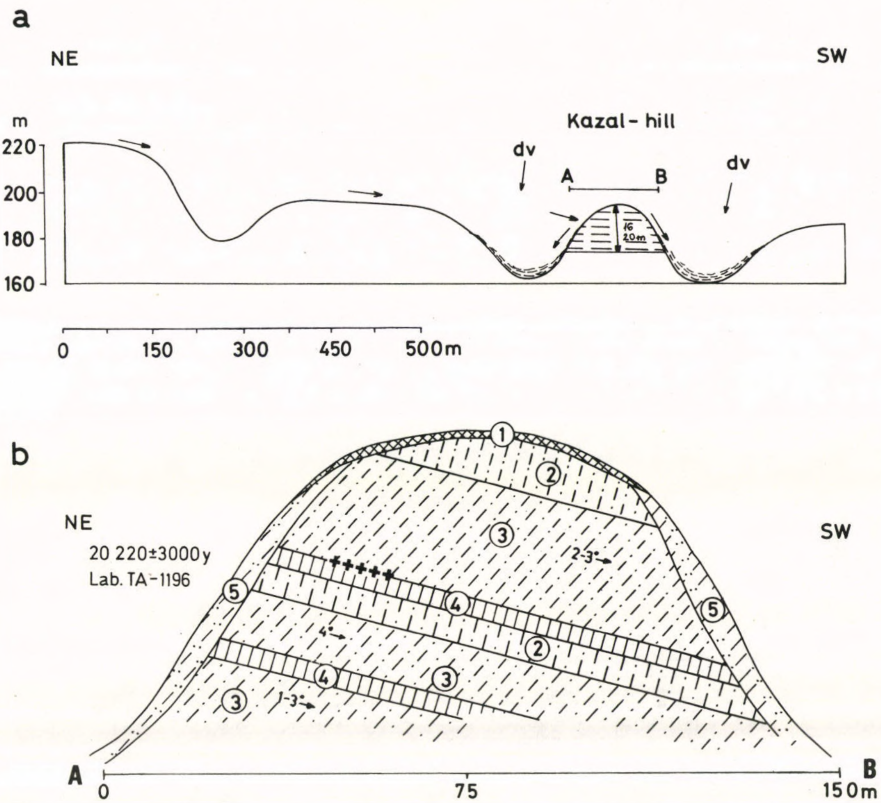


FIG.3: Youngest loess /derasional slope loess/ in foothill position /at Lovasberény/
a = surrounding of the isolated loess hill ridges and the direction of material transport /→/; dv = derasional valleys; b = cross section and lithological profile of a loess hill; 1 - recent soil, brown forest soil; 2 - derasional sandy slope loess, weakly or non-stratified, homogeneous as typical of loess; 3 = rhythmically stratified sandy slope loess, repeatedly intercalated thin layers of medium grained sand or fine silt· 4 = weakly developed humus soil, with numerous charcoal fragments, radiocarbon determination: 2o 22o±3oo y.B.P.Lab.TA-1196; /ILVES,E. - PÉCSI,M. - SEREBRJANY,L.198o/; 5 - youngest slope loess developed during or after the /dv/ derasional valley formation.

The parent material of the whole loess hill of Kazal deposited later than 2o ooo years B.P. /probably during the /maximum/ pleniglacial of Würm.

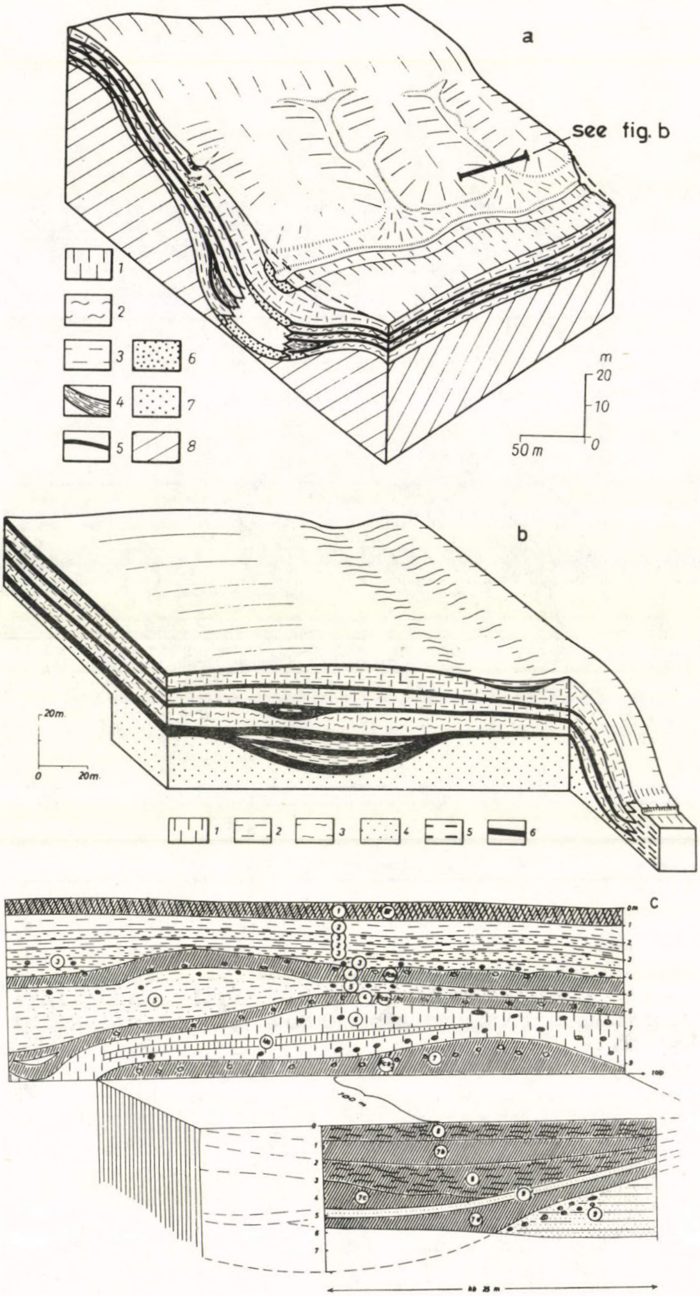


FIG. 4: Young loess in hilly region

a/ = Geomorphological position of the sequence of derasional slope loess. 1 = slope loess, non-stratified; 2 = rhythmically stratified, intercalated into No.1; 4 = reworked solum and loess, i.e. stratified semipedolith; 5 = fossil soils, usually dark steppe soils; 6 = fine sand; 7 = medium-grained sand; 8 - old loess or Pannonian sandy, clayey formation;

b/ Stratification of derasional type of valley slope loess/near Kaposvár/. 1 = slope loess;2--3 = stratified slope loess and sandy loess intercalated into No 1; 4 = sand, mainly fluvial; 5 = muddy, silty material on the bottom of the valley; 6 = fossil soils, partly semipedolith.

c/ Lithological profile of valley loess at Kaposvár. 1 = Grey brown podsolic soil; 2 = weakly stratified slope loess; 3 = stratified slope loess, locally with krotovinas; 4 = fossil soils, chernozem-like with numerous krotovinas; 4/a = humic loess; 5 = stratified sandy slope loess; 6 - pale yellow typical loess /non-stratified/; 7 - well developed dark fossil soil, chernozem-like with many krotovinas /animal borrows/; 7/b, 7/c, 7/d = autochtonous chernozem-like soils; 8 - soil sediment, loess and chernozem semipedolith; 9 = stratified sand, with remnants of Coelodonta antiquitatis, probably Riss-Würm, Early Würm/;

This young loess profile developed during the last glacial /W/.

3. In Hungary, lithologically, stratigraphically and chronologically significant and typical loess exposures occur on river terraces and on old, sandy alluvial fans.

In a favourable geomorphological situation almost the whole young loess series is preserved along with 4--5 well-developed fossil soil complexes on the second floodfree terraces of the Danube and some of its tributaries.

The basis, chosen for the subdivision of the Hungarian /last glacial/ young loess is supplied by the profiles presented in FIG.5 and FIG 6. These are the stratotypes of young loesses as well /PÉCSI,M.1965, 1975, PEVZNER,M.A., PÉCSI M.198o/.

The thickest, the best subdivided loess exposures and the stratotypes of old loess series of Hungary can be found in the Danube Valley in the Hungarian Great Plain /FIG.7,8,9,1o,12/.

The loess bluff of the meso-region "Mezőföld" borders the broad flood-plain of the Danube. The Mezőföld is situated 4o--6o m higher than the flood-plain. It is an alluvial plain covered by loess and sand. The alluvial fan was formed by smaller streams, flowing with alternating intensities both in space and time, from the Transdanubian Mountains via the Mezőföld, to the Great Plain. The oldest deposits of the alluvial fan can be dated from the beginning of the Lower Pleistocene /the type locality

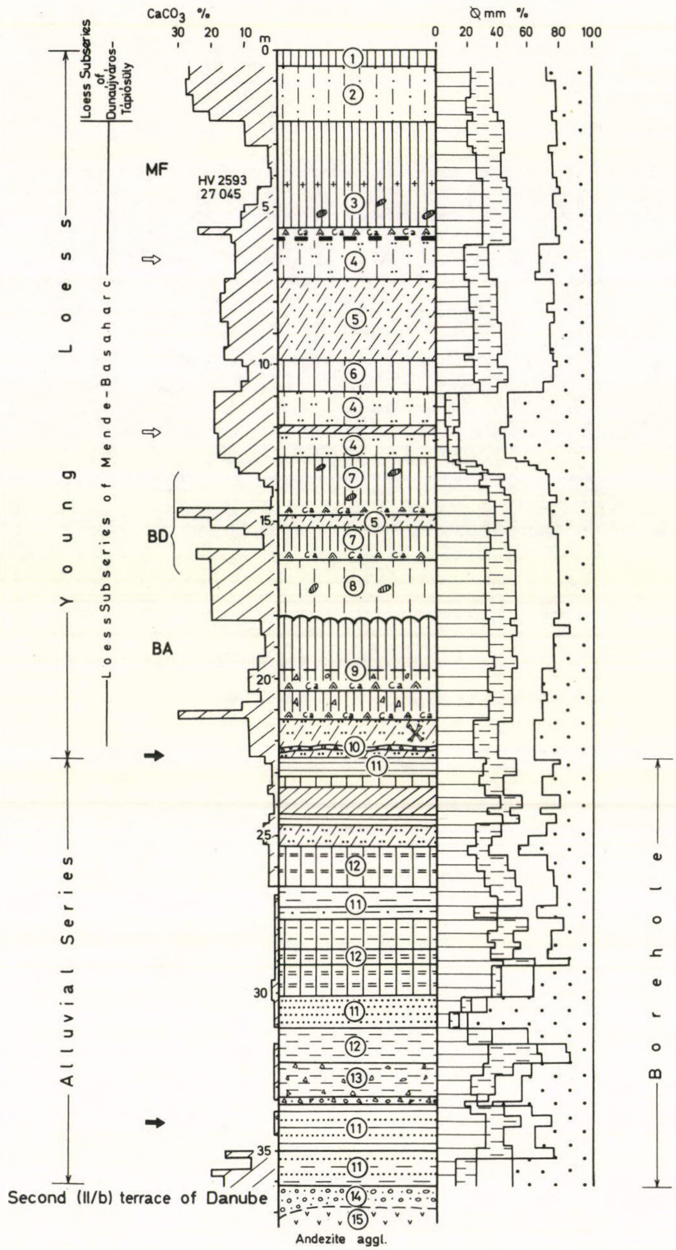


FIG.5: Young loess profile situated on the second terrace /II/b/ of the Danube /Basaharc brickyard near Visegrád/

1 = recent soil, brown forest soil; 2 = sandy loess; 3 - dark, fossil soil complex, upper part probably soil sediment /forest-steppe-like soil complex/, in the middle part of the soil B horizon numerous charcoal fragments occur /radiocarbon date 27 o45± 88o y.B.P.Lab.HV 2593/ The age of this soil complex is similar to be the same as the stratotype's; 4 = sandy loess, loessy sand; 5 - sandy slope loes; 6 - weak humus horizon with charcoal fragments; 7 = stratotype of "Basaharc double" soil complex /BD_1,BD_2/ /forest-steppe-like soil complex/, in the BD_1 fossil soil numerous charcoal fragments occur /radiocarbon date 32 loo±72o y.B.P. min.age /Lab.H V 8116/; 8 = loess with krotovinas; 9 - stratotype of "Basaharc lower" fossil soil /forest-steppe character/, below that a complete skull of an Ursus spaeleus minor was found; lo = slope loess with unconformity caused by andesite debris; 11 - alluvial /sandy/ clay, silty sand, sand; 12 - alluvial hydromorphic soils, gleyed clay; 13 - gleyed clay mixed with andesite slope debris; 14 = terrace gravel of the Danube; 15 = altered andesite agglomerate.

of the Kislángium fauna belonging to the Upper Villányium is in the Mezőföld/. Pliocene, Upper Pannonian sandy and loamy formations lie in the base of the alluvial fan or loess series. Their position is uneven: in some places they lie at the middle water level of the Danube, in others: deep below or high above it.

The 5o m loess exposure of the Paks brickyard has been studied for the longest time, and has obtained much reputation in the Quaternary literature. However, here, the exposed profile does not reveal the lowermost part of the old loess series. These latter can be well studied at the Dunaföldvár exposures, 2o km north of Paks. The documentation of the loess exposures and borehole profiles around Paks and Dunaföldvár has provided important information on not only the loess-stratigraphy of Hungary and Europe, but also on the paleogeography of the Quaternary.

Owing to the summarizing nature of our paper, the subdivision of the profiles mentioned above is not presented individually but together by characteristic loess subseries.

LITHOSTRATIGRAPHICAL SUBDIVISION OF THE HUNGARIAN LOESS FORMATION

The Hungarian loess formation may be subdivided into two distinct units of the "young loess" and the "old loess" series, based on lithological characteristics.

- The lo to lo m thick slightly compacted young loess is rich in calcium carbonate and is usually interrupted by chernozem-like dark-brown fossil soils. The ratio of sand fraction increases towards the top of the series.

- The old loess is more compact and contains less calcium carbonate, although the rhythmic layers with carbonate concretions /loess Kindchen or loess dolls/ are common even within a single loess packet. Often interbedded in the loess are fluvial sandy layers and alluvial, paludal soils. Reddish-brown and ochre-red fossil soils predominate.An altered loamy variant of the old loess is also present.

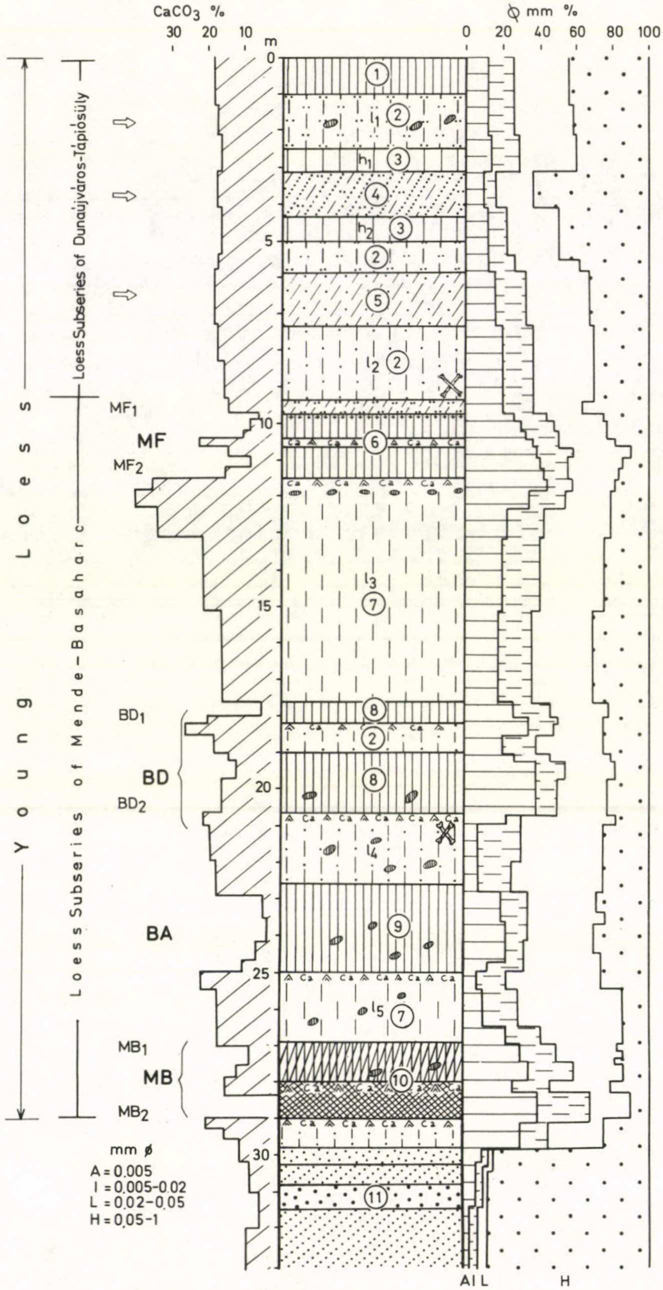


FIG.6: Typical locality of the young loess profile at Mende /near Budapest/ /PÉCSI,M. - SZEBÉNYI,E.1971/

1 = recent chernozem, locally chernozem and brown forest soil /two story profile/ 2 = sandy loess, in the l_2 loess a whole skeleton of a young Mammuth was found; 3 = weak humus horizon /with charcoal/; 4 = stratified loessy sand at the lower part reindeer bone remnants occur; 5 = stratified sandy slope loess; 6 - stratotype of Mende Upper /MF/ soil complex, it is a two-story profile of forest-steppe soil. In it upper part /MF_1/ there are many charcoals fragments /Picea, Larix, Pinus Cembra/ radiocarbon date: 29 8oo ± 6oo Lab.No.Mo 422; 27.2oo ± 14oo Lab. No.I. 313o; 27.855 ± 1589 Lab.No.Hv.5422. The Cca horizon of MF_2 is rich in lime and carbonate concretions; 7 = typical loess, but in the lower part these is a little more sandy loess; 8 = "Basaharc double" soil complex /forest-steppe-like fossil soil/ below the BD_2 there are the remnants of Elephas primigenius; 9 = Basaharc lower" fossil soil /BA/ locally the uppermost part soil sediment; lo = stratotype of Mende Base /MB/soil complex, the upper part /MB_1/ is a dark steppe-like /chernozem-like/ fossil soil; the lower part /MB_2/ is a well-developed; 11 = alluvial, proluvial sand at the Tápió brook /second terrace/; the Mende Base soil complex developed probably during the second half of the Riss-Würm interglacial, because the alluvial sand below that cca 125 ooo years old according to the thermoluminescence data /BORSY,Z. - FÉLSZERFALVI,J. - SZABÓ,P.P.198o/.

- Exposed in a few sections, at the base of the old loess, at Dunaföldvár and Paks are finely stratified pink sandy silts, sand and yellow silt layers underlain by red clay soils and gleyed clays. These latter ones cannot even be named loess,named mottled, gleyed-reddish-clay formation.

THE YOUNG LOESS AND ITS FOSSIL SOILS+

From among the sections that have been examined, we found the ones at Basaharc, Mende, Dunaujváros and Tápiósüly to be the most characteristic and suitable for the stratigraphic subdivision of the young loess and for the correlation of their fossil soil.

1/ The Dunujváros-Tápiósüly subseries the upper part of the young loess

The most complete subseries of the young loess known so far is a lo m thick loess sequence made up of sandy loess and loessy sand strata. In between these there are only two or three light grey coloured embrionic humus soils /l_2,h_2/. Above the first typical humus soil horizon there is a layer, only a few cm thick, in which charcoal remnants of Pinus cembra and Larix were found. Their age has been fixed as 16 73o ± 4oo years B.P. by radiocarbon analysis. The occurrence on a regional basis of the layer with remnants of charcoal in it and traces of burning in the loess in some places seem to indicate extensive

+The "Studies on Loess" proceedings, published by the Hungarian Academy of Sciences in Budapest, 198o, is recommended for those who are interested in the evaluation of loess exposures mentioned above.

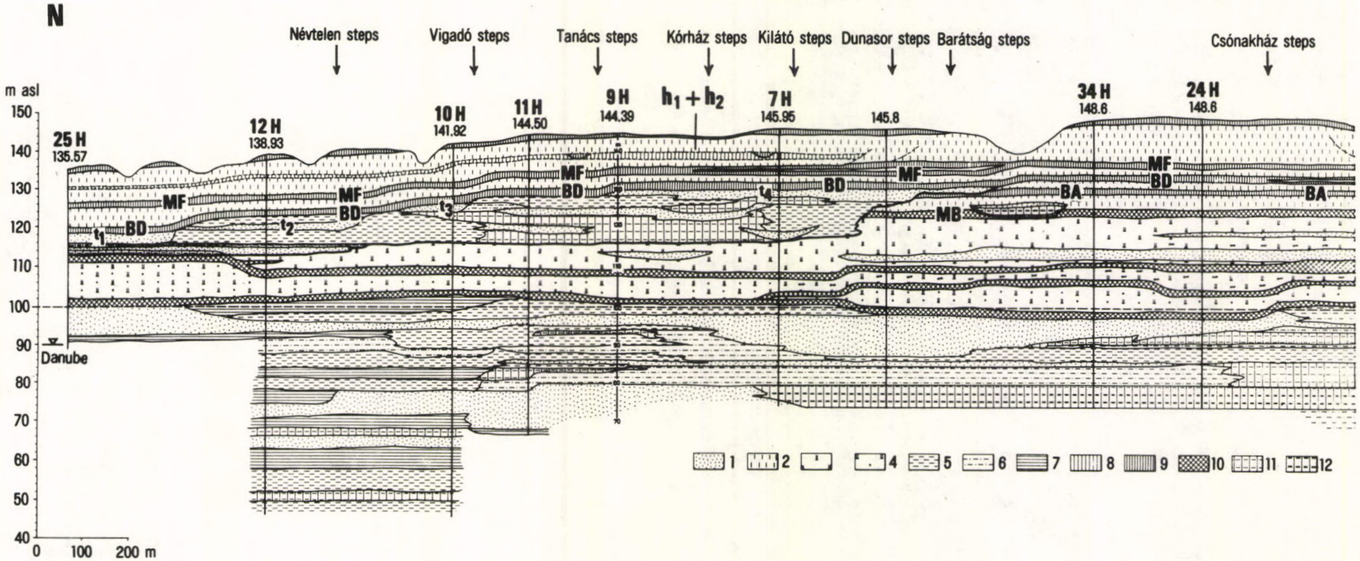


FIG.7: Young and old loess profile along the raised river bank of the Danube and Dunaujváros /PÉCSI, M. - SZEBÉNYI, E./
1 = alluvial sand occurs in different lithostratigraphical positions, the lowermost sand probably belongs to the Upper Pannonian formation; 2 = young loess; 3 = old loess situated on ancient alluvial fan; 4--5 = alluvial silt, silty clay; 6 = sandy silt; 7 = clay; 8 - embrional humic soil /h_1,h_2/ in the h_2 humus horizon, situated cca lo metres below the present soil numerous charcoal fragments occur locally, radiocarbon date: 2o 52o$\pm$29o Lab.No.HV.2591; 9 - dark steppe-like soil /chernozem-like/; lo = brown forest soil, red soil /red clay/ the lowermost one; 11--12 - alluvial hydromorphous soil, meadow soil;

MF. Mende Upper fossil soil; BD. Basaharc double fossil soil; BA. Basaharc lower fossil soil; MB Mende Base fossil soil complex; PD Paks double soil complex; t_1-t_4 alluvial fan terraces of a tributary of the Danube buried by young loess; 7H. hydrogeological borehole.

forest fires. These could either be due to natural causes or may be attributed to the reindeer harding activity of prehistoric man living in the Magdalenian Period.

The 2 m thick loess layer overlying the one with charcoal remnants sporadically though but a great number of fragments of the Rangifer tarandus' shovels.

The age of the second humus soil horizon has been correlated with various other sites and can be given as 2o--22 ooo radiocarbon years. The "Dunaujváros--Tápiósüly subseries" is complete with the sandy loess found below the second humus horizon. This layer frequently contains mammoth bones and sometimes whole mammoth skeletons were also found /FIG.3/. This subseries is the most widespread. It was formed in a paleogeographical environment that was dominated by cold-dry loess steppes with patches of coniferous forests, characterized by animals living in cold forest-steppes and steppes.

2/ The lower part of the young loess /The "Mende-Basaharc" subseries/

This loess subseries is about 2o--25 m thick and consists of four soil horizons and three loess packets enclosed by them /FIG.6,7/.

Immediately below the Tápiósüly subseries lies the "Mende upper" soil complex /MF/, which is a double soil horizon. The upper part is a poorly developed chernozem-like soil with "krotovinas" and charcoal remnants. The age of these remnants is 28--29 ooo /radiocarbon/ years. The lower layer is a well-developed chernozem soil; the age of the charcoal fragments found here is 32 ooo radiocarbon years. The "Mende upper" double soil represents either the youngest interstadial of the Mid-Würm or the uppermost part of a short interglacial "warm period" within the Würm.

In the middle of the Mende-Basaharc subseries there is a chernozem-like forest-steppe soil horizon. It has been named the "Basaharc double" soil /PÉCSI,M.1965,1966/ and is very significant from both paleogeographical and stratigraphic points of view. This corresponds to the lower part of the interglacial of the Mid-Würm stage.

The third buried soil of the Mende--Basaharc subseries is the "Basaharc base" soil /BA/. It is a remarkably well-developed chernozem fossil soil horizon which is 1.5 m thick. The absolute age can be given as 65 ooo years, and it represents an interstadial within the Lower-Würm stage. The skull of Ursus spaeleus was found in the upper horizon of this soil.

The "Mende Base" soil complex /MB/ found at the base of this series is made up of two completely different soils. The upper solum /8o--1oo cm/ is a steppe-type chernozem soil, and the lower part /8o cm/ is a well-developed brown forest soil /Braunerde, Parabraunerde/. This double soil was dated as having formed during the last /Riss-Würm/ interglacial /PÉCSI,M.1965,1975/.

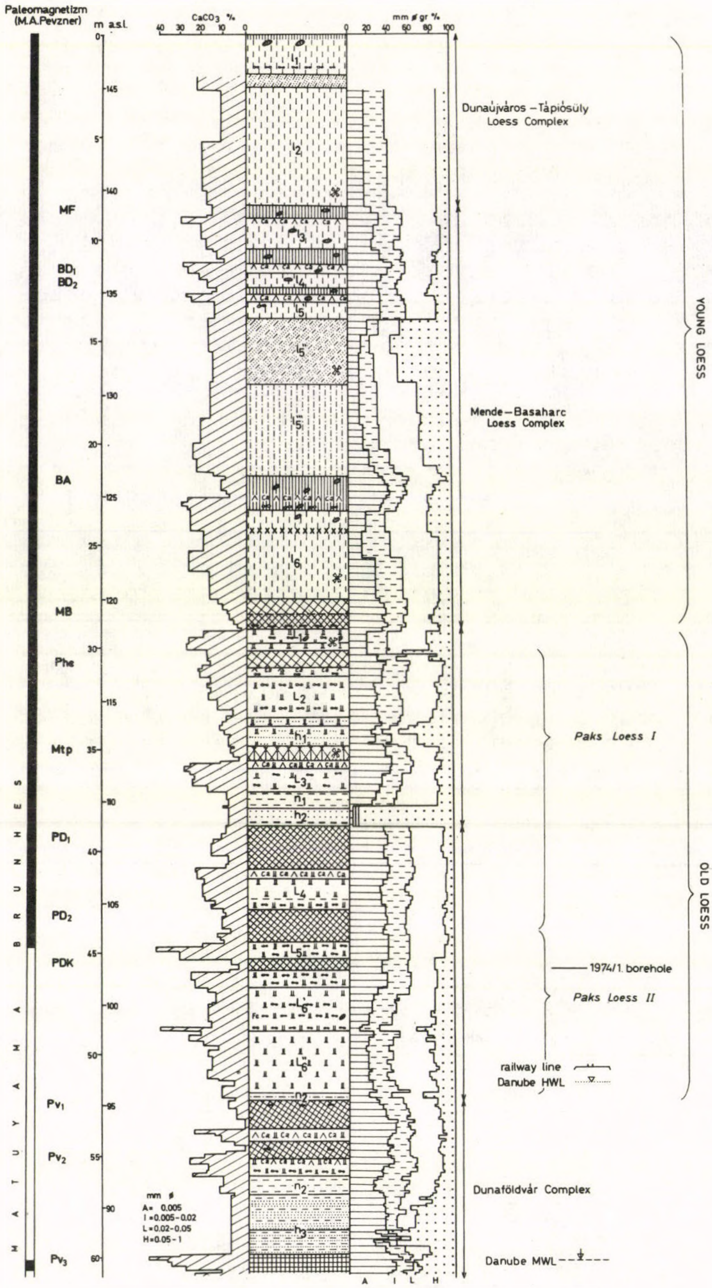


FIG.8: Lithostratigraphical subdivision of the old and young loess-formation at Paks

The lithological and pedological analysis made by PÉCSI,M. and SZEBÉNYI,E., the paleomagnetic measurements made by PEVZNER,M. A.,/Institute of Geology Acad.of Sci.USSR,1974/.

l_1,l_2 = the typical youngest loess beds of the profile; between l_1, l_2 deposited sandy slope loess in a derasional valley/dell/. the lower part of l_2/+/ fragments of reindeer bones occur as well as locally 1--2 humus horizons;
MF. = chernozem-like fossil soil of "Mende Upper", only the MF_1 remained; l_3,l_4,l_5 = young loess beds, below the fossil soil horizons /MF, BD_1, BD_2/, with many krotovinas in it; BD_1,BD_2 = "Basaharc Double" fossil soil complex chernozem-like locally hydromorphous meadow soil type; l_5'' well-stratified sandy slope loess the loessy sand filled up the derasional valley /with cervus sp. and Elephas primigenous fauna remnants/; l_5''' - sandy loess; BA. = "Basaharc Lower" forest-steppe-like dark fossil soil; l_6. = the lowest young loess bed /with Eleph.primigenius remnants/ with a thin layer of volcanic tufite too in the upper part of it; MB. = "Mende-Base" fossil soil complex; the upper part of it a forest-steppe-like soil and but the lower one a well-developed brown forest soil /according the thermoluminescence analysis of BORSY,Z. et al.198o about 1o5 thousand years old/; L_1 - old loess, sandy loess, with large "loess dolls"; molars, tusks of Elephas trogontherii/ were found on two occasions; Phe = weakly developed sandy brown forest soil; L_2,L_3 - old loess /with 2--3 layers of "loess dolls"/; Mtp = hydromorphous fossil soil /flood-plain, clayey soil/ with Allohippus sp. teeth; h_1,h_2,n_1 = sand and silty clay of alluvial fan; PD_1 PD_2 = stratotype of "Paks Lower Double" fossil soil complex, with krotovinas /Submediterranean xerophile forest soil or chestnut, usually reddish brown/ below the PD_2 fossil soil occurs the Brunhes - Matuyama boundary/; L_4,L_5,L_6 - old loess strata, with "loess doll" layers; L_6 - the lowermost old loess bed, loess dolls rarely occur; n_2,n_3,n_3 - sandy clay, silty clay and sand of alluvial fan; Dv_1,Dv_2,Dv_3 - reddish, ochre-red fossil soils, below the old loess /belong to the "Dunaföldvár formation"/;

In the Mende-Basaharc subseries "the loess packets" /l_3,l_4,l_5/ was found in between the mostly chernozem-like fossil soil horizons /MF, BD, BA/ and the chernozem and brown forest soil complex of the MB, were subdivided on the basis of their lithological characteristics into ana-, /pleni-/ and kataglacial types of deposits /FIG.7/.

The old loess and their fossil soils /The "Paks subseries"/

Old loess in Hungary was analysed in detail in the Paks profile, though similar sequences are also known from exposures along the bluffs at Dunaujváros and Dunaföldvár. The 25 m thick old loess profile was named the "Paks subseries" and it may be subdivided into two parts on the basis of its lithological characteristics /FIG.8/.

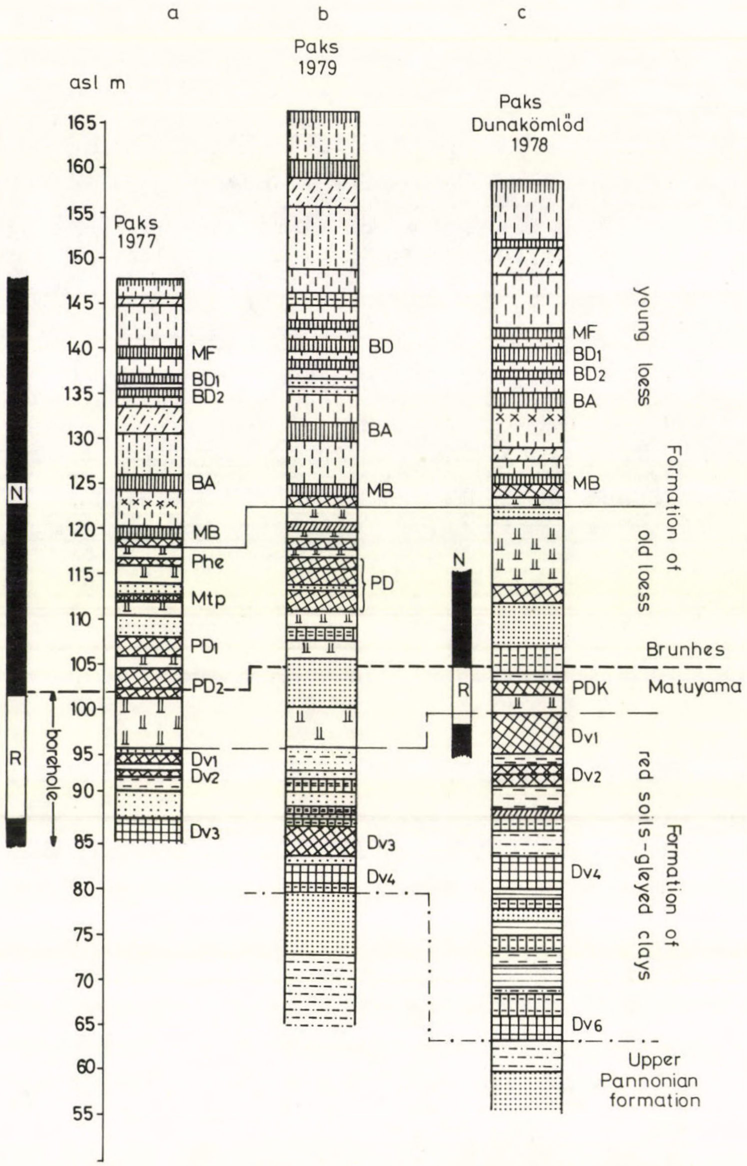


FIG.9: Lithostratigraphical parallelization of the exposures of the Paks brickyards and the borehole-profiles of the loess plateau of Paks
a = Paks brickyard exposure 1977; b = Paks borehole 1979/near the hilltop/; c = Paks-Dunakömlőd borehole 1978.

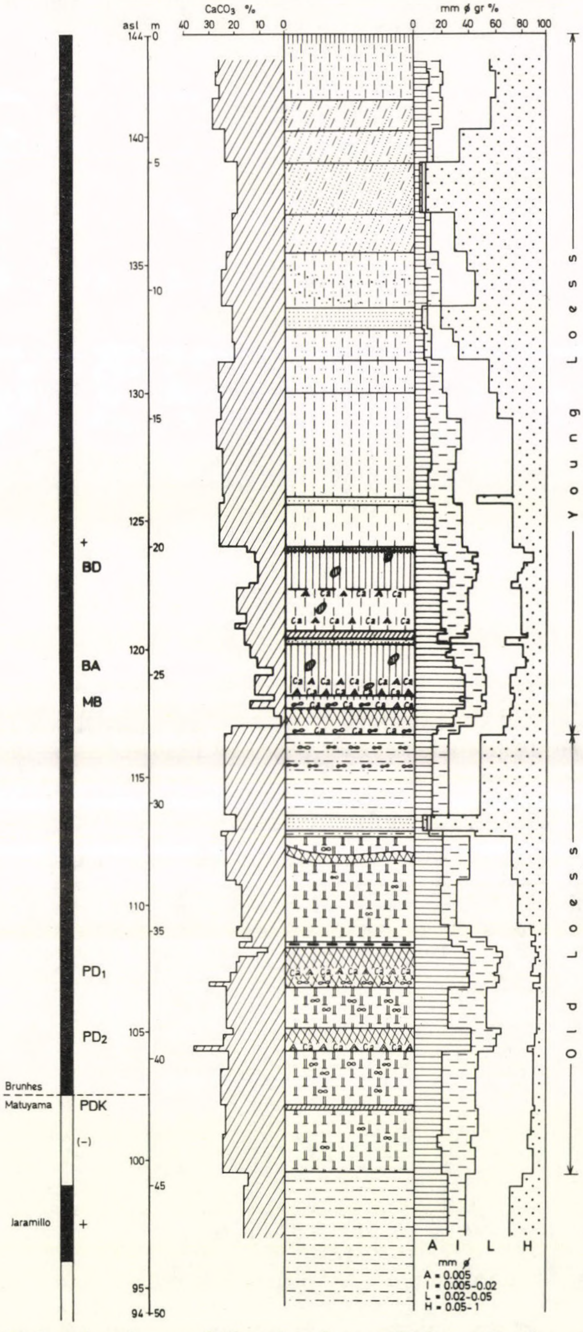
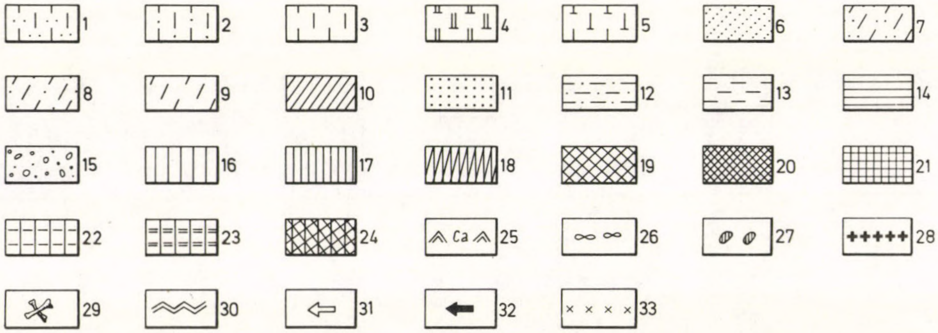


FIG.lo: Lithological, pedological profile of the open exposure at Dunaföldvár No.1. with the paleomagnetic analysis /PÉCSI,M.-SZEBÉNYI,E.-PEVZNER,M.A.
The subdivision and lithological characterization of old and young loess formation see in the text.



FIG;12: General legend to the FIGS of the Hungarian loess-profiles.
1 = loessy sand; 2 = sandy loess; 3 = loess; 4 = old loess; 5 = infusion loess; 6 = slope sand; 7 = loessy slope sand; 8 = sandy slope loess; 9 = slope loess; lo = semipedolite; 11= fluvial-proluvial sand; 12 = silty sand; 13 = silt, gleyed silt; 14 = clay; 15 = sandy gravel; 16 = weak humus horizon; 17 = steppe-type soil, chernozem; 18 = forest soil altered by steppe vegetation; 19 = brown forest soil; 2o = grey-brown forest soil; 21 = red clay; 22 = hydromorphic soil; 23 - alluvial meadow soil; 24 =forest soil /on flood-plain/; 25 = calcium carbonate accumulation; 26 = loess doll; 27 = krotovina; 28 = charcoal; 29 = macrofauna; 3o = discontinuity in profile; 31 = traces of non-linear erosion; 32 = traces of linear erosion; 33 = volcanic ash. MF = "Mende Upper"forest-steppe Soil Complex /29 8oo years B.P., Mo.421 and HV 27 855±599 years/; BD = "Basaharc-Double" forest steppe Soil Complex; BA = "Basaharc-Lower" chernozem soil; MB = "Mende-Base" Soil Complex /brown forest soil + forest steppe soil/; Phe = Paks sandy forest soil; Mtp = Paks marshy soil; PD = "Paks Lower Double" Soil Complex /brownish-red Mediterranean-type dry forest soil/; PDK = Paks-Dunakömlőd brownish-red soil; Pv_1, Pv_2,Pv_3 = Paks red soils; Dv_1 - Dv_6 = Dunaföldvár red soils; A = clay /< o.oo5/; I = silt /o.oo5--o.o2/; L = loess /o.o2--o.o5; H = sand /o.o5--1,oo/

The upper part of the Paks subseries

Fig.8. illustrates that it is bounded by the MB soil above and by the PD soil below. Black arrows indicate several erosional unconformities in these strata. Interlayered with the sand and silty-sand beds is a well-developed alluvial gleyed hydroromorphous, weakly soil /Mtp on Fig.8/. In the middle sand layer a weakly developed brown forest soil"Phe" has formed.

PHOTO 1: Loess exposure of Paks /PHOTO PÉCSI,M./

Fragments of Elephas throgontherii's teeth and tusks were found in 197o /by JÁNOSSY,D./ in the sandy old loess layer ol_1 below the MB soil complex.

The lithostratigraphical sequence in the Paks brickyard section contains hiatuses, and thus the correlation of fossil soils and loessy sandy strata with the classic climatic phases of the Pleistocene and with the chronostratigraphical time scale, becomes very difficult. It is probable, however, that the upper part of the Paks subseries represents the incomplete stratigraphical sequence of the Middle Pleistocene. The loess bed above the PD Soil Complex would then have formed during the Mindel, while the sandy, old loess strata, at the base of the MB soil, is a Riss glacial or stadial formation. The sandy strata inter-leaved with marshy soil /M_{tp}/ would represent the Mindel-Riss interglacial /see ÁDÁM,L.- MAROSI S. - SZILÁRD,J. 1954; KRIVÁN,P.196o, PÉCSI,M. - SZEBÉNYI,E. 1971; PÉCSI,M. - PEVZNER,M.A.1974; PÉCSI,M.1975; PÉCSI et al.1977, PÉCSI,M.198o/.

The lower part the Paks subseries, with the Brunhes-Matuyama boundary

The 15 m thick series consists of three old loess strata interbedded with three brownish-red fossil soils /FIG.8/.

Situated at the bottom of the Paks exposure, the "Paks-Lower" Double Soil Complex /PD/ is made up of two equally well-developed 1,5 m thick brownish-red compact, loamy fossil soils which enclose a 2 m thick loess bed. Calcium carbonate accumulation in the C horizon of both soils is intensive, marked by a layer rich in carbonate concretions, loess dolls. Large krotovinas are typical in the A_2 and B horizons. Genetically, the soils were probably well-developed Mediterranean-type, dry forest soils.

The boundary of the Brunhes-Matuyama paleomagnetic interval /o.73 million years/ was found below the PD Soil Complex at the bottom of the 2 m thick loess layer in both the Paks and Dunaföldvár exposures /PÉCSI,M. - PEVZNER,M.A.1974/.

The 1.5--2 m thick old loess stratum that underlies the PD Soil Complex also has a reddish-brown fossil soil at its base. Samples from boreholes drilled at the foot at the Paks brickyard profile and from exposures in the loess bluff near Dunakömlőd and at Dunaföldvár show that this fossil soil is a single soil horizon. The pedological description of this soil named Paks--Dunakömlőd soil /PDk/, is first attempted by PÉCSI, M. et al.1977. Genetically, the 1,5--2 m thick brownish-red redbrown loamy soil is most likely a Mediterranean-type xerophytic forest soil /FIG.8/.

A 2--3 m thick old loess bed below the Paks--Dunakömlőd soil is the last constituent of the so-called Paks subseries and is at its stratigraphic boundary. Loess strata older than these are not known from profiles in the Carpathian Basin. Similarly in loess sections in Czechoslovakia below the Brunhes-Matuyama palaeomagnetic boundary also only one soil horizon and a single loess packet has been described.

The reddish-brown coloured fossil soils known as the "Paks-Lower Double soils" /PD_1 and PD_2/and "Paks-Dunakömlőd" fossil soil /PD KC/ were presumably formed during the G-M interglacials /Comer 1--3/. The thick lowest stratum of old loess can be correlated with the Günz glacial. The whole "Paks loess" subseries was essentially formed during the Biharium /KRETZOI, M. - PÉCSI,M.1979.

Formation of "mottled, gleyed-reddish clay" below the loess formation+

A non-loessic formation of considerable thickness /2o to 35 m/ underlies the old loess series. It is banded by the above outlined lower part of old loess /Paks subseries/ on top, and by the Upper Pannonian /Pliocene/ lacustrine-marine formation at the base. The "non-loessic" terrestrial formation is basically a mottled, gleyed-reddish coloured clay and silty, sandy clay sequence, we have mainly been studying in sections along the Danube between Dunaföldvár and Paks. In this study we call this

+Some previous publications we called it "földvár complex" /PÉCSI,M.1975, PÉCSI,M. - PEVZNER,M.A.1974, PÉCSI,M.et al.1979/

sequence Dunaföldvár formation, which at the typical locality at Dunaföldvár usually contains /FIG.11./.

- 5--6 m finely stratified, pale-pink coloured, slightly clayey sand, in which some cemented sandstone bed and thin sandstone bed and thin sandstone interbeddings occur rhythmically; below that lies a -3--5 m dark-grey clay meadow soil complex. According to pedological analyses of these meadow soils they have 2--3 per cent of humus, and at their bases the $CaCO_3$ content reaches 4o--6o per cent. The soil profile comprises layers with dolomitic lime concretions too.

The most characteristic part of this formation is the ochre-red soil sequence with a thickness of about 1o--15 m, known from several boreholes at Dunaföldvár /FIG.1o./. 5--6 reddish fossil soils were identified intercalated with gleyed silty-clay beds. The pedological, mineralogical and other characteristics of red soils have been detailed previously /PÉCSI,M.et al. 1979/.

From among the red soils No 3,4,5 and locally 6 had undergone intensive weathering. It is also characteristic of these soils that their calcium carbonate content is extremely high in the B_2 and C_{oa} horizons of the soil profile. Hence it may be supposed that the red soils in the "Dunaföldvár formation" are remains of a xerophyl forest soil formed during a Submediterranean-type climate.

- 5--6 m gleyed clay and sandy clay at the lower part at the Dunaföldvár formation sandy layers had been intercalated repeatedly. In the sandy layer at the bottom, a few decimetres thick black clay was found.

These dark grey gleyed clay beds and the meadow clay soil complex lie above the red soil sequence, developed probably during some cooler climatic phases.

Based on the paleopedologic, lithostratigraphic and paleomagnetic data /see also KRETZOI,M.et al.1982 in this volume/ it may be supposed that the development of the "Dunaföldvár formation" had begun long before the Gauss epoch - it can be probably dated as far back as the early Gilbert. The deposition of the youngest bed, the pale-pink silty sand, was probably completed immediately after the Jaramillo event.

From a lithostratigraphical and paleopedological point of view the Dunaföldvár "non-loessic" series may be distinctly diffeentiated, from the old loess subseries at Paks. This marked stratigraphical boundary, - in our conclusions - probably represents the boundary between the Eopleistocene and the Lower Pleistocene. /The Dunaföldvár Subseries would then be the stratigraphic representation of the Villányium-Csernotanum according to KRETZOI,M./.

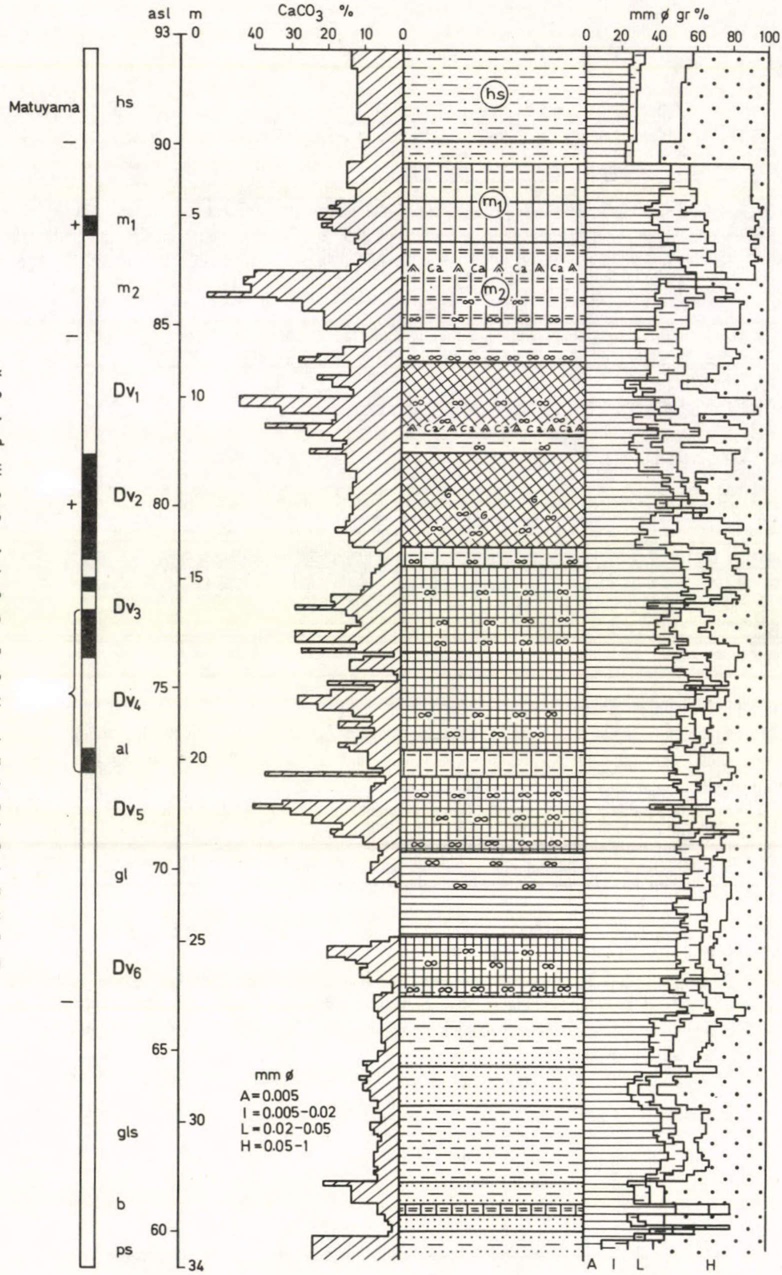


FIG.11: Stratotype of mottled, gleyed clay, red clay and silt formation below the old loess at Dunaföldvár /Dunaföldvár formation/ /Compiled by PÉCSI,M. - SZEBÉNYI,E. - SCHWEITZER F.and the paleomagnetic analysis made by PEVZNER,M.A./

The lithological units of Dunaföldvár formation are the following:
hs - pale pink coloured sandy silt, silty sand with sandstone concretion; m_1, m_2 = dark meadow soils, intercalated by gleyed clay; Dv_1, Dv_2 = reddish sandy clay; Dv_3 - Dv_6 = ochre-red and red clay soils; one or two pick of carbonate accumulation occurs in the middle of B_2 horizon; very characteristic the horizons of $CaCO_3$ concretions, where the lime content are less; al - gleyed alluvial clay soil; gl - gleyed clay; gls - gleyed sandy clay; b - black clay; ps - Upper Pannonian sand.

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LOESS AND LOESS-LIKE SEDIMENTS OF FLUVIAL ORIGIN IN THE SOCIALIST REPUBLIC OF CROATIA AND THEIR SIGNIFICANCE IN THE INVESTIGATION OF RIVER TERRACES

BOGNAR, A.

In the superficial deposits of the alluvial plains of the largest part of inland Croatia, loess and loess-like layers predominate /approximately lo ooo km^2/, which, with regard to structural and textural characteristics, differ considerable from the loess deposits of the loess plateaux, glacis regions, foothills and higher, better drained fans. In the Yugoslavian scientific literature these sediments had been separetely referred to as "march" or "terrace" loesses of eolian origin, which resulted from "loess sedimentation" on to a primarily moist base. Our recent investigations, however, have indicated that this explanation does not correspond to the real situation. For this reason, therefore, we consider it useful to present the results of our investigations in an abbreviated form in order to contribute to the more detailed study of the Pleistocene deposits in our Republic.

DISTRIBUTION

Loess and loess-like sediments of fluvial origin prevail in the superficial structure of the younger würmian terraces of the Drava and Sava /BOGNAR, A. 1974 and 1977/, and Danube rivers /PÉCSI, M. 1972/, of the older Holocene terraces of the Drava and Sava /the so-called redeposited loess, BOGNAR, A. 1974 and 1977/, and on the higher flood-plain levels of the Drava, Sava and Danube rivers. Although with regard to the manner of primary material accumulation these sediments do not greatly differ distinctions can be made as to the time of sedimentation and diagenesis from their structure, textural characteristics, and the ration of $CaCo_3$ content. The Pleistocene loess and loess-like sediments of fluvial origin /which by their distribution are linked exclusively to the younger würmian terraces, should be distinguished from the Holocene loess-like sediments of fluvial origin/ which run through the superficial structure of the older Holocene terraces and the higher flood-plain levels. In particular apart from colour, granulometrical structure and some micro-layer properties, they do not show much similarity with the fluvial loess of the younger würmian terraces and can only therefore be in a very general sense. Since the fluvial origin of these layers does not appear to be in dispute, however, the rest of this paper will deal exclusively with the characteristics and genesis of the loess and loess-like Pleistocene sediments of the younger würmian terraces.

ORIGIN

On the basis of the geomorphological characteristics of the younger würmian terraces of the rivers Drava, Sava and Danube in Croatia, and the characteristics of the lithostratigraphic-profiles of the associated loess and loess-like deposits,which predominate in the superficial structure, the following would seem to be of fluvial origin for these deposits /Fig. 1./.

1. The typical fluvial stratification of the sands in the profiles and their gradual transition into loess and loess-like layers, marked by a frequent alternation of this strata of fine sands and clayey-loams in the contact zone, is a very good indication that the primary material was deposited by running water. It should be also mentioned that no trace of erosional or denudational discordance was found in any of the investigated profiles. This is also indicated by a gradual reduction in medium sand grain size to one according with the so-called "loess structure" as one moves from the base of the profiles upwards.

2. The "loess structure" is found only in the superficial parts of the loess complexes to a depth of approximately 1--1,5 m. In this part of the lithostratigraphical profile mean grain size increases and the stratification, which is usually characteristic of the lower parts of the loess comlex is absent. Primary stratification ceases here because the formation of a carbonate envelope around silicate silts and aggregates with carbonate cementation increases grain size /BERG, L.S. 1947/ and this undoubtedly supports the hypothesis of diagenesis as a basic development factor in the development of a so-called "loess structure".

3. The increase in the pelitic and silt fractions towards the surface of the loess and loess-like deposits also points towards a decrease in fluvial influence in the morphological formation of the higher flood-plains. By this time, the amount of depositional accumulation together with the erosional action of the river current, had increased the relative height of the flood-plain, which in turn diminished the possibility of sedimentation of sand fractions. This is understandable as the transporting power of a flood wave is very small on the higher parts of a flood-plain and consequently only the finest particles are deposited there. At the same time, however, the relatively high percentage /1o--3o%/ of fine sand fractions in the granulometrical structure of the loess and loess-like deposits also supports the theory of their fluvial origin.

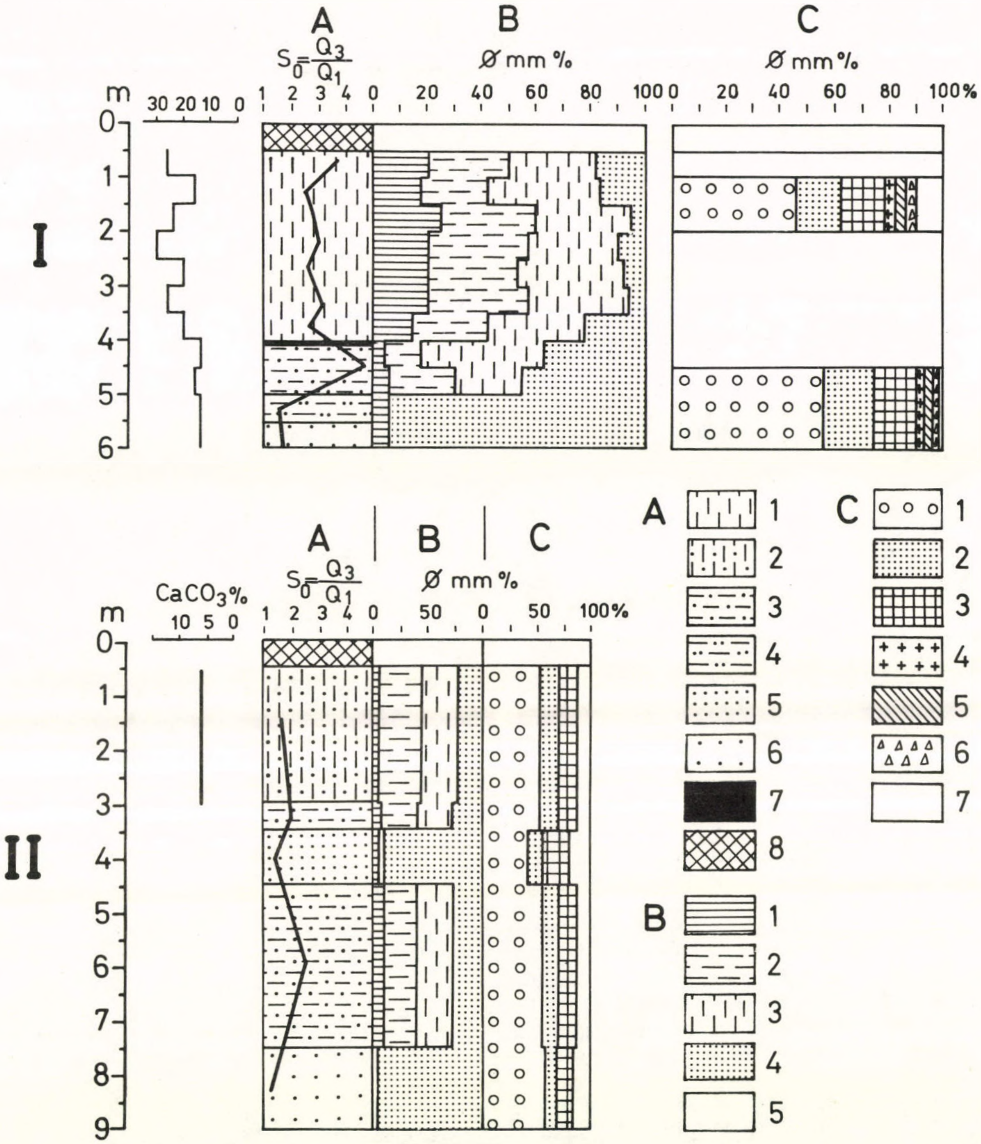

FIG. 1. Profile through the loess and loess-like sediments of fluvial origin at Knezevi Vinogradi /I/ and Medinci /II/
A. 1: Loess; 2: Sandy loess; 3: Sandy silt; 4: Silty san; 5: Fine sand; 6: Sand; 7: Hydromorphic soil; 8: Recent soil.
B. 1: Clay; 2: Loam; 3: Silt; 4: Sand; 5: Gravel. C. 1: Garnet; 2: Epidote; 3: Amphibole; 4: Staurolite; 5: Kyanite; 6: Biotite; 7: Other

4. Frequent alternations both vertically and horizontally in the pelitic, silt and fine sand content of the loess and loess-like deposits of the younger würmian terraces, indicates different conditions, with regard to time and space, during the various certain phases of fluvial sedimentation. In other words, the specific fraction deposited, depended on the relative height of the flood plain distance from the channelbed of the Drava or Sava or Danube rivers and the force of the flood wave. Where a flood-plain was relatively low in height and where the distance from the channelbed relatively short sedimentation of fine sands deposits prevailed, and so on. Because of channel migration the situation often changed and because of this there is no visible regularity in sedimentation. With the exception of the previously mentioned regular reduction in average grain size from the bottom to the top of a terrace the granulometrical structure of the loess and loess-like sediments thus demonstrates an exceptionally heterogenous picture.

5. Grain assortment values provide a further reliable indicator of the physical-geographical characteristics prevailing at the time of sedimentation of the primary material. As has already emphasized, the basal sands of the loess and loess-like deposits display tipical as sortment values characteristics of running water /approximately 2,o/. Considerable changes in the conditions of sedimentation occur in the transitional zone and particularly within the loess complex. The prevalence of a laminar type of water flow, on the flood plains is necessarily reflected in a decrease in grain assortment values and micro-stratification of the sediments. Extremly low assortment values and frequent oscillations /from 3--15/ between individual strata are a sign of the cessation of fluvial activity the onset of marshy conditions on the flood-plain and the stronger influence of eolian accumulation. This is particularly characteristic of the superficial loess and loess-like deposits immediately below the recent humus horizon, where in addition to other factors, illuviation processes around have contributed to the alteration of the primary characteristics of these sediment.

6. The peak periods of eolian and fluvial modelling of the land surface coincided during the warmer parts of the year in periglacial areas, and this was also the case in the Pannonian Region. Each a coincidence excludes the possibility of a predominantly eolian origin for the primary material of the original flood-plains, from which, by a later development, loess was created. It should be stressed that the possibility of most of the fluvial depositions reaching the riverbeds by eolian transport is not a significant point, because the final accumulation of primary material was completed by running water, which therefore becomes of greater importance in the genetic classification of the sediment. However, this does not exclude the possibility that eolian accumulation prevailed during the final phase of terrace formation, with the progressive dying out of fluvial activity on some of the higher and drier parts of the flood-plain. For this reason, a genetic classification of loess and loess-like deposits of fluvial origin should take account

of the fact that a part /smaller/ of the primary material making up the superficial strata of a lithostratigraphic profile may be of hydro eolian [x] origin.

7. A further indicator of the fluvial origin of loess and loess-like sediments on the younger würmian terraces is their extremely similar mineralogical structure to the fluvial sands in the subsoil. There are almost no differences at all between them and those that do occur can be attributed to the influence of the tributaries, flowing into the Drava and Sava rivers from the nearby mountains. The prevalence approximately 5o% of garnets is marked in the loess and loess-like deposits of the younger würmian terrace of the Drava, where the primary material is obviously of Alpine origin. A very similar situation exists in the Sava River Basin, although unlike the Drava Basin, the loess deposits here can be referred to as "epidotic" loess. This a result of the direct influence of the intensive weathering of low lying metamorphic rocks from the Medvednica, Moslavacka gora and Psunj mountains. In the case of the loess and loess-like deposits on the Danube terrace in Baranya, and near Mohács in Hungary, the occurrence of two maxima, garnets and amphibole is characteristic /CODARCEA, V. 1976/.

8. A comparison of the granulometrical structure of the loess and loess-like deposits with suspended sediment loads of the rivers Drava and Danube largely confirm these views. This can be seen from the enclosed table, which contains data on the amount and mean diameter of the bed-load and suspended sediment load of the above mentioned rivers at selected sampling points.

The mean particle size of the suspended sediment load of the Danube and Drava in Baranya, downstream from Baja /Hungary/ and at Drávaszabolcs /Hungary/ is almost identical to the mean particle size of the loess and loess-like deposits on the youner würmian terraces. The increase in the average thickness of the loess and loess-like sediments on the younger würmian terraces can be related to an increase in the total amount of suspended load in the downstream parts of both rivers. While, for example, the thickness of loess and loess-like deposits on the younger würmian terrace of the river Drava, amounts to approximately o,5o--1,5 m near Djurdjevac, and to o,5--2 m around Virovitica and Podravska Slatina in Baranya it reaches an average of 3--6 m. Similar relations are also characteristic of the young würmian terrace of the Danube where the depth of loess increases from approximately 2--3 m at Kalocsa to 4--12 m at Mohács and Dubosevica. The considerably greater thickness of loess and loess-like layers on the younger würmian terrace of the Danube relates to the larger suspended sediment load transported by the Danube.

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[x] The term was accepted by the Hungarian geologist, VENDL, A. who mentioned it for the first time in his study "Hidroaerolitische Gesteine im ungarischen Quartär". - Földtani Közlöny. Vol. 86. 1956. No. 4. Budapest. pp. 357-36o.

TABLE 1. Average annual amount and mean diameter of suspended sediment and bedload of the river Drava and Danube[x]

River	Measuring station	Mean diameter of suspended sediment load in mm.	Average grain size of bedload in mm.	Average annual amount of sediment transported in tons	
				Suspended	Bedload
Danube	Dunaujváros	o,o6--o,o7	o,3	11 6oo ooo	28 4oo
Danube	Fajsz	o,o6	o,4	lo 722 ooo	5o ooo
Danube	Baja	o,o6	o,3--o,4	18 291 ooo	44 ooo
Drava	Drávaszabolcs	o,o41-o,o57	o,25--o,33 cca	1 432 5oo	67 ooo cca

AGE

The loess and loess-like sediments are of Pleistocene age most likely deriving from a younger würmian period. The conclusion is based on the morphological position of individual terraces in the Drava and Sava valleys /BOGNAR, B. 1973 and 1975/, and is also indicated by the traces of cryoturbation processes /cryodeformation of layers and fossil ice wedges / found within the strata investigated /BOGNAR, A. 1974 and 1975/. Using M. PÉCSI's classification on soil structures /1964/ the loess marked evidence of cryodeformation features and ice wedges would seem to place them in the younger Würm. The same conclusion is also valid for the younger würmian terrace of the Danube /PÉCSI, M. 1981/. The presence of biotite in the mineralogical composition of all investigated profiles is further indicator of the late Pleistocene age of there loess and loess-like deposits of fluvial origin.

[x] Data for the river Danube are taken from PÉCSI, M. 1959."Entwicklung und Morphologie des Donautales in Ungarn". - Földrajzi Monográfiák. Budapest. 36 p.; while data for the river Drava have been obtained from the Water Board, Osijek.

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CHRONOLOGICAL EVALUATION OF LOESS SNAILS FROM PAKS USING THE THERMOANALYTICAL METHOD

SZÖŐR,Gy. - BORSY,Z.

EMERGENCE OF THE PROBLEM

During the last few years the chronological evaluation of the loess exposures in Hungary has yielded significant results. With radiocarbon methods it was possible to determine, for the first time, the ages of the Dunaujváros-Tápiósüly Soil Complex and the "Mende Upper" Soil Complex which lie in the upper part of the loess profiles /PÉCSI,M.1972/. Two years later PÉCSI,M. and PEVZNER,M.A. /1974/ succeeded in establishing the 73o ooo years Brunhes-Matuyama epoch boundary in the older loess profile underlying the "Paks Lower" Double Soil, at the depth of 47 m in the Paks Brickworks.

Since there have not been any successful attempts to determine the age of formations older than 32 5oo years with the use of radiocarbon methods, only estimated values can be given for the ages of the strata lying between the "Mende Upper" Soil Complex and the Brunhes-Matuyama epoch boundary. Thus, PÉCSI,M.estimated the age of the "Basaharc Double" Soil to be 45 ooo-5o ooo years, that of the "Basaharc Lower" Soil Complex was placed at 65 ooo-7o ooo years, whereas the "Mende Base" Soil Complex was dated as 11o ooo-12o ooo years B.P. /PÉCSI, M. - PEVZNER, M.A. 1974/.
For the age of yet older strata it is not easy to give even estimated values, since there has been significant erosional loss of strata at many places in the loess exposures, e.g. between 27--42 m at Paks.

Some time ago we made efforts to date some of the more important loess and fossil strata using the thermoluminescence method /TL/. With this method the loess underlying the "Mende Base" Soil in the Paks exposure proved to be 125 ooo ± 2o ooo years old,while the age of the fine sandy loess at a depth of 37 m was planed at 2oo ooo ± 3o ooo years. The "Mende Base" Soil found in the exposure at the Mende Brickworks was determined as 1o5 ooo ± 17 ooo years old /BORSY,Z. - FÉLSZERFALVI,J. - SZABÓ,P.P.1979/. The Paks loess exposure is still being studied with the thermoluminescence method.

During the course of these continuous investigations the idea emerged of correlating the TL data with the results of a thermoanalytical method which was in a state of elaboration. The research background for the application of the new method was provided by the comprehensive paleobiogeochemical work published by SZŐŐR,Gy. in 1979. On investigating the fossil Molluscan material of Quaternary and neogenic provenance, the author established that the derivatographic measurement of the organic matter of shells is capable of yielding useful relative chronological data. Within identical taxon and sediment facies the amount of organic matter in the shell proportionally decreases from the time of embedding. In the present paper the initial results of these investigations are reported on.

MATERIALS AND METHOD

From the strata lying at depths of 3, 5, 8 and 37 metres in the Paks loess exposure, numerous individual specimens of three loess snail species, Arianta arbustorum Linné, Trichia hispida Linné and Helicella hungarica Soós, were collected and examined.

The derivatographic measurements, which formed the basis of the work, were supplemented by infrared spectroscopy, emission spectroanalysis, atomic absorption spectrophotometric examination and microscopic evaluation. Measurements were performed with the use of Derivatograph /MOM/ instruments, namely a Perkin-Elmer Type 283, a ISZP-3o Quartz Spectrograph and a Unicam SP 19oo.

The preparation of fossil shells and the analytical methods applied have been described in detail in previous communication SZŐŐR,Gy.1972, 1975, 1979/.

REVIEW OF RESULTS

The DTA curves of the shell material of the three loess snail species are summarized in FIGS. 1,2, 3 and the percentage composition of their thermal products by weight are given in TABLE I. From an evaluation of these data we were able to draw useful conclusions with regard to taxonomical identification and chronology /sediment correlation/.

The thermal decomposition process observable in the carbonates takes place characteristically at species taxon level. This is established by the regular changes that take place in the correlated rates of thermogravimetric data, and the specific differences in their values. This can be demonstrated by plotting the B and O values representing bound organic matter content as a binary function /FIG. 4./. It is obvious from the figure that the coordinate points characteristic of the three species are separated from one other, which suggests that the degradation of shell protein /conchioline/ changes by species in the successive loess strata.

The different degree of fossilization of the three species is

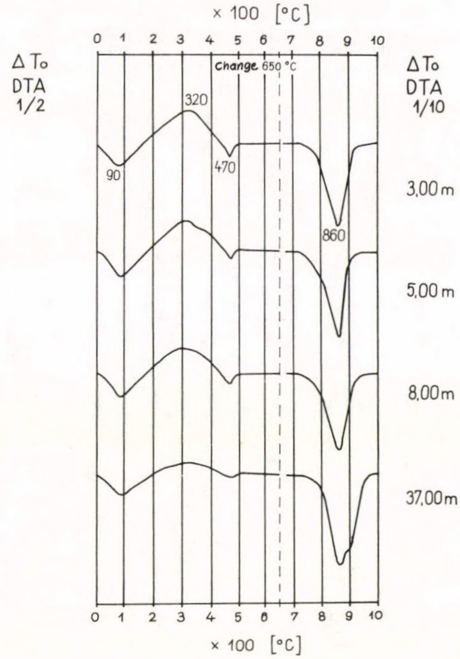

FIG.1: DTA curves of the loess snail Arianta arbustorum /L./ collected from depths of 3,5,8 and 37 metres

also proved by the depth-dependent differences in carbonate structure. From studying the DTA curves we draw some conclusions on the incorporation of the changing Mg^{++} content. The "dolomite double peak" in the case of Arianta arbustorum can be observed only at the deepest level, while it occurs at as little as 5.o m depth with Trichia hispida, and with Helicella hungarica shells is apparent in all strata.

In the course of the investigations the question was raised whether or not the effects of fossilization /dissolution, oxidation and element exchange/ destroyed the original shell structures, i.e. whether or not the shall material undergo such drastic changes/contamination by organic matter, recrystallization, impregnation by siliceous solution, etc./ that would influence its chemical and mineralogical integrity. Although this possibility had already been refused by the derivatographic analysis itself, we thought it necessary to perform some supplementary examinations.

FIG.5 presents the infrared spectrum of the fossil shells collected from the deepest stratum examined by us. In agreement

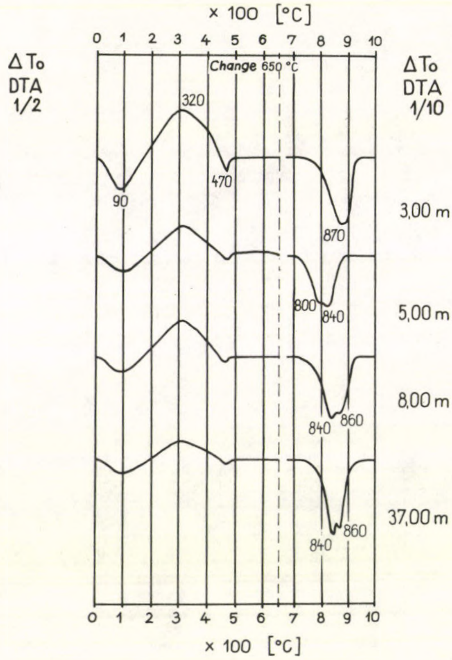

FIG.2: DTA curves of the loess snail Trichia hispida /L./ collected from depths of 3,5,8 and 37 metres

with the other samples this example also demonstrates that only the characteristic bands of carbonates and organic matter can be observed on the spectrum, i.e. the sample had not been impregnated by either silica or iron-containing solutions. The shells of terrestrial Gastropoda are built up of aragonite.The basic structure of the fossil shells was similarly aragonite, i.e. it had not recrystallized into calcite or dolomite-like minerals, although the displacement of some bands suggests Mg^{++} incorporation. The results of trace element examinations are summarized in TABLE II. Shells collected from the different depth of the Paks exposure, together with four samples of recent control material, have been analysed.

Comparing the trace element spectra, it can be stated that the elements detected in both the recent and fossil samples are qualitatively and quantitatively very similar.

Fossilization had changed the shell structure only to a very slight degree and regular changes could only be established in the case of a few elements. In the fossil samples there is somewhat less calcium and manganese, and somewhat more iron and magnesium, indicating dissolution with the former two elements

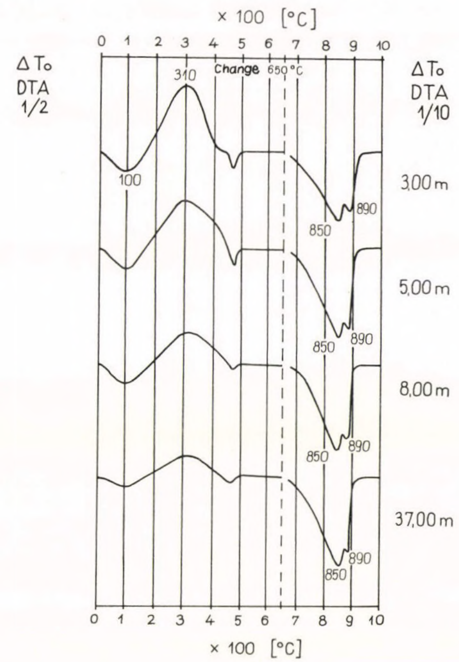

FIG.3: DTA curves of the loess snail Helicella hungarica/Soós/ collected from depths of 3,5,8 and 37 metres

and incorporation with the latter two. It is very interesting to note that magnesium can already be detected in the shells of recent samples which suggests that magnesium incorporation is a result of a biogenic process that may be enhanced during the course of fossilization. The presence of tin in the recent control material can perhaps be accounted for by the effects of anthropogenic pollution.

The microscopic analysis that supplemented the infrared spectroscopic and trace element examinations showed no significant difference between the structural build-up of fossil shells collected from the various fossil layers and that of shells of recent provenance.

After the comparative evaluation of the inorganic matter offossil shells let us now pass on to consider the changes in the organic components. In FIG.6 the composition of material gradually released up to 65o°C during the derivatographic measurements, the so-called derivatographic parameters were compared by species and by depth of burial. The A, B and O values refer to the amounts of organic macromolecules bound at various strengths. As can be seen,

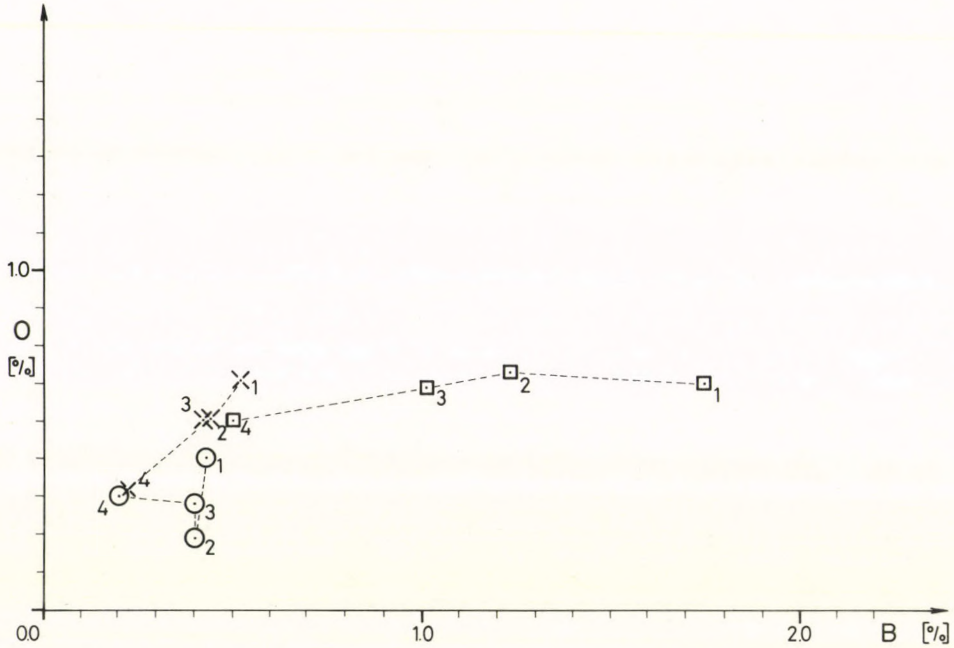

FIG.4: Comparison of the bound organic content of Pleistocene loess snails of Paks with the use of a coordinate system. Amounts of material released at temperatures of 2oo--4oo ^{o}C /B/, and 4oo--65o ^{o}C /O/, determined by the evaluation of the DTG, TG curves. ⊡ = Helicella hungarica /Soós/; ⋊ = Trichia hispida /L./; ⊙ = Arianta arbustorum /L./. Samples collected from depths of 1--3 m, 2--5 m, 3--8 m, 4--37 m.

the total amount of material measured up to the thermal dissociation of carbonates gradually decreases as a function of the depth of burial, i.e. as a function of geological time. The total of thermodecomposition products released is an easily measurable quantity even in the case of Arianta aebustorum, which has the lowest organic matter content. We have assumed that, as with the dating of Quaternary vertebrate material /SZÖŐR,Gy.1979/, by measuring the derivatographic parameters of loess snail shells a new absolute chronological method can be established.

The serial measurements are most practicable with Helicella hungarica shells, since these contain the largest amounts of organic matter.

CONCLUSIONS

The derivatographic measurements of the organic content of shell material collected from loess sediments in Hungary can be utilized in stratigraphic investigations. This chronostratigraphic method of analysis, however, can only be applied if identical

TABLE I: Thermogravimetric parameters of loess snails from Paks

Species	Depth m	Percentage values of TG-curve by weight					
		A	B	O	C	1	2
Arianta arbustorum	3,oo	o,4o	o,43	o,4o	42,o2	43,25	56,75
	5,oo	o,39	o,4o	o,19	42,56	43,54	56,46
	8,oo	o,18	o,4o	o,28	42,2o	43,o3	56,97
	37,oo	o,lo	o,2o	o,3o	42,5o	43,lo	56,9o
Trichia hispida	3,oo	o,3o	o,52	o,61	41,21	42,62	57,38
	5,oo	o,36	o,44	o,5o	42,28	43,58	56,42
	8,oo	o,2o	o,42	o,5o	41,19	42,31	57,69
	37,oo	o,lo	o,22	o,31	42,63	43,26	56,74
Helicella hungarica	3,oo	o,64	1,75	o,6o	41,53	44,52	55,48
	5,oo	o,55	1,23	o,64	41,52	43,94	56,o6
	8,oo	o,49	1,lo	o,59	41,83	44,ol	55,99
	37,oo	o,14	o,5o	o,5o	42,o4	43,18	56,82

A = water content weakly bound to organic and mineral **struc-tures**; B;O = release of bound organic matter content; C = carbon dioxide released in the heat dissociation of carbonates; $_1$= total loss of material other heating to 1ooo^{o}C; $_2$ = residue after heating to 1ooo^{o}C

species are compared and if the original structure and trace element composition of the shells has remained essentially during the process of fossilization. The establishment of an absolute chronological scale, based on shell organic matter determinations requires further lengthy and careful research. First of all the collection and serial examination of large amounts of statistically evaluable sample material is necessary. The scattered findings from other loess sites can then be correlated to a standard series which has calibrated with the use of existing radiocarbon and thermoluminescence data.

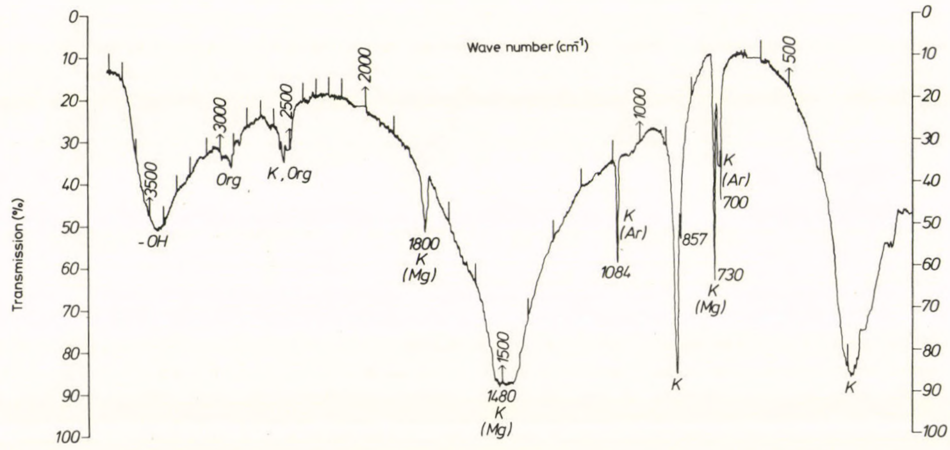

FIG.5: Infrared spectrum ofthe loess snail Helicella hungarica /Soós/ found at a depth of 37 metres at Paks. K = carbonate; K/Ar/ = aragonite; K/Mg = Mg^{++}-containing carbonate; Org = organic matter; -OH = water content.

For ages exceeding the measurement limits of the radiocarbon method, our data can be correlated with that obtained from the TL method, as well as with chronological data obtained from the racemic aspartic acid /BADA,J.L. et al.1974, BADA,J.L. - DEEMS, L. 1975/ and uranium-helium /BALOG,K.198o/ procedures.

Given the instrumentation available in Hungarian laboratories the practical introduction of the derivatographic method of dating should make the establishment of a substantially wider range of chronological data possible.

ACKNOWLEDGEMENTS

Thanks are due to BARTA,I. /ELTE/ for the determination of trace elements spectra, to DINYA,Z. /KLTE/ for the preparation of infrared spectra, and to KROLOPP,E./MÁFI/ for the determination of the malacological material.

TABLE II: Trace element spectra of fossils collected from depts of 3-, 8- and 37 metres at the Paks exposure and recent control material.

Gastropoda	Sn	Cd	Cu	Zn	Pb	Ni	Li	Ba	Sr	Mn	Fe	Mg	Na	K
m o d e r n	11	5	7	12	2	2	2	6o	43o	15o	137	238	357	6o4
3 m	-	5	3	11	2	-	o.7	6o	578	48	255	563	256	376
8 m	-	4	3	9	-	2	o.7	5o	495	65	243	393	228	342
37 m	-	5	2	11	4	-	2	4o	455	24	425	825	174	367

Concentration in ppm; - = below the limit of detection; Analyst: BARTA,I./KLTE/

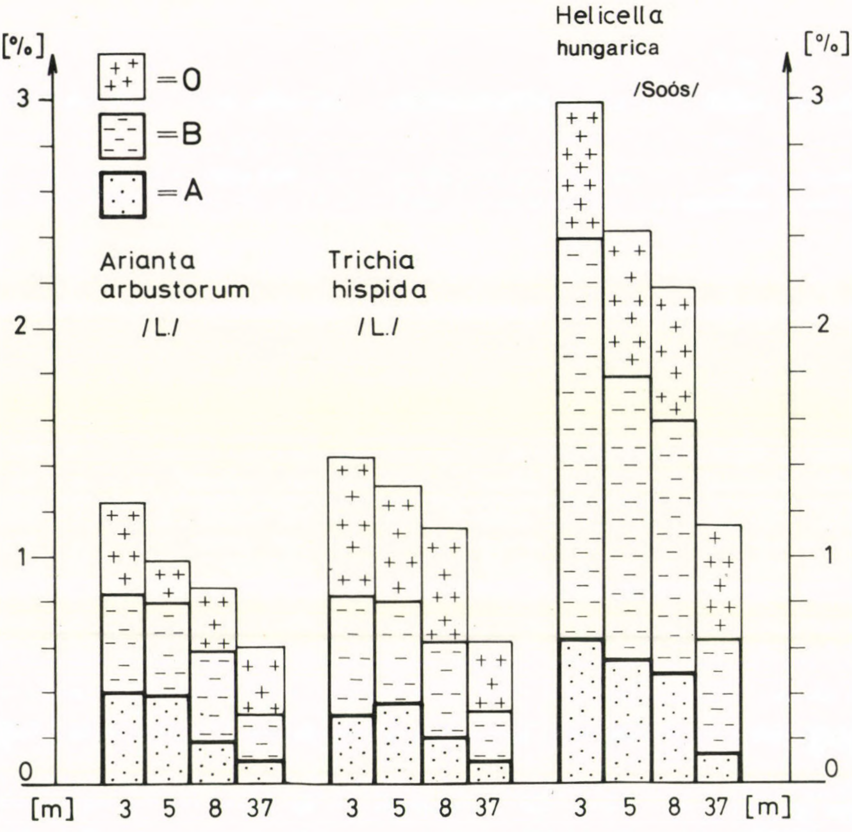

FIG. 6: Comparison of the derivatographic parameters of Pleistocene loess snails of Paks. Amounts of material released at temperatures of 2o--2oo°C /A/, 2oo--4oo°C /B/, 4oo--65o°C /O/, determined by the evaluation of the DTG, TG curves.

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MOBILE SAND PHASES IN THE NORTH-EAST PART OF THE GREAT HUNGARIAN PLAIN

BORSY, Z. - Mrs. CSONGOR, É. - SZABÓ, I.

In the north-east part of the Great Hungarian Plain an area of about 5 2oo sq. km is covered by wind-blown sand. In addition to the Nyirség, such areas occur in the northern part of the Hajduhát, in the Taktaköz and on the Tisza-Bodrog Interfluve /FIG. 1/. The varied dune-covered surface of the Nyirség, and the blown-sand of the Taktaköz and Tisza-Bodrog Interfluve attracted the attention of researchers at an early date. /CHOLNOKY, J. /19o2, 191o/ and NAGY, J. /19o8/ attempted to explain the origin of the blown-sands of the Nyirség and the conditions of sand-dune formation. /CHOLNOKY, J. /19o7/ was also concerned with the origin of the sand-dunes of the Taktaköz, while TRENKÓ, Gy. /19o9/ made valuable observations on the blown-sands of the Tisza-Bodrog Interfluve.

Although several workers were concerned with the above blown-sand regions between the two World Wars, their thorough study only began in the early fifties /KÁDÁR, L. 1951, 1957; Mrs. BORSY, Z. - BORSY, Z. 1955; BORSY, Z. 1961, 1969, 1971, 1974, 1978/. These autors succeeded in clearing up the origin of the blown-sands, categorized the types of sand forms and also established that sand movement was most intense during the Upper Pleniglacial phase.

We had no exact knowledge of later wind blown-sand movement until 1979. In this respect no concrete data were offered by stratigraphic, pedologic or palynologic investigations.

A new era in our examination of the region opened in the years 1979-198o when, through radiocarbon dating, we succeeded in determining the age of fossil soils interbedded with the sand-dunes. With the use of these radiocarbon dates and recent geomorphological investigations /Mrs. CSONGOR, É. - BORSY, Z. - SZABÓ, I. 198o; BORSY, Z. 198o; BORSY, Z. - Mrs. CSONGOR, É. - FÉLEGYHÁZI, E. - LÓKI, J. - SZABÓ, I. 1981; BORSY, Z. - LÓKI, J. 1982/ we wish to survey the wind-blown sands and establish the principal mobile phases.

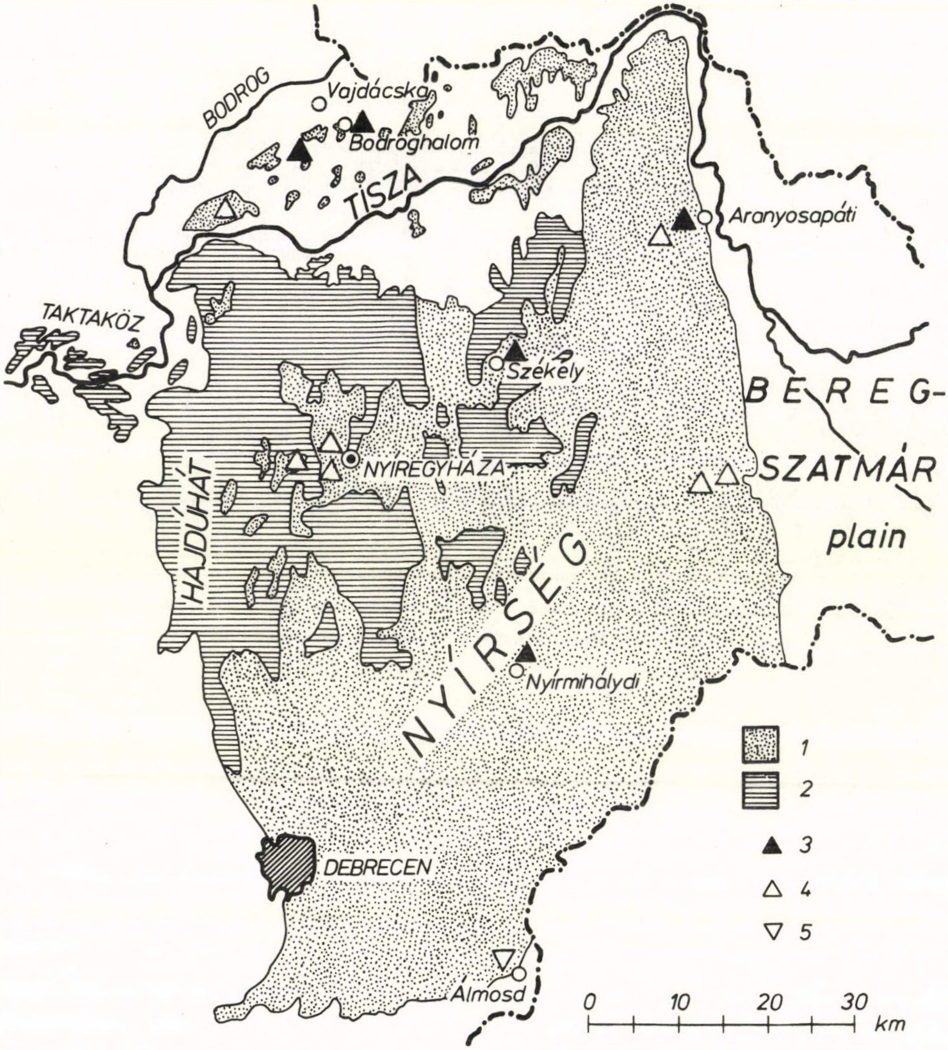

FIG. 1 Blown-sand areas of the NE part of the Great Plain
1: blown sand; 2: blown-sand covered by loessy blanket; 3: radiocarbon dates; 4: fossil soils of Late Glacial age /Bölling, Alleröd/; 5: fossil soil buried in the early Subboreal.

THE EVOLUTION OF WIND-BLOWN SAND AREAS

An investigation of the evolution of the wind blown-sand regions of the Great Plain must necessarily go back to the Pleistocene period. At the beginning of the Würm the surface of the north-eastern part of the Plain presented a different picture from that of today. The drainage network especially was at variance with the present system. The rivers draining to the North Eastern-Carpathians and northern Transylvania followed north-south, and north-east-south-west courses and tended towards the Körös region /FIG. 2/, they continued to build alluvial fans on the Tisza-Bodrog Interfluve of the Bereg-Szatmár Plain and in the Hajduhát and Nyirség as they had started to do in the early Pleistocene.

FIG. 2 Network of rivers in the Lower Pleniglacial

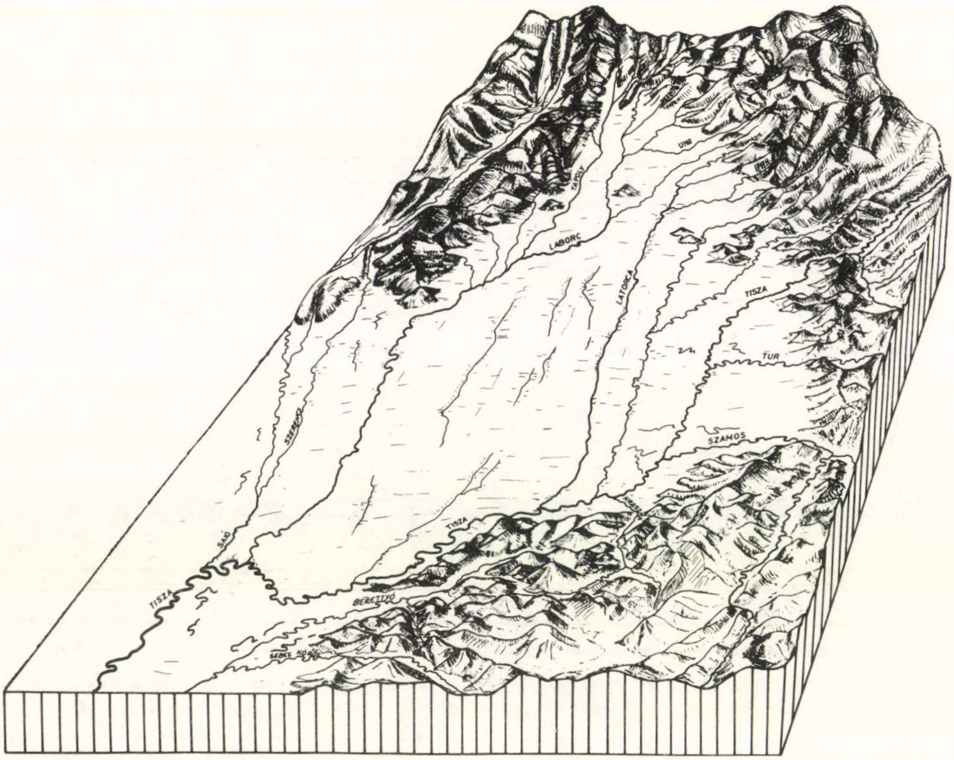

FIG. 3 Network of rivers in the Upper Pleniglacial

The first significant change in the evolution of the region took place at the beginning of the Interpleniglacial phase, when the Tisza and the Szamos shifted their courses from the Nyirség to the area of what is now the Ér valley /FIG. 3/. The Ancient-Tapoly-Ondava-Laborc, on the other hand, continued their flow from north to south through the Tisza-Bodrog Interfluve and the Nyirség.

The rivers and streams of the north-east part of the Plain, during the process of alluvial fan construction deposited sediments to a thickness of 5o-3oo m onto the underlying Pliocene strata, the overwhelming majority of which consist of sands, silts, and clays. As indicated by borehole data much of the fine and medium grained sands, which were later to be subject to eolian action, were deposited during the Upper Pleistocene.

In the evolution of the region a new phase began with the Upper Pleniglacial period. Due to the existence of a cold and arid climate the superficial fluvial deposits were only covered by sparse semi-arid vegetation, and as this was unable to protectthe soil from the prevailing northerly winds, eolian action and the development of various sandforms began. According to stratigraphic and geomorphological research the most intense mobile phase took place between 26 ooo and 2o ooo years ago, during which time oval shaped sand hummocks, residual ridges and parabolic dunes, and large-scale deflational plains and depressions were formed. The large amount of material derived from the latter form extensive areas of deposition sometimes several kilometres wide.

The first cold maximum of the Upper Pleniglacial phase was followed by a transitional period with a slightly milder and more humid climate around 2o ooo years ago /the Lascaux optimum/, which lasted about 3 ooo years. During this phase, the lower dunes and the deflational plains were better protected by vegetation and dust began to accumulate on the surface. Part of this dust was derived from areas, where the sands were still mobile, while the remainder was deflated by the strong northerly winds from the flood plains of rivers which were dry at low water. The dust deposited on the lower dunes and in the deflational hollows evolved into loess under the processes of diagenesis in the cold arid climate. At places where fine and very fine sand was intermixed with the dust, sandy loess or loessic sands were produced. Loess was formed mostly in the north-western part of the Nyirség and in the northern half of the Hajduhát, where by the end of the Upper Pleniglacial period a loess blanket loo to 55o cm in thickness had been formed which has preserved the various sandforms up to our day. In the north-eastern part of the Great Plain it is these loess covered sand dunes that are the oldest.

In those areas lacking a loess cover, for instance in the large accumulational sand fields and in the southern part of the Nyirség where parabolic dunes had formed, the sands were mobile until the Late Glacial phase.

EVOLUTIONAL HISTORY OF BLOWN-SAND AREAS DURING THE LATE GLACIAL PHASE

In spite of the occasional intense lowering of temperature, a gradual improvement of the climate was characteristic of the Late Glacial phase. During the Bölling interstadial, when the climate turned somewhat milder and more humid than before, a steppe-like vegetation gradually spread over the whole surface of the dunes. Shrubs also took hold in places and the sparse of mixed birch and pine appeared. Under this vegetation cover, characteristic of cold continental forest stepps, the formation of a steppe-like soils began, as evidenced both in the Nyirség and the Tisza-Bodrog Interfluve. As indicated by the exposures near Aranyosapáti in the north-eastern part of the Nyirség and south-west of Vajdácska in the western part of the Tisza-Bodrog Interfluve, the process of soil formation was in-

TABLE I Conventional radiocarbon dates /$T_{1/2}$= 5568 years; $\delta^{13}C$ to 25%; 95% of oxalic acid AD 195o/ and 1 σ counting errors derived from carbonaceous samples taken from the north-eastern part of the Great Hungarian Plain

Lab. No	Site	Conventional radiocarbon date /years B.P./	Mean value of conventional radiocarbon date
Deb 128	Vajdácska I.	12 33o ± 32o	
Deb 135	Vajdácska II.	12 23o ± 4oo	12 1oo ± 21o
Deb 133	Vajdácska III.	11 72o ± 36o	
Deb 13o	Vajdácska I.	11 48o ± 4oo	
Deb 155	Nyirmihálydi I.	11 93o ± 34o	11 59o ± 24o
Deb 157	Nyirmihálydi II.	11 25o ± 34o	
Deb 196	Aranyosapáti	12 9oo ± 36o	12 9oo ± 36o
Deb 199	Székely	11 35o ± 36o	11 35o ± 36o
Deb 287	Bodroghalom lower I.	11 1oo ± 4oo	
Deb 315	Bodroghalom lower I.	11 6oo ± 5oo	
Deb 288	Bodroghalom lower II.	11 46o ± 4oo	11 4oo ± 25o
Deb 312	Bodroghalom lower II.	11 4oo ± 5oo	
Deb 291	Bodroghalom mean	11 25o ± 35o	11 25o ± 35o
Deb 293	Bodroghalom upper	1o 83o ± 4oo	11 ooo ± 3oo
Deb 311	Bodroghalom upper	11 24o ± 5oo	

interrupted shortly thereafter. The changeable character of the Late Glacial climate is proved by the fact that the sands again become mobile near Aranyosapáti around 12 9oo ± 36o years ago /TABLE I/, and overwhelmed the Upper Pleniglacial dune and loess surface. The high intensity of sand movement is indicated by the fact that in places 6 to 1o m of sand was deposited on the previous forms, and the carbonification of the engulfed vegetation began. The sands belonging to these two phases together with 2 to 3 m of interbedded loess and associated fossil soil can be studied at the sandpit W of Aranyosapáti /FIG. 4/.

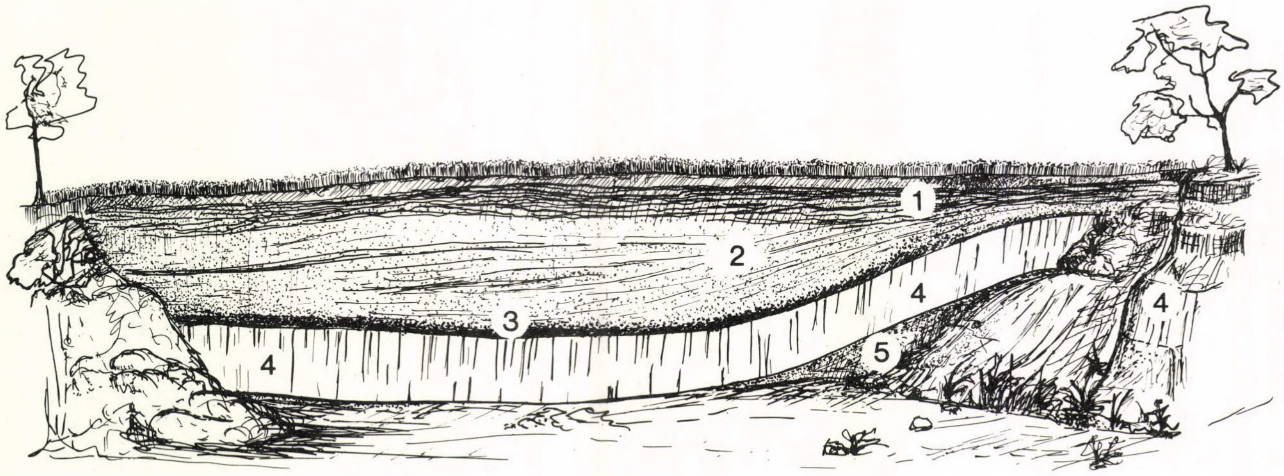

FIG. 4 Exposure W of Aranyosapáti

1: brown forest soil with iron-pan layers; 2: blown-sand evolved in the older Dryas; 3: fossil soil from the Bölling interstadial; 4: loess; 5: blown-sand evolved in the first part of the Upper Pleniglacial

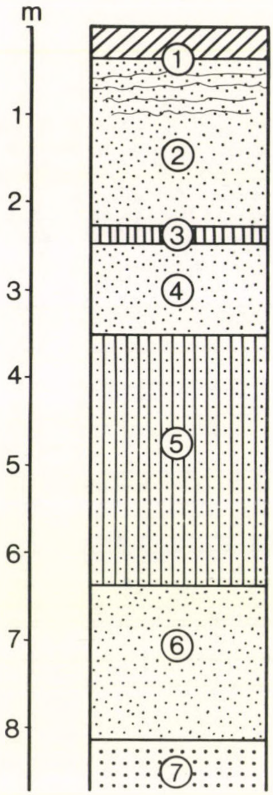

FIG. 5 Segment of the exposure SW of Vajdácska
1: brown forest soil with iron-pan layers; 2: blown sand from the older Dryas; 3: fossil soil from the Bölling interstadial; 4: blown-sand from the second half of the Upper Pleniglacial period; 5: loess; 6: blown-sand evolved in the first part of the Upper Pleniglacial; 7: fluvial sand.

The soil formation of the Bölling Interstadial lasted a few hundred years longer in the western part of the Tisza-Bodrog Interfluve. The mean conventional radiocarbon date of charcoal samples found in the fossil soil of the exposure at Páterhomok, to the south west of Vajdácska has been established at 12 ooo ± 2lo years /TABLE 1/. It can thus be assumed that this fossil soil /FIGS. 5, 6/ was covered by sand which began to move in a southward direction during the Dryas II stadial. During the older Dryas a relatively rapid cooling took place for a short period and at the same time the climate turned more arid. The decreasing vegetation cover was unable to protect the sand surfaces in all places, which is why sand movement could again start.

The fossil soil layer in the exposure south-west of Vajdácska is somewhat thicker than those in the north-eastern part of the Nyirség. The carbonaceous material found in this soil indicates that during the Bölling period the sand areas in the western part of the Tisza-Bodrog Interfluve were covered by forest steppe, in which pine and birch were predominant.

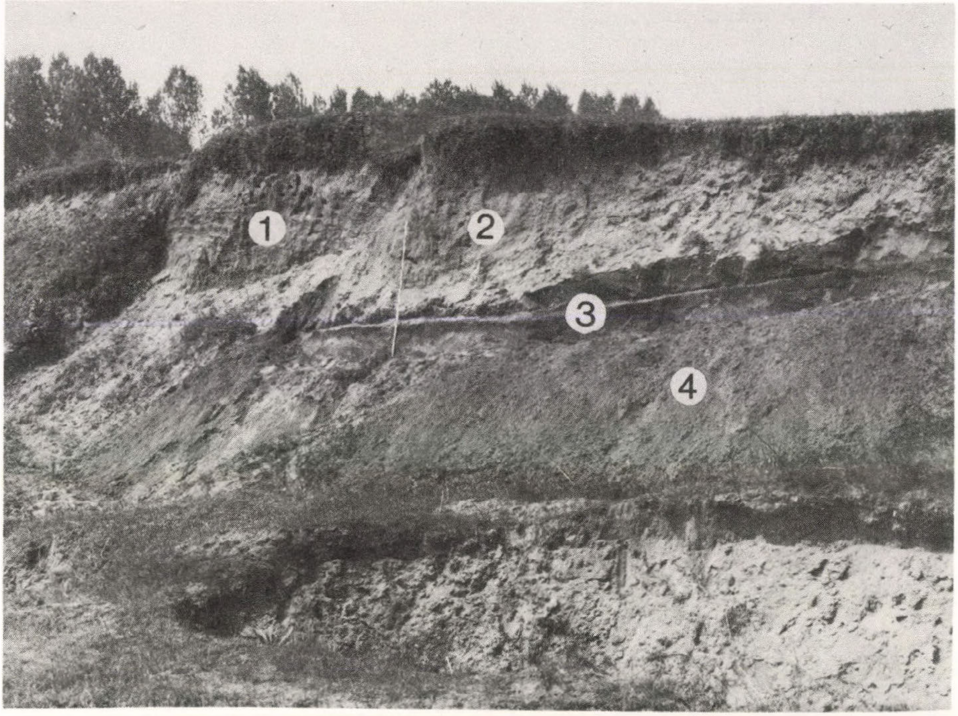

FIG. 6 Sand pit SW of Vajdácska
1: iron-pan layers; 2: blown-sand from the older Dryas; 3: fossil soil from the Bölling interstadial; 4: sand dune formed in the Upper Pleniglacial

The short cool phase during the Dryas II stadial was followed by rapid improvement in the climate during the Alleröd interstadial. According to MANLEY, G. /1949/, during the warmest period of the Alleröd the mean temperature for July was about 4° lower in Central Europe than it is at present. As a result of the milder, somewhat more humid climate the sand surfaces become increasingly vegetated. Forest steppe developed on the lower dunes while the somewhat higher and drier dunes were overgrown by steppe vegetation, which offered fairly good protection from deflation. A steppe-like soil formed on the dunes covered by the loess blanket, while the blown-sand surfaces developed a steppe-like sandy soil. In recent years we have had the opportunity to study this soil layer, which is very similar to the soils of the present-day cold steppes, in several exposures. The soil is thinnest on the summits of the Upper Pleniglacial dunes, but in the depressions attains a thickness of as much as 6o-8o cm. This phenomenon is the result of the erosion of soil from the tops of the dunes, probably due mainly to summer showers.

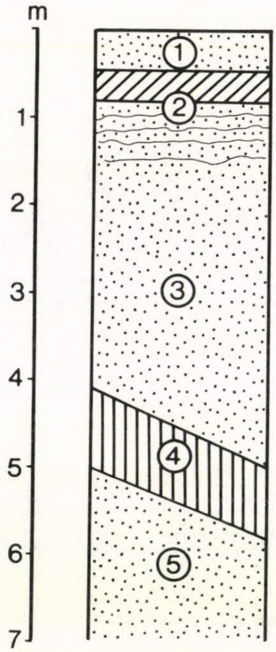

FIG. 7 Segment of the exposure at Nyirmihálydi
1: recent blown-sand; 2: brown forest soil with iron-pan layers; 3: blown-sand evolved in the younger Dryas; 4: fossil soil from the Alleröd period; 5: blown-sand evolved in the Upper Pleniglacial

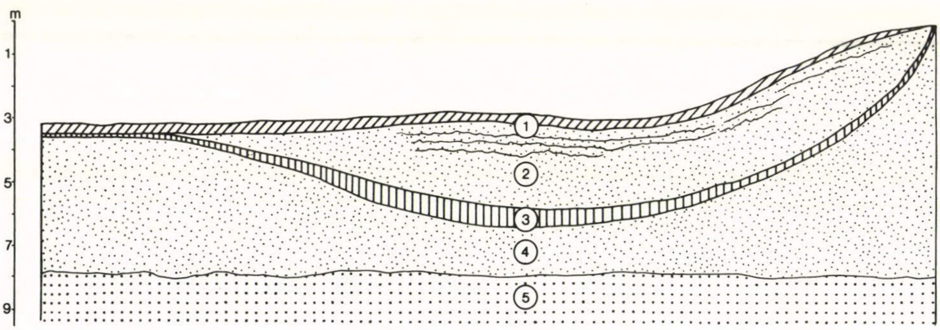

FIG. 8. Exposure at Bodroghalom
1: brown forest soil with iron-pan layers; 2: blown-sand from the younger Dryas; 3: fossil soil from the Alleröd period; 4: blown-sand evolved in the Upper Pleniglacial; 5: fluvial sand.

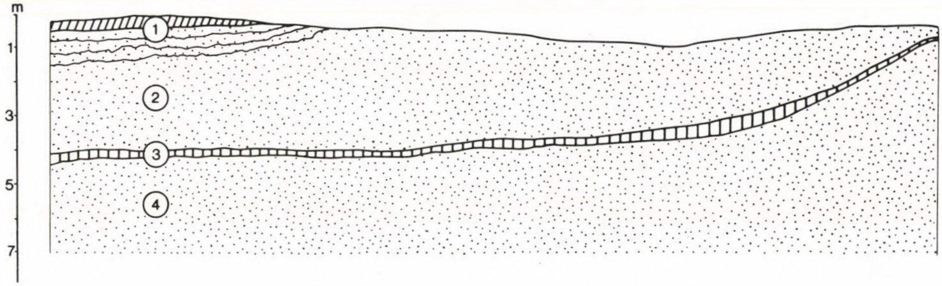

FIG. 9 Exposure at Székely
1: brown forest soil with iron-pan layers; 2: blown-sand evolved in the younger Dryas; 3: fossil soil from the Alleröd period; 4: blown-sand of Upper Pleniglacial age.

The fossil soils of the Alleröd period are exposed in several places both in the Nyirség and on the Tisza-Bodrog Interfluve /FIGS. 7, 8, 9/. The radiocarbon age of the oldest carbonaceous material found in them is 11 93o ± 34o years at Nyirmihálydi and 11 6oo ± 5oo years at Bodroghalom, while the youngest carbonaceous material has been dated as lo 83o ± 4oo years at Bodroghalom and 11 25o ± 3oo years at Nyirmihálydi. A mean value of 11 35o ± 36o years has been obtained at Székely, where the carbonaceous content of the fossil soil is low /TABLE I/. The radiocarbon ages of the samples unequivocally show that the fossil soils in question were all formed during the Alleröd epoch.

This phase of soil formation was, however, brought to an end in several places by the intensive cooling during the younger Dryas, notably in the higher and drier sand areas and on the Nyirség watershed. During this phase the mean temperature was some 7-8^{o} C lower than today, and the climate was more arid.

As a result of this climatic deterioration lasting a thousand years, the forested areas decreased and the steppe vegetation became more sparse, and the sands again became mobile, particularly on the higher dunes. Evidence for this is provided by the fossil soil which developed during the Alleröd interstadial, on which the younger Dryas sand blanket attained a thickness of 3-lo m. The large laminae running parallel with one another, as seen in the exposures /FIG. lo/, is indicative of the intensity of sand movement and the aridity of the climate during this phase. Earlier there was little knowledge about this period of sand movement when the concept was that the wind blown-sands overlying the fossil soils were deposited in their present locations during the Boreal phase.

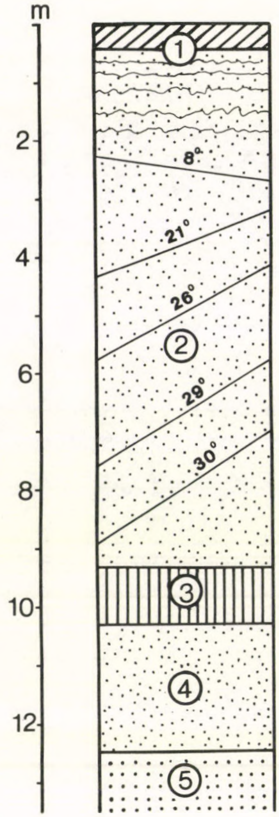

FIG. 1o Segment of the exposure in the NW part of Nyiregyháza
1: brown forest soil with iron-pan layers; 2: blown-sand from the younger Dryas; 3: fossil soil from the Alleröd period; 4: blown-sand evolved in the Upper Pleniglacial 8°, 21°, 26°: slope of laminae.

After the ages of the fossil soils exposed in the Nyirség and the Tisza-Bodrog Interfluve had become known, all the sand exposures in the two regions were examined. In addition, supplementary geomorphological observations were carried out in order to attain a precise picture of the areal extent of Late Glacial sand movements. During the course of these investigations it has been established that the sand movements of the older and younger Dryas stadials covered a much smaller area than those of the second half of the Upper Pleniglacial phase. During the Late Glacial period, the sands only became mobile on the accumulational sand fields and on the more arid sand surfaces.

The evolution during Late Glacial phase further differs from the Upper Pleniglacial phase in that during the former, due to the better protection of the sand surfaces, the possibility for the evolution of large-scale sand forms was not present. Thus, deflational flats and accumulational sand fields, which formed extensively in the northern part of the Nyirség during the first half of the Upper Pleniglacial phase, could not come into being. Neither could such vast windrifts as can be observed at several places in the areas covered by the loess blanket form.

By contrast, in those parts of the Nyirség, where sand movement was more intense during the younger and older Dryas stadials, the ensemble of forms becomes very complicated. This is due to the fact that older forms produced by earlier sand movement show through the younger sand blankets. This fact was not known earlier and amounts for the difficulties that occurred over the genetic classification of forms.

Recently supplementary data on the southern part of the Nyirség, where parabolic dunes are found, has been obtained. The this fossil soils and loess sand layers found in the dunes here indicate, that the parabolic dunes were also formed during the Upper Pleniglacial phase. Little sand movement occurred in this region during the Late Glacial period.

SAND MOVEMENT DURING THE HOLOCENE

After the Late Glacial period at the end of the Würm the Holocene meant the advent of a warmer climate. Vegetation slowly reestabilished itself over the sand surfaces and sand movement gradually ceased. According to recent investigations in the north-eastern part of the Great Plain there was no marked sand movement during the Holocene. It is true that during the Boreal and Atlantic phases some limited movement occurred, but this made hardly any changes in the previously formed picture.

Owing to anthropogenic factors small scale sand movement reemerged as early as the first part of the Subboreal phase, but resulted in hardly any morphological changes. Neither did deforestation during the Middle Ages exert any significant influence on the surface. This situation completely changed, however, between the 16th and 18th centuries, when deforestation extended to larger and larger areas, and even embraced the dunes of higher relief energy, in order to conquer newer and newer territories for agriculture. However, these newly acquired lands produced good yields for a few years only, since the soil was easily eroded from the higher parts of the dunes. As a consequence, eolian erosion once again accelerated and the sands become mobile in many places. This period of sand movement was characterized by fragmentation, producing much smaller forms than those that evolved during the Würm. It is obvious that the present-day climate is not favourable for sand movement.

CONCLUSIONS

The dating of the fossil soils occurring in the dunes of the Nyirség and the Tisza-Bodrog Interfluve has helped to clarify both the periods of blown-sand movement, and the geomorphological consequences of late glacial climatic changes, knowledge that was lacking before. The significance of the new findings extends beyond the north-eastern part of the Great Plain, and the fossil soils occurring in other blown-sand areas call attention to the possibility of blown-sand movement in other parts of the country during the Late Glacial period.

Such investigations also offer support to stratigraphic studies, since they allow the superficial deposits in the blown-sand areas to be dated more exactly than it was possible before.

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EXAMINATION OF THE GRAIN-SIZE COMPOSITION OF PERIGLACIAL PIEDMONT SEDIMENTS IN THE HUNGARIAN MEDIUM-HEIGHT MOUNTAINS

PINCZÉS, Z.

The slopes of the Hungarian mountains of medium-height are covered by periglacial sediments of varying grain-size which evolved during the Pleistocene period. Their formation was the outcome of frost action, and the amount of debris produced was primarily determined by the rock type, its bedding and lamination, the structure of the mountain range, and the exposure and steepness of slope. Of the various rock types occurring in the mountains dolomite has been the one most subjected to fracturing, and at the same time, has been reduced to the smallest grain size. While debris of various grain-sizes has been formed from limestone, laminated thinly-bedded strata being reduced to debris of small grain-size, and the more massive limestones breaking down to larger blocks. The rocks of volcanic origin present as essentially similar picture. Andesites and basalts have generally broken down more slowly into large blocks although the andesite material associated with the most recent volcanic eruptions has been fractured into thin plates of a few centimetres thickness, as in the Zemplén mountains. In the area built up from volcanic tuffs, by contrast, the most varied types of debris can be found. Soft, porous tuff of loess-structure was fractured quickly under the action of frost, and now forms primarily sandy piedmont detritus. Tuffs permeated by hydrothermal siliceous solutions, on the other hand, are more solid, and have broken down into highly variegated blocks of a few centimetres or decimetres in size under the action of frost.

From all this it would follow that the grain-size composition of piedmont deposits is determined by the effect of frost on the structure and nature of the parent material. Further changes only occur if the debris, continues to move down the slope, under the action of frost, which has the effect of sorting the material such that it becomes finer as one moves away from the source of debris formation. However, the material redeposited this is also exposed to other effects, which also contribute to it becoming finer. On the one hand, the coarse debris continues to be broken down during the course of transport, while on the other hand, it becomes intermixed with finer alien material. This latter may be of eolian origin, but it may also be derived from the fossil soil or semipedolite covering the slope. At the same time, the debris remaining at the source suffers further attrition under the influence of frost. In consequence, the amount of coarse material in a periglacial deposit decreases gradually while the fine fraction, and within this a particular grain-size steadily increases. DÜCKER, A. /1937/, on examining the structural soils in the Riesengebirge, found that 5o% of the material was comprised of grains of o.1--o.2 mm in diameter, the remainder being made up of equal parts of sand and silt. A similar result was obtained by BESKOW, G. /193o/ in an analysis of structural soils in Lapland, where he found the strong predominance of grains of o.1--o.o2 mm in size.

In the present paper, we shall examine the effect of frost and freeze-thaw conditions on various types of rocks, investigating the grain-size of materials remaining at the origin and that of materials transported further along the slope, with the use of periglacial samples taken from Hungary, Lapland and Norway. We wich to examine the extent to which the evolution of grain-size and the proportion of grains of various size in frost derived debris and piedmont sediment is related to rock types, under the effect of the single external factor of frost.

TALUS FIELDS /SCHUTTHALDE/ EVOLVING ON ANDESITE AND LIMESTONE

Talus fields are a frequent periglacial form in the mountains of Hungary. The talus fields may be as large as loo m in size consisting as a rule, of coarse grained material. Samples of material with grain sizes of less than 2o cm were collected from talus fields for examination, comprising 4o andesite samples from the Zemplén Mountains, and 25 samples limestone from the Bükk Mountains. For each grain-size category the arithmetic mean, range and variance were calculated /TABLE I./. It is striking, and seems paradoxical at first sight that the percentage of debris of grain size averaging more than lo mm is higher on limestone than on andesite, although this category only involves grains of lo--2o mm in size. In talus fields consisting of limestone, due to the quicker fragmentation of the rock, this medium grain size is predominant. At the same time, the formation of larger blocks is characteristic of andesite - which was not taken into account during the investigation. The effect of rock structure on the process of fragmentation is also reflected in the range between the highest and lowest percentage values. Characteristic of the grain-size distribution of both andesite and limestone debris is gradual trend towards finer grain sizes, which is only interrupted from medium size sand grains falling into the o.63--o.2 category and for the loess fraction belonging to the o.o5--o.o2 category. For both types of rock the grain-size percentage is twice the value of the previous category in the first case, in the second instance

TABLE I. Characteristic values of the grain-size composition of talus fields evolving on andesite /4o samples/ and limestone /25 samples/

Grain-size in mm	lo	lo-4	4-2	2-1	1-o.63	o.63-o.1	o.2-o.o5	o.1-o.o2	o.o5-o.ol	o.o2-o.oo5	o.ol-o.oo2	o.oo5-o.ool	o.oo2-	o.ool
<u>Talus field on andesite</u>														
Arithmetical mean /x=/	17.56	lo.54	9.o9	6.92	5.54	lo.84	6.38	4.62	8.14	6.51	6.31	5.32	2.14	2.21
$x_{max.}$ 1/	6o.4	31.1	44.o	24.5	15.9	23.6	15.1	12.5	17.8	2o.3	14.4	13.1	3.9	5.8
$x_{min.}$ 2/	o.4	1.3	2.8	1.6	1.5	4.4	o.2	o.7	o.4	o.8	o.6	o.6	o	o
Standard deviation	14,22	6.87	8.35	5.55	3.12	5.47	3.9o	2.96	4.3o	3.46	3.31	3.53	1.13	1.72
<u>Talus field on limestone</u>														
Arithmetical mean /x=/	38.41	9.23	4.26	1.89	1.98	3.95	2.26	3.36	lo.43	8.2o	5.35	4.2o	2.46	3.52
$x_{max.}$ 1/	79.6	19.4	9.3	4	4.1	6.7	9.5	lo.4	23.7	19.8	lo	14.8	9	8.6
$x_{min.}$ 2/	3	o.6	o	o.2	o.3	o.7	o	o	o	o	o	o	o	o
Standard deviation	18.6o	4.93	2.34	1.12	1.o7	1.63	2.41	2.63	5.86	4.79	3.o6	3.o4	1.7o	2.61

1/ highest percentage value for each category

2/ lowest percentage value for each category the corresponding value is nearly twice for andesite and three times for limestone. The rise in the value of the loess fraction /rock flow/ is even more conspicuous if the o.o5--o.o2 mm and the o.o2--o.ol mm fraction are combined, as is commonly done in the international literature, when the proportion is 14.6% and 18.6% for andesite and limestone respectively. It is only natural, due to incomplete chemical weathering, that the proportion of clay fraction should be lowest for both rock types 4.3% for andesite and 5.9% for limestone.

It is striking that both the mean and maximum values are higher for andesite than limestone when grain sizes larger than o.o5 mm are examined. With finer fractions the two sets of values are generally close to each other, although in the case of the o.o5--o.o2 and the o.o2--o.ol mm fractions, limestone has the higher values. Similarly, the effect of rock type is reflected in the fact that whereas the lowest values, i.e. o%, for the andesite occur in only the clay fractions < o.oo2 mm, on limestone this value is found in nine categories, and values below 1% occur in a further four categories.

The amount of variance / δ / also confirms that has been said so far. For fractions coarser than o.1 mm, the variance is higher for andesite, whereas for finer fractions the two values approximative each other and in certain cases /i. e. the o.o5--o.o2, o.o2--o.ol mm categories and the clay fraction variance/ for limestone is higher.

The grain-size distribution curves plotted from the arithmetic means /FIG. 1./, as might be expected, are considerably differ-

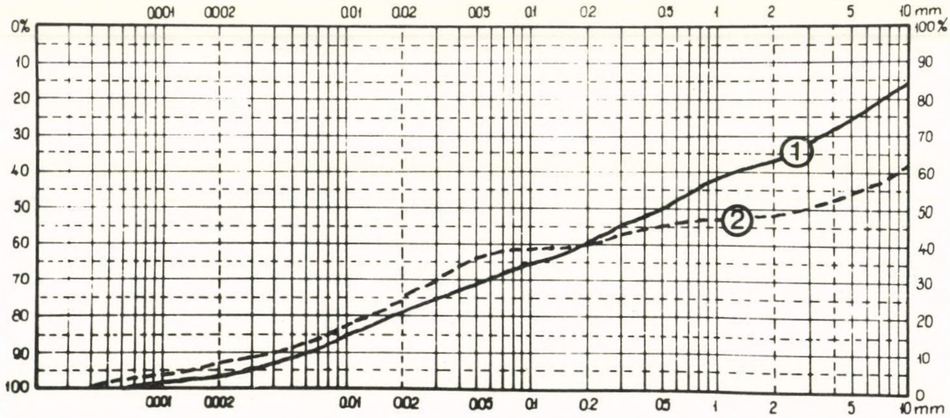

FIG. 1. Grain-size composition curves of samples from talus fields plotted from the arithmetical means.
1: Talus field deposits formed on andesite /4o samples, 56o values/; 2: Talus field deposits formed on limestone /25 samples, 35o values/.

ent percentages of grains larger than lo mm. The two curves meet at grain-size o.o2, then run parallel to each other, which goes to show that the shattering effect of frost is independent of rock type for grain-size at below o.2 mm.

The grain-size curve shows the poorly sized nature of both rock types. The value of sizing for andesite debris /S_o/ is 14.14, and for limestone is even worse: S_o = 24.49, while the symmetry coefficients are o.6 and o.o2, respectively. The data for andesite, however, show the better size-classification of the coarser fraction.

GELISOLIFLUCTIONAL SEDIMENTS DEPOSITED ON ANDESITE AND LIMESTONE

Gelisolifluctional sediments formed on andesite were collected in the Zemplén Mountains, for examination, while those on limestone came for the most part from the Bükk range, and to a lesser extent from the Buda Hills. In this case it was necessary to be more cautious in sampling. Whereas in talus fields the grain-size of the finer Pleistocene material found between the larger blocks is generally representative of the original composition and has undergone little alteration soils have formed on the gelisolifluctional material covering the slopes. Therefore, the grain-size composition of levels A and B has been considerably changed by soil-formation process. This is why the samples were taken from C level without exception which still preserves the original grain distribution from the Pleistocene.

On the basis of a comparison of the arithmetic means of 67 andesite samples with those obtained from 23 limestone samples, the following identities and differences can be drawn /TABLE II./ For andesitic materials the percentage occurrence of grain-sizes above lo mm is less than the corresponding values derived from the talus fields, which is a consequence of a further fractioning of the andesite. As a result of this grain sizes of between lo and 4 mm from the largest category. By contrast in the case of materials formed on limestone grain size above lo mm still form the largest category somewhat larger indeed than the corresponding values obtained from the talus fields. The percentage of grain-sizes falling into the less than 4 mm category decreases gradually in the case of andesite but quickly with limestone, and similar interruptions to those occurring in the talus field material can be observed, although they are even more pronounced in the next category. Thus, in the andesite series the higher percentage category o.63--o.2 mm, is surpassed by the contribution of the o.2--o.1 mm category. Similarly, the percentage of grains falling into the o.o5--o.o2 mm class is higher than that the previous category, but is again surpassed by the percentage in the o.o2--o.ol mm group. In spite of the fact that, as a result of migration along the slope, finer soil particles from an earlier geological time may have been admixed, the proportion falling in the clay fraction was not essentially different from the values obtained for the talus fields.

TABLE II. Characteristic values of the grain-size composition of gelisolifluctional sediments formed on andesite /67 samples/ and limestone /23 samples/

Grain size in mm	lo	lo-4	4-2	2-1	1-o.63	o.63-o.2	o.2-o.1	o.1-o.o5	o.o5-o.o2	o.o2-o.ol	o.ol-o.oo5	o.oo5-o.oo2	o.oo2-o.ool	o.ool
Gelisolifluctional slope sediments on andesite														
Arithmetical mean /x=/	11.3	11.46	7.72	5.86	4.42	8.o4	lo.o6	5.68	7.93	9.32	7.69	5.69	4.lo	2.87
$x_{max.}$ 1/	7.o6	21.5	27.6	15.5	15.5	26.3	17.9	lo.6	26.6	15.7	12.3	14.9	9-6	25.4
$x_{min.}$ 2/	o	o	o.5	o.8	1.3	4.3	1.3	o.6	2.3	1.1	o	o	o	o
Standard deviation	14.o7	12.lo	6.45	3.97	2.75	5.48	lo.77	2.86	6.21	3.91	3.46	3.o8	3.o6	2.o8
Gelisolifluctional slope sediments on limestone														
Arithmetical mean /x=/	39.47	11.99	3.31	1.37	o.99	1.26	3.92	3.23	9.13	9.66	7.16	4.81	2.31	3.39
$x_{max.}$ 1/	78.7	28.8	13.3	5.4	3.2	5.2	12.7	8.6	18.9	21.1	16.3	9.5	7.5	lo.4
$x_{min.}$ 2/	12.9	2.o	o.3	o	o	o	o.3	1.1	1.1	2.8	1.4	1.1	o.3	o.5
Standard deviation	15.o6	7.33	3.41	1.47	1.o	1.3o	3.32	1.96	4.99	5.o2	4.17	2.48	1.67	2.18

1/ Highest percentage value for each category

2/ Lowest percentage value for each category

In the case of andesite this value in one and a half times higher, whereas on limestone it is almost identical.

On studying the gelisoliflunctional material of polar areas GRAF, K. found that the percentage occurrence of the fraction below o.ol mm was 15--2o% and on examining the same grain size in Hungarian, i. e. fossil materials, a high degree of similarity with graf's data was found, the arithmetic means being 2o.35 and 17.67 per cent for in in areas built up from andesite and limestone respectively.

Examination of the maximum and minimum percentage occurrences indicates that for the first two categories, the highest values are found in limestone areas as was the case with the mean values, but thereafter the andesite values are considerably higher. The two exceptions are the categories o.o2--o.ol and o.ol--o.oo5 mm.

As for the minimum percentage occurrences, the data from the limestone areas are invariably lower. However, it is striking that while the value is o% in nine of the talus field categories, with the gelisolifluctional materials only in three.

The variance data support the above relationships. The variance for grains above lo mm is higher on limestone, but thereafter the relationship is reversed, the exceptions being only the categories o.o2--o.ol and o.ol--o.oo5 mm. It is also interesting to note that the variance for limestone is markedly lower,which would suggest that intra-category fluctuations are less than for andesite based material.

The grain-size distribution curves plotted from the arithmetic means /FIG. 2./ are similar to those derived from the talus field samples. The coarse fractions on the two curves are quite far from each other, but thereafter they curves gradually approach each other meeting at the fraction o.1 mm, and then following practically identical paths.

Size-classification values as well as symmetry coefficients have also been calculated for the two types of material. The result was suprising in that virtually the same values were obtained as for the talus field material, i. e. 14.4 and 24.49 for andesite bared and limestone based material respectively. Thus, in both cases the sizing of the material is very poor. The value of the symmetry coefficient was 2 for andesite, o.oo96 for limestone. In the first case the fine fraction is better sized as compared to the coarse, whereas with limestone the case is reversed, and the coarse fraction is the better sized.

AN EXAMINATION OF THE MATERIAL MAKING UP FROST POLYGONS

Lastly, the grain-size composition of polygons has been examined on the basis of samples taken from inside the polygons, i.e. samples of the fine fraction. The small number of samples collected did not permit an analysis using the above classifica-

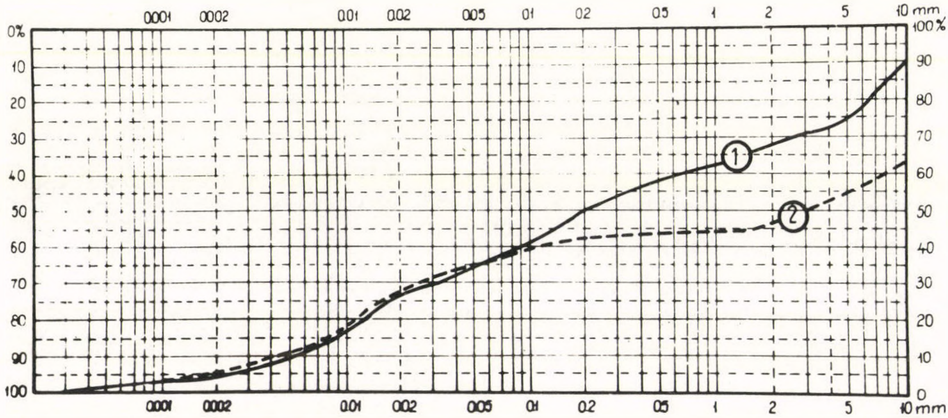

FIG. 2. Grain size composition curves of gelisolifluctional sediments plotted from the arithmetical means.
1: Gelisolufluctional sediments formed on andesite /67 samples, 938 values/; 2: Gelisolifluctional sediments formed on limestone /23 samples, 322 values/.

tion. Instead, the material making up three polygons found in the Zemplén Mountains and that from one found in the Buda Hills, was compared with material collected from five polygons in Lapland / Finland/ and Norway. A characteristic they all had in common is that each was formed on hard rock /TABLE III./. The percentage of clay fraction, both in recent and fossil polygons is low /3 and 5.7%, respectively/. In the case of fossil polygons grains ranging from o.63 to o.2 mm in size occupy the largest percentage, with a second maximum appearing in the o.o5--o.o2 mm grain-size categories. This is again similar to the talus field debris provided only the sand and of finer grained material are taken as the basis for comparison. With recent polygons the highest percentage occurrence falls to grains of o.2--o.1 in size whereas the secondary maximum appears in the o.o2--o.ol mm category. On the other hand, the share of category o.o5--o.o2 mm is nearly identical. It is worth noting that the percentage weight of material in the o.63--o.ol mm grain categories amounts to more than half the total material comprising the polygons, being 57.92% in the case of recent polygons and 5o.31% for fossil polygons. These values are in agreement with the data that has already been published in the literature. DÜCKER, A. /1937/ reports that the polygons of the Riesengebirge are characterized by an absolute predominance of grain in the o.1--o.o2 mm size category. In Hungary in terms of the arithmetical means this grain-size amount for 22.84% of the material in fossil polygons.

27.6 per cent was the maximum value /x_{max}/ found in the fossil polygons which fell into the o.63--o.2 mm category, in recent ones the corresponding values were o.o2--o.ol mm /23.7%/, and o.2--o.1 mm /23.4%/. As for the minimum occurrence /x_{min}/ we

TABLE III Characteristic values of the grain-size composition of material collected from inside polygons

Grain size in mm	lo	lo-4	4-2	2-1	1-o.63	o.63-o.2	o.2-o.1	o.1-o.o5	o.o5-o.o2	o.o2-o.ol	o.ol-o.oo5	o.oo5-o.oo2	o.oo2. o.ool	o.ool
Recent polygons														
Arithmetical mean /x=/	4.o6	7.64	3.82	7.32	5.81	lo.86	12.68	11.34	11.5o	11.54	7.o4	4.5	1.98	1.o6
$x_{max.}$ 1/	12.1	14.6	7.1	lo.7	8.3	13.o	23.4	16.9	16.2	23.7	16.5	9.7	2.7	2.9
$x_{min.}$ 2/	o	o	o	5	3.2	8.1	4.2	6.2	7.4	6.4	2.4	1.4	1.2	o
Standard deviation	4.34	4.85	2.26	2.52	1.9o	1.66	7.96	3.87	2.91	6.34	5.18	3.o6	o.56	1.31
Fossil polygons														
Arithmetical mean /x=/	7.9o	6.oo	5.25	5.oo	6.55	15.15	8.38	7.55	12.o3	7.2o	5.43	6.95	2.9o	2.8o
$x_{max.}$ 1/	22.8	12.2	8.3	8.3	9.7	27.6	13.7	12.4	16.1	11.3	8.7	lo.8	6.6	4.8
$x_{min.}$ 2/	o	2.4	1.6	3.6	3.4	5.5	5.1	3.8	8.7	o.9	3.6	3.4	o.4	1.3
Standard deviation	9.o2	3.99	2.79	1.93	2.25	7.94	3.49	3.15	2.65	3.9o	2.o9	3.ol	2.45	1.26

1/ Maximum percentage value for each category

2/ Minimum percentage value for each category find o% in 4 categories in recent and in 1 category among the fossil polygons.

The analysis of variance also confirms these findings, the highest standard deviations occurring in fossil polygons at o.63--o.2 mm /= 7.94/, and in recent polygons at o.2--o.1 / = 7.96 /, and o.o2--o.ol mm / = 6.34/.

The grain-size composition curves plotted from the arithmetical means for fossil and recent polygons are represented in FIG. 3. The two curves is almost identical. This shows that the ef-

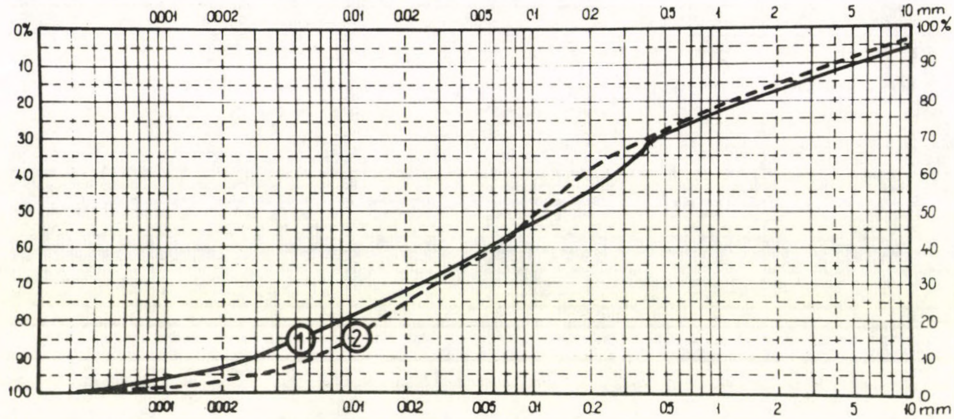

FIG. 3. Grain-size composition curves of polygons deposits plotted from the arithmetical means.
1: Fossil polygons deposits from Hungary /4 samples, 56 values/;
2: Two recent polygons deposits /Lapland and Norway; 5 samples, 7o values/.

fect of frost is to shutter rocks to nearly identical grain sizes regardless of hardness. The curves also indicate in terms of weight, that the finest grain sizes are somewhat less well represented in recent polygons. This can be perhaps accounted by the fact that the material of fossil polygons has already been exposed to a long period of weathering during the Holocene period.

Judged by the size classification values, the material of both recent and fossil polygons is poorly sized. This value for fossil polygons is 8.1 and for recent ones 5.9. It should be noted, however, that their values were markedly worse in the case of the talus field and gelisolifluctional deposits.

The symmetry coefficients for the two materials are again at variance. With the fossil materials it is the coarse fraction that is somewhat better sized /S_k = o.66/, whereas with the recent polygons it is the fine fraction that is better sized /S_k = 1.4/.

SUMMARY

From the analysis it is possible to draw the following conclusions:

- Grain-size studies on periglacial slope sediments of andesite and limestone composition from Hungary and partly from Scandinavia show that the influence of frost-induced fracturing is similar. It is by and large independent of the type of rock, which only has a slight effect on grain composition, resulting in some refinement.

- The production of large blocks is characteristic of andesite. Whereas limestone areas are rich in pebble-sized debris of lo--2o mm diameter.

- During the Periglacial period the process of weathering is either absent or greatly reduced in extent. As a result of this, the clay content of our samples was small. In percentage terms the clay content of the deposit still in situ was 3--5% and of that redeposited on the slope, 5.7--6.9%.

- As a consequence of frost-induced shattering the fine-grain sand and loess /rock flour/ fractions, i. e. grains of o.63--o.ol mm in size, come to form the highest percentage category. It is also in these categories that we always find the maximum and the secondary maximum values. More than half the material comprising the polygons/57.9% for the recent and 5o.3% for the fossil variety/is composed of grains in this size range. Such grains also form a considerable part of the talus field deposits /36.49 for andesite and 28.2% for limestone/ and of the gelisolifluctional material too /41.3 and 27.2%/. It is interesting that in both cases the values are considerably higher for the andesite based deposits probably due to the faster rate of rock shattering.

- The manner in which the maxima and secondary maxima of the arithmetic means are distributed within the four mentioned categories have also been examined. From the material of the forms described 2 maxima fall in the o.63--o.2 mm grain-size category, 2 in the o.2--o.1 mm category, 1 maximum and 4 secondary maxima in the o.o5--o.o2 mm category, adn 1 maximum and 3 secondary maxima in the o.o2--o.ol mm category. The two highest percentage values did not occur within the o.1--o.oo5 mm grain size category.

- On examining the grain-size categories we can observe that the percentage of each grain size tends to decrease gradually with andesite and rapidly with limestone. This general trend is interrupted twice, however, and the percentage values are higher in the o.63--o.2 and o.o5--o,o2 mm grain-size categories of the talus field deposits and in the o.2--o.1 mm and o.o2--o.ol categories of the gelisolifluctional material. Such an increase in value is also manifested by the polygon deposits by the o.2--o.1 mm and o.o2--o.ol mm categories for the recent polygons, simi-

larly to the gelisoliflluctional sediments, in the fossil ones and by the o.63--o.2 and o.o5--o.o2 mm categories for the fossil polygons, similarly to the talus field deposits.

- The effect of rock type on frost-induced shattering is reflected in the changes in the maximum and minimum percentage values and in the variance. On andesite, with the talus fields the maxima are much higher in the grain-size categories above o.o5 mm and with gelisolifluctional sediments above o.o2 mm. At the same time in the case of grains finer than that the values are nearly identical for both andesite and limestone,with a tendency for the limestone values to be the higher.

- The minima in talus field deposits always occur on limestone, but with gelisolifluctional sediments the minima display little difference between those bared on andesite and those bared on limestone.

- The analysis of variance is consistent with the above findings. In the categories above o.o5--o.o2 mm, the standard deviation is much higher on andesite than on limestone, while for the finer fractions the values are similar.

- From this it follows that the percentage composition of the coarse fraction varies little from sample to sample on limestone, i. e. the grain-size composition of different samples is similar. By contrast, in the andesitic material the corresponding percentage varies within wide limits. On the other hand, with the fine fraction, it is the limestone-based materials that show the greater variability.

- The various grain-size composition curves show great similarities. All 6 curves follow diagonal paths, which demonstrate frost-induced shattering, and the poor degree of sizing of the material. /The changes in the direction of size classification are shown by the curves for the polygons./ The curves run together from o.1 mm on, in the case of the talus field deposits from o.2 mm, showing that this rock was shattered by the effect of frost, to this and even smaller grain sizes.

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THE ROLE OF GEOMORPHOLOGICAL FACTORS IN THE EVOLUTION OF THE PLEISTOCENE CRYOPLANATIONAL FORMS OF THE NORTHERN HUNGARIAN MOUNTAINS

CSORBA, P.

In the evolution of the present-day geomorphological picture of Hungary a considerable role has been played by the Pleistocene Periglacial period. The extremely cold climate which returned several times, resulted in new qualitatively different gradational and depositional forms. These forms and sediments can be equally found in plain, hill and medium-hight mountainous regions. Due to the change in climate during the Holocene, the sedimentary forms have lost some of their original character, especially on the Great Plain. Despite this, however, there are still places, primarily in the higher parts of the medium-height mountains where, even today, the specific richness of Periglacial forms is preserved.

In the northern part of Hungary there is a range of mountains with peaks at between 6oo and 1ooo m, the periglacial forms and sediments of which have been investigated by several researchers over the last thirty years. Of primary interest is the work of KEREKES, J. /1941/, LÁNG, S. /1955/ and PÉCSI, M. /1961a, 1961b, 1963, 1964, 1966/, together with the more detailed studies of PINCZÉS, Z. /196o, 1974, 1977, 1979, 1981/ and SZÉKELY, A. /1961, 1965, 1969, 1973a, 1973b, 1977/. The latter works are especially valuable since the investigations were performed in mountains of varied types. Thus PINCZÉS, Z. compared the cryogenic forms of the limestone mass of the Bükk Mountains with the forms of similar origin found in the volcanic Zemplén Mountains, while SZÉKELY, A. correlated the periglacial forms of the Buda Hills with the examples in the Mátra.

The present work builds on the results of the above mentioned authors, in attempting to assess the extent to which the evolution of periglacial cryoplanation forms is determined by various factors, namely rock type and structure, the tectonic conditions, exposure, the microclimate, drainage system and soil and vegetation. An assessment is made of these factors that play a primary role, and those that are only of secondary importance.

THE CRYOPLANATIONAL FORMS

Cryoplanational processes have given rise to a number of characteristic degradational and depositional forms. The most striking gradational formations are the frost-riven cliffs and the bare rocks walls that have retreated due to cryoshattering attain a maximum height of 2o-25 metres in Hungary. Frost-riven cliffs, however, only rarely form long, continuous features and more characteristically take on a broken columnar form. According to DEMEK, J. /1969/ the receding cliff disintegrates into solitary columns at the summit level and at the same time, decreases in height. A good example of this stage of evolution in Hungary is the Penge-kő in the Zemplén Mountains. The retreating cliff leaves behind a gradually widening surface, which itself is a degradational form, although it is nearly always covered by a talus field. Each surfaces, which in Hungary attain a maximum width of 8o-1oo m and length of 1oo-2oo m are formed frost-riven steps or terraces[x]. Their common characteristic is that their slope is considerably gentler /5-1o^{o}/ than that of the mountain-side, while they are covered by fractured debris.

Depositional materials and forms are also highly varied. If the debris is produced locally, then we speak of a block field. The material of block fields is no longer mobile, and is usually the depositional form on summit levels with gentle slopes. The size of block fields is varied and they can cover areas 2o-1oo m in diameter.

The escarpments of frost-riven cliffs are even today fractured by frost action and large quantities of talus are thus produced. On the step formed by frost action in front of the cliff a talus field is formed under the influence of gravity. This type of accumulation is that most frequently occurring and contains the most varied forms of debris. At the same time is relatively small in size with a width of 2o-4o m., but its length is a function of the size of the cliff. When the shattered debris migrates far along the slope, and covers the mountain side, it is called a talus mantle, which may be as long as 1oo-2oo m. In the zone of such mobile talus large block slides can be found, which may attain a size of 2x3x1 m. Other mobile debris variants include stone streams and stone strips /PINCZÉS, Z. 1974/.

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[x] Frost-riven terraces are larger than steps, have a gentler slope and are covered with finer debris.

The mixture of cryoplanational forms surveyed in the foregoing is different on every peak and slope, but a detailed survey demonstrated that one or two forms are dominant at each place. At the same time basic elements such as frost-riven cliffs and talus field may be completely sedimentary and subordinate. A cryoplanational ensemble of forms, in which all the various elements can be equally found is rare. On analysing the different arrangements of forsm, we can state the factors that shape the forms at a given place. In the following the significance of these will be illustrated with the use of a few examples.

THE ROLE OF ROCK TYPE AND STRUCTURE

The effect of rock type can be hardly investigated independent of the conditions of settlement. True, rocks differ from one another in their sensitivity to frost, one of the main factors here being the proportion of fine-grained mineral components. When comparing the various forms and sediments the important factors are the horizontal bedding and vertical joint pattern. If a rock is shattered into very small fragments no sharp cryoplanational forms are produced, and uniform accumulation deposits come into existence. Such rocks are dolomite, and to a lesser extent lamellar limestone and soft volcanic rock /e. g. rhyolite tuff - PINCZÉS, Z. 1974/.

The material of typical cryoplanational forms and sediments is derived from thinly bedded rocks, out of which andesite is prominent. Andesites in fact comprise a significant component of the Visegrád Mountains, Börzsöny, Mátra and Zemplén Mountains which helps account for the fact that it is in these mountains that the largest frost-riven cliffs and steps are found and since andesites withstand mechanical and chemical weathering relatively well, large talus mantles have also formed. In the case of a thinly-bedded limestone the cryoplanational forms are somewhat more moderate than those produced by andesites, and the accumulation forms, due to copious debris formation, are widespread. Large talus fields and talus mantles are found for example, in the Buda Hills /SZÉKELY, A. 1969/ and in the Bükk Mountains /e. g. Odorvár/.

In the limestones and the volcanic lavas are of block structure cryofracturing is slow debris production small, and the cryoplanation forms are poorly developed. If, on the other hand, the presense of vertical joints yields possibilities for frost activity, exceptionally large talus fields with columnar blocks may form. A good example of this can be found near Füzér in the Zemplén Mountains.

A specific case occurs when the conditions suddenly change although the baserock remains the same. Numerous examples of that can be found in the Zemplén Mountains. On Sólyombérc, for example, the upper part of the cliff consists of thinly-bedded pyroxene andesite, whereas the lower part of the cliff is more of block character. In this case the replacement of debris is slow, and the block structure slows down the cryoplanational process.

The evolution of cryoplanational forms is always started by cryofracturing processes attacking the escarpments, which are ideal points for the destructive activity of frost. Large frost-riven cliffs have therefore always formed where escarpments are found. The layers have counter-slope on the face of the cliff. According to our measurements, the slope of these layers is generally 15-3o^{o}. Where slope angles are larger than this /3o-4o^{o}/ the cliff is no longer perpendicular, for instance Nagy-Hemzső in the Zemplén Mountains. The foot of the 8-lo m high cliff protrudes 2-4 m further that the summit and the cliff has taken on a stepwise form.

THE IMPACT OF STRUCTURAL CONDITIONS

The possibility as for the evolution of cryoplanational forms is determined by the rock type. The spatial arrangement of forms and deposits, however, possesses features, that can be traced back to the overall structural and tectonical conditions of the whole mountain range. In the northern part of the Zemplén Mountains, in the triangle enclosed by the settlements of Telkibánya, Regéc and Ujhuta, a detailed survey was made of the spatial arrangement of cryoplanational forms. The summits of the mountains here everywhere consist of thinly laminated pyroxene andesite. Apart from petrological and stratigraphical similarities the pattern of the frost-riven cliffs shows a surprisingly small degree of scattering. In particular, eastward directions are predominant /FIG. 1/. This circumstance raised the question as to wheather eastward exposure may have been favourable for the evolution of the cliffs. An analysis of the geology of the region /GYARMATI,P. 1977/ established that the rocks of the mountains studied by us may have originated from the same eruptive centre, supposedly located SW of our region, although the individual lavas do not always reflect the original direction of flow. In fact, during the Pleistocene there were significant tectonic movements in the Zemplén Mountains, which later modified the original dip of the strata. On Nagy-Hemzső the strata dip northwards, and their escarpments thus face southwards. On Sólyombérc, east of the eruptive centre, the strata dip eastwards, corresponding to the original direction of flow and the escarpment cliff runs westwards. Later movement can be inferred in the region of Szarvas-hegy, and Nagy- and Kis-Pétermennykő, since here the strata do not uniformly follow the assumed original direction of dip.

The lava flows entered the region mostly from the south, southwest and east, although by assuming later movements, the eastward direction is the most frequent. Thus, the evolution of eastward running frost-riven cliffs is not a function of their easterly exposure but rather of the out-cropping escarpments. The intensity of cryofracturing in the evolution of the cliff is thus connected not so much with the direction of exposure as with the outcrop of the escarpment.

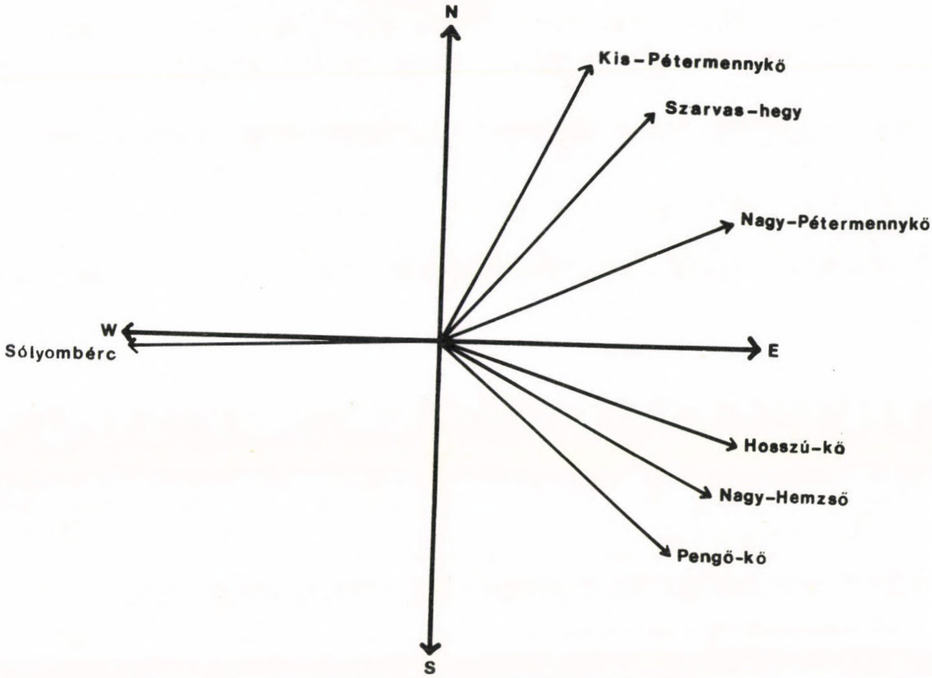

FIG. 1 Exposure of frost-riven cliffs

In spite of all this we can cannot rule out the modifying role of exposure either. In fact, under periglacial conditions the north-east slopes must have been exposed to more severe micro-climateic effects than those facing south, and the snow that accumulated during winter may have remained here for a longer time during the spring thaw. Freeze-thaw conditions may have occurred not only during the transitional seasons, but during summer too, owing to unfavourable radiation conditions, while the moisture indispensable for gelisolifluctional or solifluctional movements was also available for the greater part of the year.

As to the role of relief asymmetry arising from mountain structure there are references in the literature to this in connection with the Mátra and Börzsöny /SZÉKELY, A. 1969/. The slopes evolving on the northern side of the Mátra and on the escarpments on the eastern side of the Börzsöny are shorter and steeper. Here debris moves more quickly and typical talus mantles have accumulated in the piedmont areas. The South-Mátra and West-Börzsöny slopes, which are larger due to structural reasons and also gentler are characterized by a qualitatively different kind of debris which has become finer through slow resedimentation.

EFFECT OF OTHER MODIFYING FACTORS

The evolution of valley networks through the exposure of escarpments also increase the possibilities for frost action. From the location of the frost-riven steps and terraces some tendencies can be seen in the region under study. Frost-riven steps or terraces do not necessarily occur in front of the frost-riven cliffs. Where no such form is found, a steep slope of 25 to 3o^{o} runs towards the local erosion basis. The steep slopes lead to the most deeply incised stream valleys, for instance Kemence-stream and Köves-stream. If frost-riven steps, perhaps terraces ever existed, on these slopes, for example, the north-east slope of Kis-Pétermennykő and the south east slope of Hosszukő, they fell victim to postglacial, Holocene erosional processes. Frost-riven steps occur today on the less steep slopes and these usually overlook slightly incised tributary valleys as at Szarvas-hegy and Pengő-kő.

The evolution of the cryoplanational forms may also have been influenced by another surface-forming process. On the southern margin of the Bükk plateau there are distinctive morphological forms such as Zsérci-Nagy-Dél the evolution of which can be attributed to the combination of karst and periglacial processes. Cryoplanational frost-action produced a large amount of limestone debris and the debris filled up to depressions that evolved during pre- or interglacial periods. The depressions linked up along the southern margin of Nagymező were opened up by headward erosion or frost action, and through these widening features gelisolifluction and solifluction processes transported the debris to the western slopes of the mountains. Accordingly, today we find depressions opening onto the southern arc, which are filled with periglacial debris to form flat surfaces. In the majority of cases, towards the southern foreland we find two or three series of periglacially re-formed depressions arranged stepwise one below the other, through which progressively finer continuous debris flows moved downwards.

It is also possible that the cryoplanational forms were altered by the vegetation on the periglacial surfaces Alpine rock grasses grew on the northern slopes of the mountains during the coldest periods, which may have helped stabilize the debris. However, such effects can only be established by very detailed stratigraphic examinations. The sparse wooded vegetation of the summits /Pinus cembra, Pinus mugo, Larix sp./, and even more so of the southern and southwestern slopes, which have more favourable climatic conditions, may also have influenced the movement and accumulation of debris. Some cryoplanational forms may still be influenced considerably by vegetation. The surfaces of the autochtonous blockfields of the summits are covered in many places with a rich moss vegetation, and chemical action associated with biogenic processes rounds off the edges of the originally sharp stones. This biogenic effect results in conspicuous differences between different parts of the talus fields. For instance, at the centre of such fields, the debris is a bare pile of rocks and the stones have sharp eges, whereas on their margins where the influence of tree foliage is felt, the stones are covered by cushions of moss and the surface of debris is rounded off. Through the mediatory role of the cushion of moss, the foliage, by regulating irradiation and moisture, shapes the stone surfaces as well, for instance, at Nagy-Hemzső in the Zemplén Mountains.

Lastly reference should be made to the fact that the evolution of cryoplanational forms may be modified by the soils formed during interglacial and interstadial periods. If the derbis produced by cryofracturing is not transported away from the area of formation, it then serves to protect the underlying intact parent rock from the effect of frost action, and the morphological status quo is preserved. In other words for the rapid development of cryoplanational forms not only is intensive debris formation necessary, but also transport away from the source area is a further precondition. Transport was facilitated by the existence of a fine fraction created during the soil formation processes of interglacial and interstadial periods.

PLEISTOCENE CRYOPLANATIONAL FORMS FROM THE ZEMPLÉN MOUNTAINS /SZARVAS-HEGY/

To show the spatial arrangement of the fossil cryoplanational forms and deposits, an example was chosen which is fairly complex, but at the same time can illustrate the majority of the aforesaid characteristics. Szarvas-hegy /FIG. 2/, a peak in the central area of the Zemplén Mountains, is built up of thinly-bedded pyroxene andesite. It is 6oo m high. The escarpments face NE, and the southern slope of the mountain falls steeply to the Vajda-valley.

The summit level of the mountain is a slightly undulating surface loo-12o m in diamter, which is largely covered area by autochtonous block field, consisting mainly of stones of 4o-5o cm diameter. The north east margin the summit level is made up of a frost-riven cliff, lo-12 m high at its highest point, which begins at it western end as a step 1-2 m in height. The central highest section of the cliff is dissected into stone bastions of 6-8 m in width, while talus debris is found among the rock turrets. The counter-slope of the cliff is between 14-25°. The cliff describes a mild arch upon eastward direction and ends as isolated stone bastions. A frost-riven step along the whole length of the front of the cliff has been formed, having a width of 2o-4o m and on average slope of 8-15°. The slope of the talus field abutting against the foot of the cliff is 24-28°, and is covered with fairly coarse debris of mixed composition, from large blocks /1-2 m diameter/ to stone of 2o cm diameter. There is intensive movement of debris at the eastern end of the cliff, since this section drops steeply, towards the slope leading to a lower-laying frost-riven terrace. This slope is 4o m wide, and has an angle of 3o-34°. The lower-laying frost-riven terrace has width of 6o-8o m, a length of 15o-18o m and slopes of

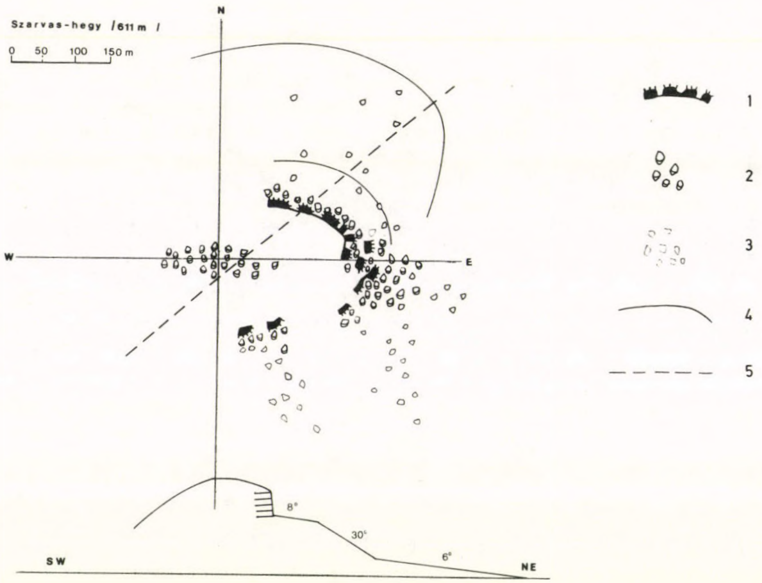

FIG. 2 Spatial location of cryoplanational forms and sediments on Szarvas-hegy
1: frost-riven cliff; 2: autochtonous block field, talus field; 3: talus mantle; 4: frost-riven step or terrace; 5: line of cross action.

6-1o° in a north east direction. The surface here is already covered by a highly detrital skeletal soil. In addition to the debris consisting of 5-15 cm diameter stones, which form the skeletal soil, there are several huge blocks, still in one piece, that have moved away from the cliff. Beyond the terrace the mountain sides slopes gently towards a weakly incised tributary of the Vajda valley.

The frost-riven cliff and step ends on the eastern side of the mountain, where they are replaced by slope covered of highly mobile debris. This material is characteristically more uniform than the debris on the frost-riven step and the majority of stones are of 2o-3o cm diameter. The bassets face north east i. e. on the south eastern side frost has already disintegrated the laminar plates. The debris originating from the laminar plates, owing to the thinly-bedded character of the baserock, consists of andesite plates of hard size that can slide along easily on top of one another. On the southern side of the mountain, which falls steeply to the Vajda valley, the frost-riven cliff is missing, and 4o-6o cm high outcropping laminar plate edges are to be found in only a few places. At their front patches of talus mantle occur, while block slides are found on the lower section of the slope. The predominant species of tree on the autochtonous block field of the summit level and on slopes covered by less coarse debris is the beech /Fagus silvatica/. As soon as we reach the coarse debris of the talus mantle, the wooded vegetation is represented by the lime /Tilia platyphyllos and Tilia cordata/ and birch /Betula pendula/.

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ENGINEERING GEOLOGICAL INVESTIGATIONS OF THE LOESS SEQUENCES ALONG THE DANUBE IN HUNGARY

Mrs. FODOR, T. - SCHEUER, Gy. - SCHWEITZER, F.

INTRODUCTION

In Hungary loess and loess-like sediments are widespread and are the most frequent superficial and near-surface rock varieties. Investigations for different purposes, e.g. geomorphological, geological, and engineering geological, are therefore of great importance. During the last few decades in conjunction with large-scale building operations an interest in the engineering geological properties of loesses has come to the fore since given their dissimilarity to other rock types they possess physical characteristics that can have an adverse effect on technical projects.

In the Danubian loess region numerous problems have arisen in connection with the foundations of projects which have required the application of special techniques during the course of building and have provided new tasks for designers and structural engineers alike. The dry near-surface loess stratum, above the groundwater table is free-standing in excavations without timbering which facilities the carrying out of subsurface works, such as the laying of public utilities and the excavation of foundation. By the contrast, loess strata are inclined to slump when moisture to their macro-porosity which requires the protection of trench bottoms against water.

In case of the Dunaujváros power plant and blast-furnaces which have been two of the most significant post-war constructions projects in Hungary, firing and piling compaction were applied to the strongly slumping loess strata to depth of lo m before the completion of the foundations. Due to these operations not only was the void ratio decreased, but the loess structure was also destroyed and its propensity to slump reduced.

Accordingly, it would seem useful to report the results so far obtained from engineering geological investigations of the Danubian loess sequences, and to connect these to the geomorphological research achieved up to now.

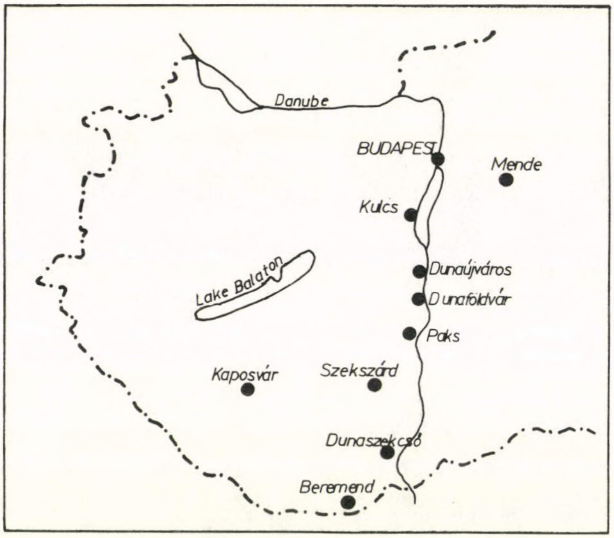


FIG. 1 Location of the most important loess exposures in Hungary

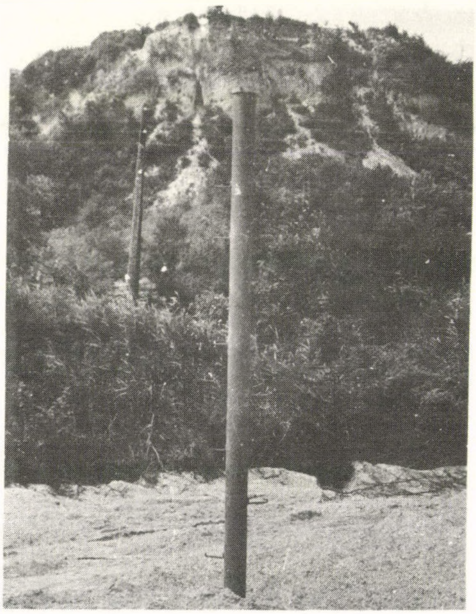


PHOTO 1 Characteristic Danubian bluff at Dunaujváros. In the foreground is a water-table observation well

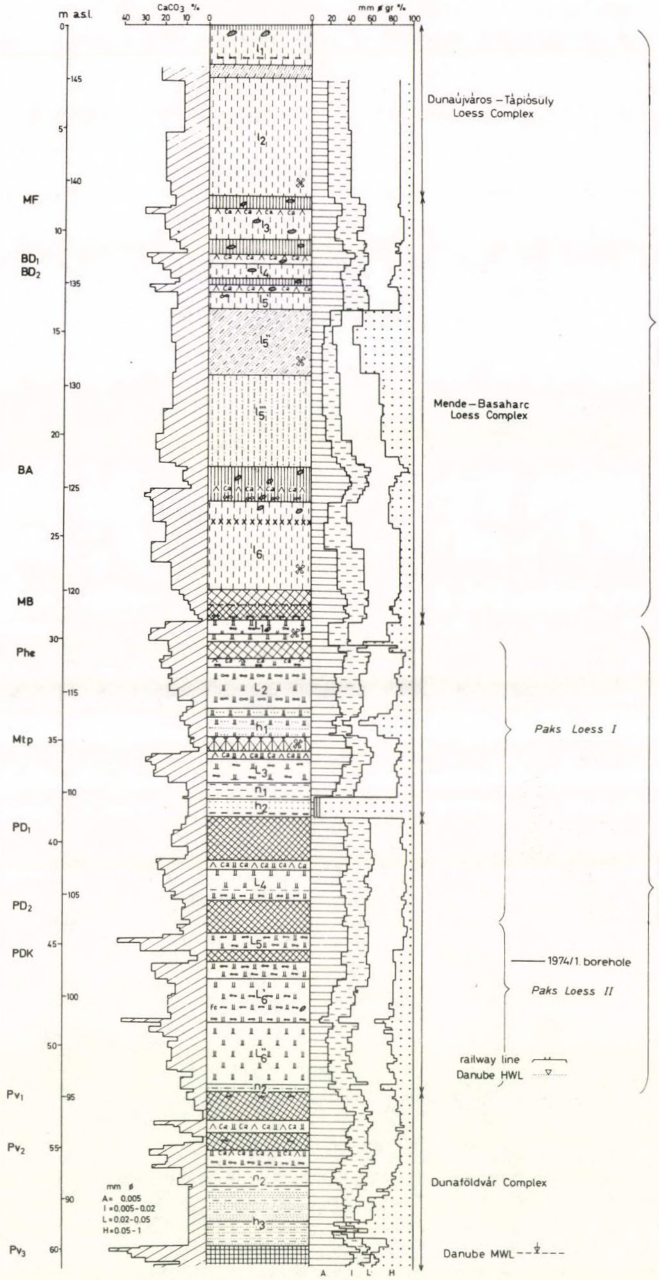


FIG. 2 Loess profile of Paks /1977/ together with the 1974/1 borehole profile /Pécsi, M. - SZEBÉNYI, E./

During the last decade, based on new fundamental investigations and observations, the geological and geomorphological research into loess headed by PÉCSI, M. has progressed considerably. Although these investigations have embraced the most significant loess occurrences in Hungary, emphasis has been placed on the Danube bluffs /FIG. 1, PHOTO 1/ where the Pleistocene loess sequence is most complete /FIG. 2/.

The Pleistocene loess sequences of Hungary together with the equivalent strata and fossil soil complexes have been classified into five loess sequence groups by PÉCSI, M. /1979/. The uppermost part is termed the youngest loess sequence of Dunaujváros-Tápiósüly. It has a thickness of some 5 to 6 metres and as regards age has been placed in the Upper Würm /PHOTO 2/.

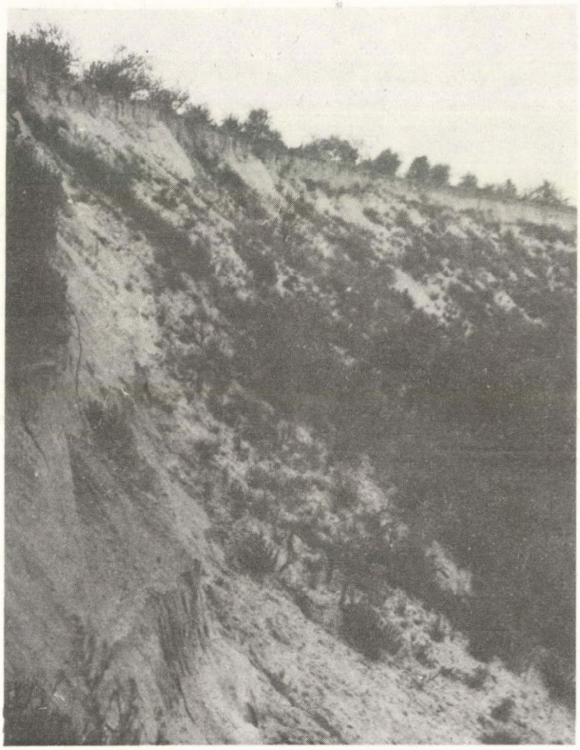


PHOTO 2 Upper loess sequence of the slumped Dunaföldvár bluff

The underlying group of about 2o m in thickness has been distinguished as the Mende-Basaharc young loess sequence in which several fossil soils are found which have been genetically classed as steppe or forest steppe soils. According to PÉCSI, M. the age of the Mende base soil complex can be placed as Riss-Würm, and the overlying loess sequence can thus be assigned to

PHOTO 3 Part of the Kulcs bluff, with older loess strata and red-brown fossil soils.

PHOTO 4 Smaller-scale slide at Dunaujváros

the Würm. The older sequence of about 25 m in thickness which underlies the Upper Pleistocene loesses is believed to be bipartite and can be divided into the Upper and Lower Paks loess sequences. The base of the Pleistocene sequence including the oldest Pleistocene members has been formed the Dunaföldvár sequence. The thick loess sequences described, identified and genetically evaluated by PÉCSI, M. /175-1977/ /PHOTO 3/ are suitable for the carrying out of comparative investigations concerning their soil characteristics since mechanical and stability investigations have been carried out several times on the Danubian bluffs during the last two decades, in addition to the more specific geomorphological research /PHOTO 4/.These data provide not only information on the physical characteristics of the strata making up the loess sequence, but occassionally, through of the recognition of the specific characteristics of each stratum their genetic origin can be evaluated, and a chronology established.

RESULTS

Physical investigations have envolved the determination of the plasticity, consistency, grain-size composition and underwater behaviour of the strata constituting the sequence.Mechanical analysis showed the strata of the Pleistocene loess sequence to be composed of sandy silts, silty sands, silts, sandy muds, muds, and sandy /PHOTO 5/, intermediate and rich clays. At se-

PHOTO 5 Strata of the Lower Paks loess sequence at Dunaujváros, with dessication cracks.

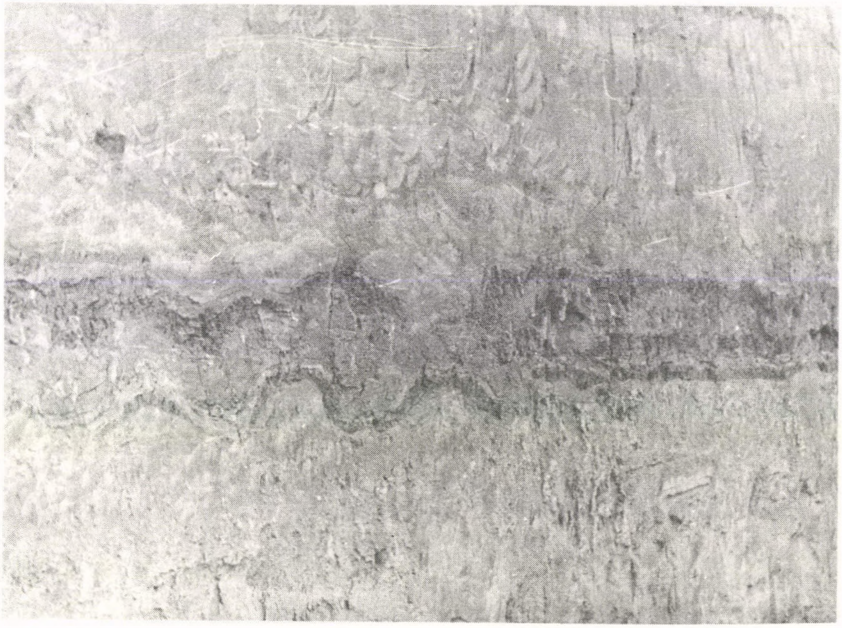


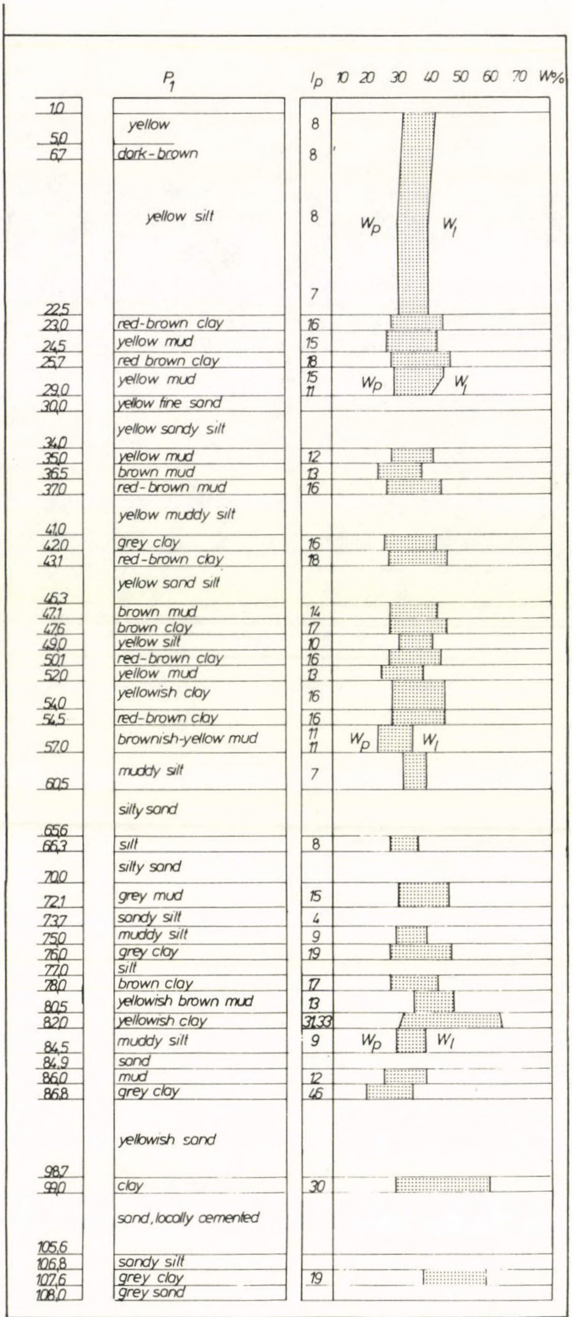
PHOTO 6 Changes of volume of marshy origin and clay-caused strata disturbance at Dunaujváros.

veral sites within the sequence periglacial phenomena, for instance, frost wedges, and strata disturbances caused by volume changes can be observed /PHOTO 6/. The sequence established from borehole P_1 located near the brickyard of Paks is given as an example /FIG. 3/.

When comparing the more than ten thousand available data, the following can be stated:

The Dunaujváros-Tápiósüly Youngest Loess Sequence consists of sandy silts and muddy silts. As to the slump experiments elements within the sequence are either inclined to slump or slump badly and are dangerous. Based on the plasticity index the interbedded humus rich horizons may be described as muddy silts. The strata of the young Mende-Basaharc Loess Sequence proved to be made up of fine sands, sandy silts, silty muds, muddy silts, muds and lean clays.

In harmony with other research, the Mende Upper and Basaharc Double soils, which are genetically assigned as steppe and forest steppe soils, proved to be muds. At the same time, the Basaharc Lower and the Mende Base fossil soils proved to be lean clays, according to their plasticity indices. Void ratios and bulk volume change as a function of depth, the former unambi-



I_p = plasticity index ; W_p = liquid limit ; W_l = plastic limit

FIG. 3 Mechanical and physical profile of the exploration borehole P_1 at Paks.

guously decreasing and the latter gradually increasing. This is also reflected on the slump experiments, since the ability to slumpdecreases as a function of depth and eventually disappears.

Samples taken from the Lower Paks Loess Sequence lying at depth of between 3o and 5o m provided varied results. Strata were described as fine sands, muds, and lean, intermediate and rich lays. The Paks Double Soil Complex proved to consist of lean and intermediate clay according to the plasticity indices. In line with the results from the slump from experiments, the strata of this sequence are nov overly inclined to slum. The void ratio /e/ decreased and bulk volume increase as a direct function of depth.

The physical analysis showed the lowermost Dunaföldvár Sequence to consist of sandy muds, muds and different types of clays. The sandy silts are characterized by lower plasticity values, while the dark-grey hydromorphous and gleyed strata of the fossil soils have medium and high plasticity indices.

CONCLUSION

1. As demonstrated by the investigations the individual strata produced characteristic plasticity values. The plasticity index of fossil soils is higher in all cases than of neighbouring strata and increases directly with depth. On the basis of plasticity the soils of Würm age can be fairly well distinguished from older soils. The hydromorphous and gleyed marshy clays are characterized by high plasticity values /FIG. 4/.

2. Compaction analyses are also suitable for the separation of individual strata. It can be unambiguously stated that the degree of compaction is a direct function of depth, and the highest void ratio is thus found in the youngest loesses. In certain cases, however, sudden changes do occur and can be concluded that considerable hiatus is to be expected within the sequence. The bulk volume and the crushing strength also increase with the age of the strata.

3. From the engineering geological point of view, slumping due to the effect of water, is the most dangerous property of loesses and many investigations have been carried out to obtain exact data as this characteristic. From these data it can be stated that slumping is only associated with the loess of the younger Würm sequence, the Upper Würm Dunaujváros-Tápiósüly loess sequence being most dangerous from the point of view. Ability to slump decreases and eventually disappears as a direct function of age, and is completely absent from the Paks Loess Sequence. This can be obviously explained by the fact that in case of these older strata certain transformations, for instance compaction have taken place, which have favourably altered this extraordinarily dangerous potential feature of loess.

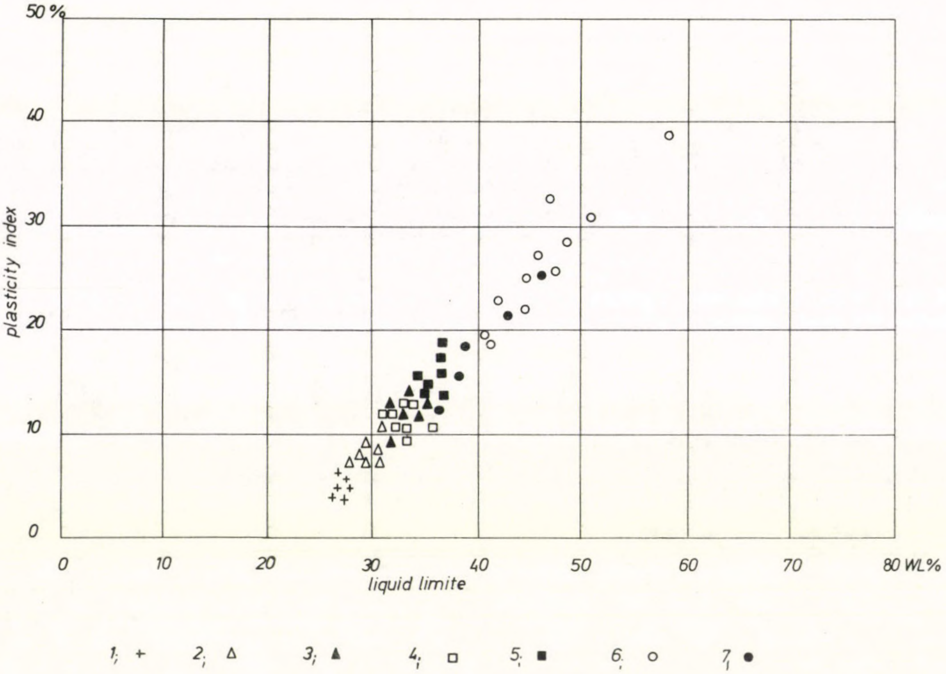


FIG. 4 Arrangement of loessic strata and fossil soils of different age in the Casagrande-diagram
1: The Duanujváros-Tápiósüly Sequence; 2: The Mende-Basaharc Loess Sequence; 3: Fossil soils of the Mende-Basaharc Sequence; 4: Strata of the Paks Sequence. Fossil soils of the Paks Sequence. 6: Fossil soils of the Dunaföldvár Sequence; 7: Other strata of the Dunaföldvár Sequence.

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ENGINEERING GEOLOGICAL EVALUATION OF THE DANGER SURFACE MOVEMENT ON THE RAISED SHORELINES ALONG LAKE BALATON

HORVÁTH, ZS.

INTRODUCTION

The eastern and southern shores of the basin of Lake Balaton from Balatonfüzfő as far as Balatonberény are delimited by raised shorelines elevated by tectonic movements at the end of the Pleistocene. Similar raised shorelines can also be found around the Tihany peninsula.

These raised shorelines have been subject to movement and destruction during the historical past as well. Surface movements were especially rapid at the end of last century, as well as at the beginning of the century, when in the eastern basin of the Balaton large-scale shoreline collapses were generated. In the formation of these surface movements, the destabilizing effect of road and railway construction played a decisive role. It was these movements which directed the attention of the best experts of the country towards the raised shorelines of the Balaton. The outcome of this activity was the undertaking of preventive measures as a result of which extensive shoreline collapses no longer occur.

During the last few decades, however, an increase in the number of minor surface movements can be experienced. The cause of this can be looked for in the inherent instability of the raised shorelines and associated detritus slopes. These problems have been increased by the fact that water supply generally takes precedence over drainage. In many places hill slopes have been undercut and the forest removed. Especially after spring and winter rains as a consequence of this surface movements affecting small areas, but at the same time causing considerable damage to buildings frequently FIG.1.shows the sites of the greatest known shore collapses around the Balaton basin, most of which are seen to be concentrated in the eastern basin.

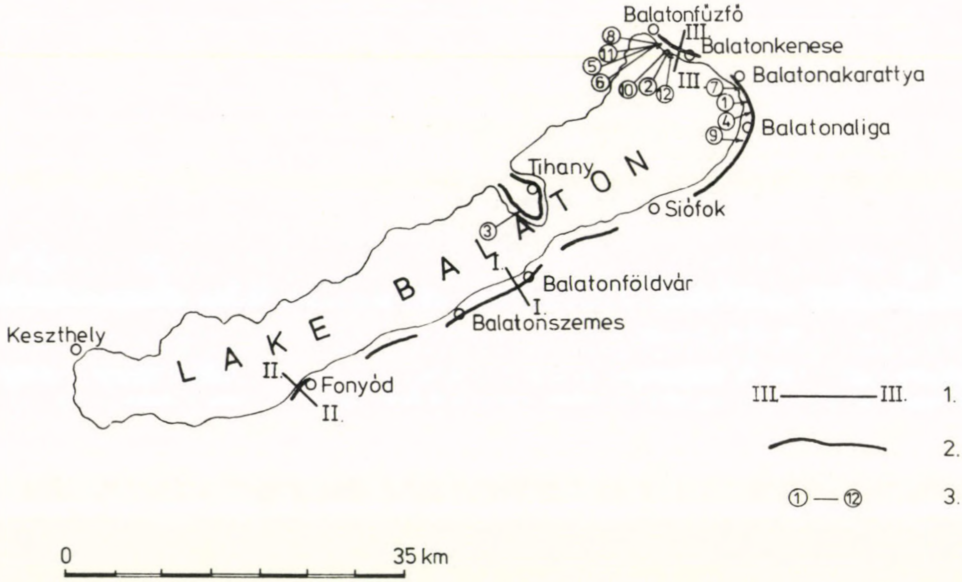

FIG.1. Sketch plan of sites of shore collapses in historical time observed in the Balaton basin.
1 = direction of the engineering geologic profile; 2 = raised shorelines; 3 = place of the shore collapses

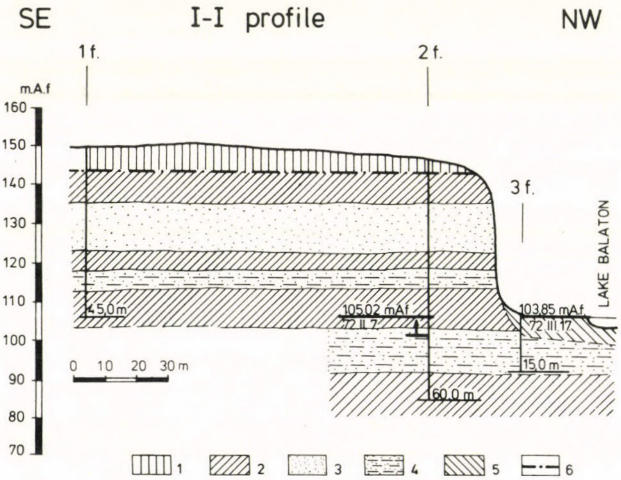

FIG.2. Engineering geological profile of the raised shorelines at Balatonföldvár
1 = loess; 2 = clay; 3 = sand; 4 silty sand; 5 = sediment and upfilling of Balaton; 6 - upper-Pannonian-Quaternary boundary

Between 1875 and 1946 the raised shoreline at Balatonkenese in the eastern basin of the Balaton suffered 7 extensive surface movements. Before the elaboration of the protecting proposals against surface movements the natural endowments of the area were surveyed at several stages. Using the results of these surveys the translocation of railroads and roads were planned and the methods of shoreline stabilization were elaborated. As a result - at least in relation of the undercutting great shore collapses and slides - this raised shoreline section became at last stabilized too.

Small slides and collapses primarily because of human interference, have also occurred frequently in the recent past.

Without giving detailed information about these surface movements it can be stated that in all cases before surface movement occurred either the concentrated drenching of the steep slopes happened, or some other stability diminishing human interference occurred in an area which in any case was in an unstable state of equilibrium.

ENGINEERING GEOLOGICAL EVALUATION OF THE RAISED SHORELINES

As it can be seen from the previous section the raised shorelines of the Balaton did not react in the same way to the great nature transforming activities started during the second half of the last century. With those raised shorelines where the abrasion activity of the Balaton played the most decisive role in the surface movements /at Balatonföldvár, Fonyód/ the efect of human activity regulating the water level of the Balaton /cca 1o5 m above Baltic sea/; the road and railroad; the recreation areas built out between the raised shorelines and the Balaton; - except for small collapses - have stabilized the raised shorelines without any important protective devices. At these raised shorelines the tectonic, morphological, geological and hydrogeological conditions are not favourable for great shore collapses. At those mixed shoreline sections /from Balatonfüzfő as far as Balatonaliga/ where beside the abrasive activity of the Balaton for the tectonic, morphological geological and hydrogeological conditions were favourable for great shore collapses the human interferences diminishing stability /steep slopes, lack of surface and ground water regulation, the dynamic effect of traffic etc./ increased the conditions for occurring surface movements.

I characterize the raised shoreline sections having different parameters from the point of view of the great collapses with the following engineering geological profiles. FIGS.2 and 3 show the engineering geological parameters of the raised shorelines at Balatonföldvár and Fonyód /HORVÁTH,Zs. - SCHEUER,Gy. 1975/ having favourable stabilities from the viewpoint of great shore collapses: FIG.4 presents the raised shorelines at Balatonkenese /DOMJÁN,J. - PAPPFALVY,F. 1963/ which are the most critical from this aspect.

The studied raised shorelines are 5o--6o m above the lake level.

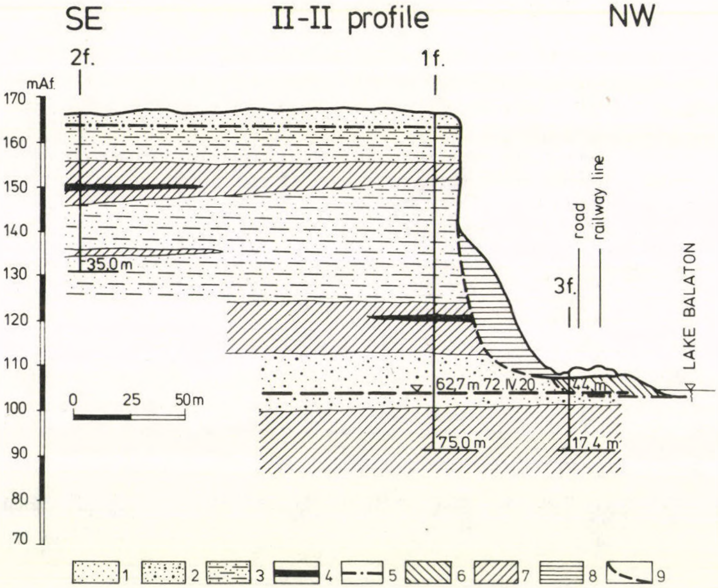

FIG.3: Engineering geological profile of the raised shoreline at Fonyód.
1 = blown sand; 2 sand; 3 = silty sand; 4 lignite; 5 - Upper-Pannonian-Quaternary boundary; 6 = sediment and upfilling of Balaton; 7 = clay; 8 = detritus slope; 9 = slide plane

The upper part of the shore walls is nearly vertical continuing in a steep slope which is the detritus slope of the earlier fallen down and collapsed earth masses where the abrasive activity was the most important factor in the formation of shore collapses, the detritus slope is smaller because the Balaton washed away the earth masses accumulated in front of the shore collapses.

The great detritus slope in FIG.4 proves that the abrasive activity of the Balaton could not keep up with the continuously occurring shore collapses that is to say they were created after the ceasing of the lake's abrasive activity.

The raised shorelines are built up essentially by shallow sea sand from the Upper Pannonian age,by silty sand and clay layers from the same age. Loesses, sands and sandy gravels from the Pleistocene age are sedimented on these formations /FIGS.2,3 and 4/.The raised shoreline at Fonyód is different. The base is formed by Upper Pannonian formations too. However, this series of sediments was broken through basalt-tufa due to the basalt volcanoes of the Balatonfelvidék /Balaton Highlands/, can be seen only on a small area on the castle hill /233 m/

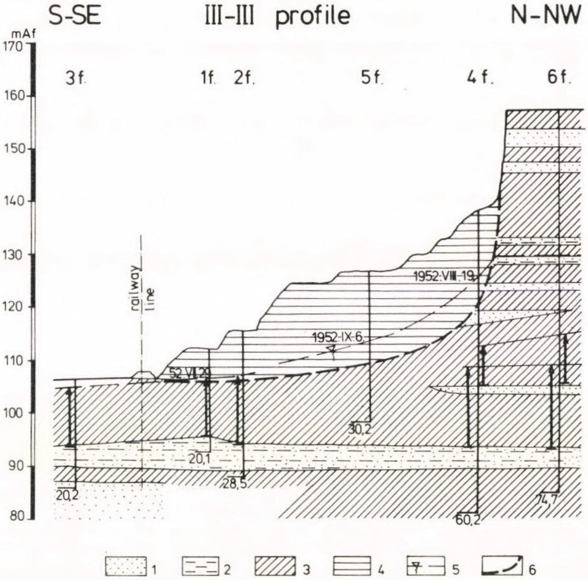

FIG.4: Engineering geological profile of the raised shoreline at Balatonkenese
1 = sand; 2 = silty sand; 3 = clay; 4 = detritus slope; 5 - Upper-Pannonian-Quaternary boundary; 6 = slide plane

and in its near environment. In the foreground of raised shorelines the Holocene detritus slopes /fallen down and collapsed from the raised shoreline/ and the lake sediments /being generally sandy and silty formations/ are located. From the boreholes on the area at the mole of Balatonföldvár HORVÁTH,Zs. - SCHEUER,Gy./1973/ described a gravel layer consisting of limestone basalt and red sandstone gravels, proving the supposition that before the sinking of the Balaton-basin the brooks running down from the Balaton-Highlands and from the Bakony deposited their sediments in meridional valleys similar to the Köröshegy-valley.

If we study the geology of the raised shoreline sections characterized by profiles, we shall find such differences which are not decisive geologically but important from the aspect of stability. While at Fonyód and Balatonföldvár the Upper Pannonian strata consist of sand and clay layers of great thickness, at Balatonkenese the fine layers are characteristic. Here the overwhelming clay layers are densely separated by sand veins and sand layers of little thickness inclining towards the Balaton. The stratification of the soil is very variable especially down to 28--3o m. Clay layers of different colours and plasticity are to be found alternatively with sandflour and sand layers. So called moor levels of dark brown colour are located among these layers too.

The deviations in the geological and morphological-tectonic structure determine that hydrogeological difference which gives an explanation for the different stabilities. While behind the raised shorelines extending from Balatonfüzfő as far as Balatonaliga. There are extended highlands with thin layers inclining towards the Balaton, the highland-like terrain behind the raised shoreline at Balatonföldvár gets narrow and has a very limited extension in the east-west direction. The layers are inclining south-southwest, i.e. not towards the Balaton. At Fonyód we find an island-mount elevating high from its environment, i.e. the possibility of water supply is very limited at the raised shorelines at Balatonföldvár and Fonyód. The previously outlined geological, morphological and tectonic survey provides an explanation for the different hydrogeological situations of the engineering geological profiles in FIGURES 2,3 and 4. As we can see from the profiles, the raised shorelines - both at Balatonföldvár and Fonyód - are dry in their whole depth. The only important water storing layer is the sand on the lower part of the raised shorelines in which the statical level of the layer water was lo5,o2 m above Adriatic sea /8.2. 1972/ at Balatonföldvár and lo2.8 m above Adriatic sea /2o.4. 1972/ at Fonyód. The layer water is under pressure only to a little degree at Balatonföldvár while at Fonyód fills out only partially the water conducting sand layer. The water holding layers exposed during the raised shoreline drilling, are continuing over the shore wall too and the layer- and ground-water stored in them is in direct connection with the water level of the Balaton. In case of the raised shoreline at Fonyód, the water supply is mainly from the direction of the Balaton.

We can see a completely different hydrogeological condition in the profile No 4 of Balatonkenese. Groundwater was reached at the depth of 26,9o m /133,o m above Adriatic sea/ /19.8.1952/ in borehole No 7 on the raised shoreline. The groundwater table descends along a depression curve to the level of the Balaton, soaking through the detritus slope. The second - layer water level under pressure - was elevated to the height of 45,4o m. The layer pressure was so about o,1 mPa at the time of the measurement /27.9.1952/. The same layer was reached by the borehole No 4 too but it was not crossed already by the other boreholes towards the Balaton.

The third - also containing layer water under pressure - layer starts at 93,lo--93,6o m and is settled continuously in the shole profile. In the borehole No 3 near to the shore of the Balaton, the static water level was lo4,43 m above Adriatic sea. In boreholes No 7 in the same layer the level of the layer water was elevated by 1,7 m above the level of the Balaton,and lo6,32 m above the Adriatic sea /21.lo.1952/. The aquifers receive a constant water supply from the areas behind. These waters, getting into the detritus slope together with the periods with much rain, are soaking through the detritus slope considerably dimishing its stability. Beside the protection against shore collapses and the translocation of the railway line, the solution of the surface and groundwater protection of the detritus slope and of the raised shoreline always had to be taken into consideration.

How can we explain the lack of great shore collapses on this very actively surface moving area since 1946? As the natural factors have changed this favourable situation has been formed as a result of human activity. These favourable human interferences lasting for several decades, are the following:

1. Translocation of the railway line. By this the dynamic effect has ceased.
2. Water regulation on the surface and under the surface /belt trenches, drains/.
3. Equilibrium position due to the static condition of the previously collapsed earth masses.
4. Surface regulation.
5. Afforestation.
6. The edge of the detritus slope and the raised shoreline has not been built up.
7. Regulation of the water level of the Balaton.

The stability condition is quite different on that part of the raised shoreline where the detritus slope was built in. Here we meet diminishing stability caused by human activities, like

1. Formation of steep slopes.
2. Earth works with transporting earth masses in an inefficient way.
3. Elimination of vegetation /forest/.
4. Increased drying of sewage-water.

In order to avoid the occurrence of similar surface movements the raised shorelines and especially the detritus slopes in their foreground must not be built in. If it cannot be avoided
- a severe drying prohibition must be ordered, and the water supply must be provided with canalization resp.;
- a building prohibition must be ordered in a 5o m wide strip reckoned from the edge of the raised shorelines;
- all kinds of elimination of the vegetation on the raised shoreline and on the detritus slope and earth works diminishing stability must be prohibited;
- the previously built objects for water protection on the surface and under the surface, must be kept in order and completed with new ones according to necessity.

With observing the above measures and proposals the stability of the raised shorelines around the Balaton can be assured for long periods concerning both the shore collapses of great extent and the landslides affecting less areas .

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ENGINEERING GEOLOGY AND THE FERTILITY OF THE SAND SOILS OF THE SOUTHERN DANUBE–TISZA-INTERFLUVE

PÉCSI, M. - ZENTAY, T. - GEREI, L.

INTRODUCTION

In Hungary the area covered by young Pleistocene blown-sands is of wide extent and the amelioration of the sand soils of the Danube-Tisza-Interfluve, the largest such area, has been of considerable importance especially from the agricultural point of view. The fertility of the sand areas is generally rather low most frequently because of low water storage capacity,weak nutrient uptake and relatively rapid nutrient digestion. In certain cases an impermeable hard pan is also present which adversely affects the nutrient budget. The investigation of the micromineral composition of such soils as well as the underlying sedimentary parent material provides some possibility for increasing their fertility.

In Hungary there is a valuable research tradition dealing with the increase of fertility of sand soils. EGERSZEGI, S. /1956, 1957/ elaborated the underlying fertilization method of amelioration while LÁNG,I. /1957, 1961/ studied the leaf surface and pigment of the deeply fertilized autumn cereals and the effect of distributive sand amelioration on sand-beans. In addition LÁNG, I. and GÁTI, F. /1958/ dealt with distributive sand amelioration in relation to the nutrient intake of maize while ANTAL, J. /1956, 1957/ dealt with the question of general biological amelioration. The geographical distribution of sand soils on the Danube-Tisza Interfluve is given on the genetic soil map of Hungary, edited by STEFANOVITS, P. and SZÜCS, L. /1961/, and the question of classification has been summarized in the "Handbook of genetic soil mapping" by SZABOLCS, I. et al. /1966/. More detailed mapping at a scale of 1:loo ooo has been carried out by VÁRALLYAY, Gy. - SZÜCS, L. /1978/ and by VÁRALLYAY, Gy. - SZÜCS, L. - MURÁNYI, A. /1979/. The aim of the present paper is to contribute to this body of work through an investigation of the agro-geological characteristics of sand soils.

Numerous research has dealt with the geology of the area under consideration. At the turn of the century agrogeological mapping began and was followed by several phases of pedological mapping. The first significant geological mapping carried out for non-agricultural purposes is attributed to SÜMEGHY, J. - MIHÁLTZ, I. /1948/, and this work continued throughout the Great Plain during the early 1950s culminating in the comprehensive maps prepared by the Department Lowland Research of the Hungarian State Geological Institute.

In order to untertake practical research a knowledge of the Quaternary evolution of the area was also needed, and according to RÓNAI, A. /1971/ the following formations are found in the region:

Certain uneroded red clay occurrences, as well as the coarse-sandy and gravelly-sandy formations can be assigned to the Lower Pleistocene. Formations of Middle Pleistocene age are composed of fossilized soils made up of clayey loess, loessic sands and blown sands interbedded with loess, as well as the older fluviatile formations of the Tisza Valley, and the fluviatile sands, muds and clays deposited by the Danube, all of which are buried below the recent surface.

The major part of the surface is covered by sediments from the Upper Pleistocene i. e. blown sands, loessic sands, loess, sodic loess, transformed muddy loess, infusion loess, clayey loess, fluviatile sands and muddy sands.

The Early Holocene formations are of patchy distribution and are made up of blown sands, fluviatile sands, muddy-loessic sands, fluviatile muds, sodic muds, loess-muds, calcareous muds and sands with calcareous muds.

During the Late Holocene sodic muds, loess-muds, bog-clays, peat bogs, alluvial muds and silts, alluvial clays, meadow clays and fresh alluvium made up of clay, mud and sand were formed.

The reader is referred to FIGURE 1 which gives the location of the profiles discussed below. From among the geological formations enumerated above, the base of profile 1. is a Late Holocene meadow clay. This was formed in floodplain depressions at some distance from rivers and inundated areas, and on consequence fine-grained components predominate in its structure. Profiles No. 2. and 3. show a Late Holocene loess mud floor on what weak-meadow chernozem, and sandy meadow bog soils have formed. The latter is a pale-yellow porous sediment, similar to loess both in its external features and in its grain-size compositions and calcareous content, but different in that it contains more fine grains. The soils of profile lo, the multi-layered humic sands of profile 16, the sandy meadow chernozem developed on the calcareous sands of profile 17, the humic sands

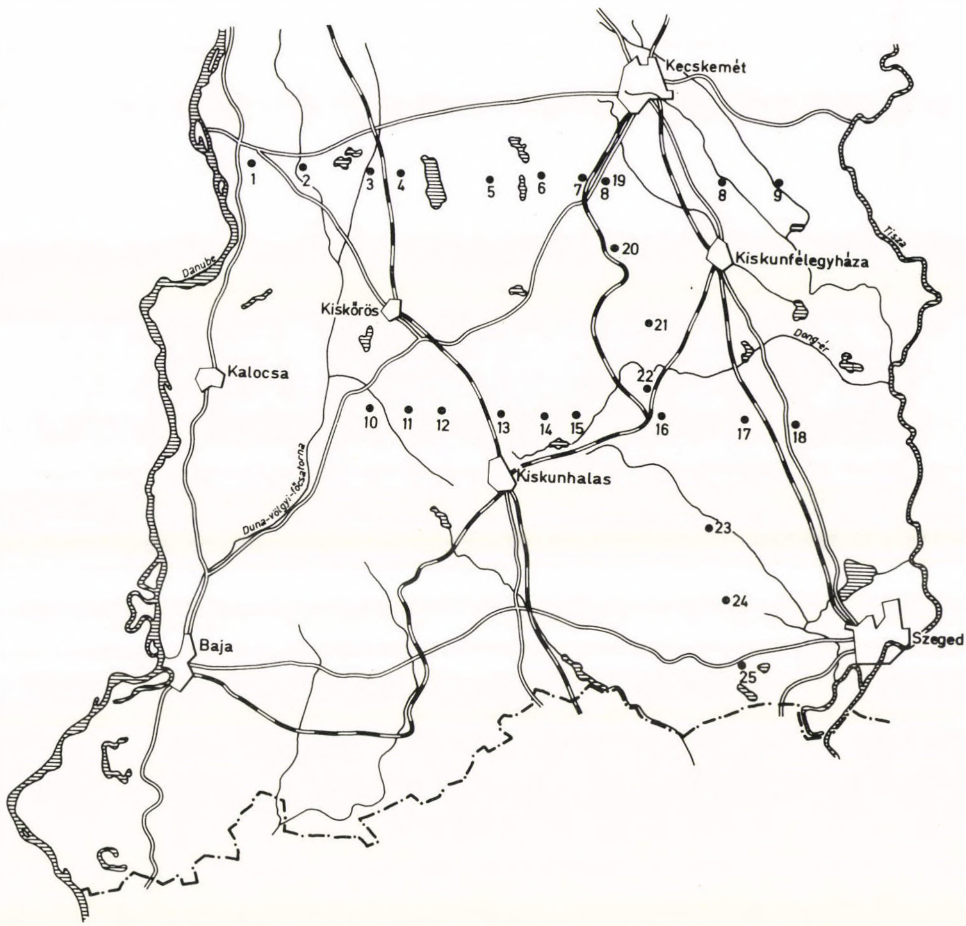

FIGURE 1 Location of profiles in the study area

of profile 18, the multi-layered humic sands of profile 2o and the meadow sands of profile 24 are all found on Late Holocene blown-sand overlying calcareous muds. The calcareous hydromorphous humic sand revealed by profile 11 is underlain by Upper Pleistocene loessic sands. The floor of all the other profiles consists of redeposited Upper Pleistocene eolian sands, which are rounded, strongly sorted and finely coated by rust. The predominant grain-size ranges from o.1 and o.2 mm and a small quantity of fine-grained clay is also present. Their calcareous content leads to compaction, especially when vegetable matter and humic acids also contribute to this.

GEOMORPHOLOGY

Most research workers agree that the ridge of the Dunube-Tisza Interfluve is a remnant of a large alluvial fan deposited by the Danube during the Upper Pliocene and Pleistocene periods, whose recent surface at least since the last interglacial has not been effected by either the erosional or depositional activity of the Danube. The major part of the basement built up from fluviatile sands, sandy muds and clays, with eolian sediments, such as re-constituted loess and blown sands playing a subordinate role. During the last glacial period and Holocene dry phases the fluviatile sediments were redeposited by the wind action and reached a considerable thickness, with the result that the recent surface is covered mostly by Late Quaternary loose permeable eolian sediments. Semi-bound sand dunes and extensive areas of feature less sand cover alternative with sandy loess, loessic sands, while in the flat intra-dunal depressions impermeable meadow clays, bog-clays, meadow limestone-dolomites, dolomitic-limestone-muds, and muddy loess are found. According to borehole data, the material of the alluvial fan increases in thickness from west to east and from northwest to southeast, respectively, and grain-size becomes finer. The Upper Pliocene and Pleistocene alluvium deposited by the Danube which overlies the Upper Pannonian sediments, fills a funnel-like depression of some 4oo to 8oo m in depth, which widens out towards Kecskemét, Kiskunfélegyháza and Szeged. The research carried out by SÜMEGHY, I. /1948/, ERDÉLYI, M. /1955/, PÉCSI, M. /1959, 1967, 197o/, URBANCSEK, I. /1963/ and MOLNÁR, B. /1965/ has demonstrated that these sediments are made up of a succession of fine /impermeable muds and clays/ and coarser /water storing sands, and gravelly sands/ strata interbedded in such a way that the whole sequence becomes finer as one moves from the base to the surface.

As the surface of the alluvial fan was dry during the last glacial, the movement of blown-sand and the formation of loess became predominant.The prevailing northwestern winds scoured NW-SE trending depressions in the superficial sands,the material thus removed being redeposited as linear dunes of similar orientation or as parabolic dunes while between the depressions elongated sand ridges remained. In other localities dune groups of large extension developed which limited the area of the flat basins.

From geomorphological point of view the alluvial surface of the Danubian-Tisza-Interfluve is composed of mosaic-like associations of featureless sand and sandy loess cover, and sand-dune regions surrounded by gentle intra or inter-dunal depressions.

Sandy loess forms an expensive cover mostly in the Kecskemét region. Here dunes elongated in NW-SE direction are covered by a sandy loess deposit of 2 to 15 m in thickness, frequently separated by the small oval intra-dunal basins which sodic soils and locally alkaline lakes are to be found.

The extensive sand cover is characteristic of the northern part of the area, in the vicinity of Vecsés, Cegléd and Abony and of the eastern Majsa-Dorozsma area fronting the river Tisza.

The monotonous sand surfaces are cut by elongated depressions trending from NW to SE direction, inwhich dolomite-calcareous muds and sodic soils locally overlain by sand, have formed. The high carbonate content of the subsoil provides excellent conditions for the growing of peaches, and given the favourable climate peach orchards could be extended throughout the sand region of the South Kiskunság. In the interest of improving agricultural productivity drainage of the partly sodic depressions may also be necessary.

In the southern part of the Danube-Tisza Interfluve three extensive dune fields again trending from NW to SE are found /FIGURE 2./. The western margin the first, contains the best preserved and most variegated semi-bound sand forms, and throughout this region an intensive programme of vine plantation and less intensive programme of afforestation are in progress. The afforestation of the semi-bound blown sand dunes together with the levelling of the topography and soil amelioration, for fruit and vine plantation are in progress at the present time.

AGROGEOLOGICAL CHARACTERIZATION OF THE PROFILES INVESTIGATED

The in-situ examination of the profiles was carried out to a depth of 5 m, and yields the following classification: profile I.1. was a loamy clay soil used as the type example for comparative purposes; profile II. 5. was a blown sandy skeletal soil; profile III. 19. was a sand-cover soil; profile IV. 25. was a humic sand soil; profile V. 2o. was a stratified humic sand soil; and profile VI. 13. was a humic hydromorphous sand soil /FIG.1./.

Based on the in-situ investigation of the agrogeological profiles the following conclusions were drawn:

a/ Relatively few examples of blown sand soils in the original state are present and most of them have been affected by cultivation represented by humic horizons.

b/ In several profiles, above the humic horizon, a skeletal sand soil is found which does not contain humus.

c/ In most of the sand soils humic horizons occur, and in

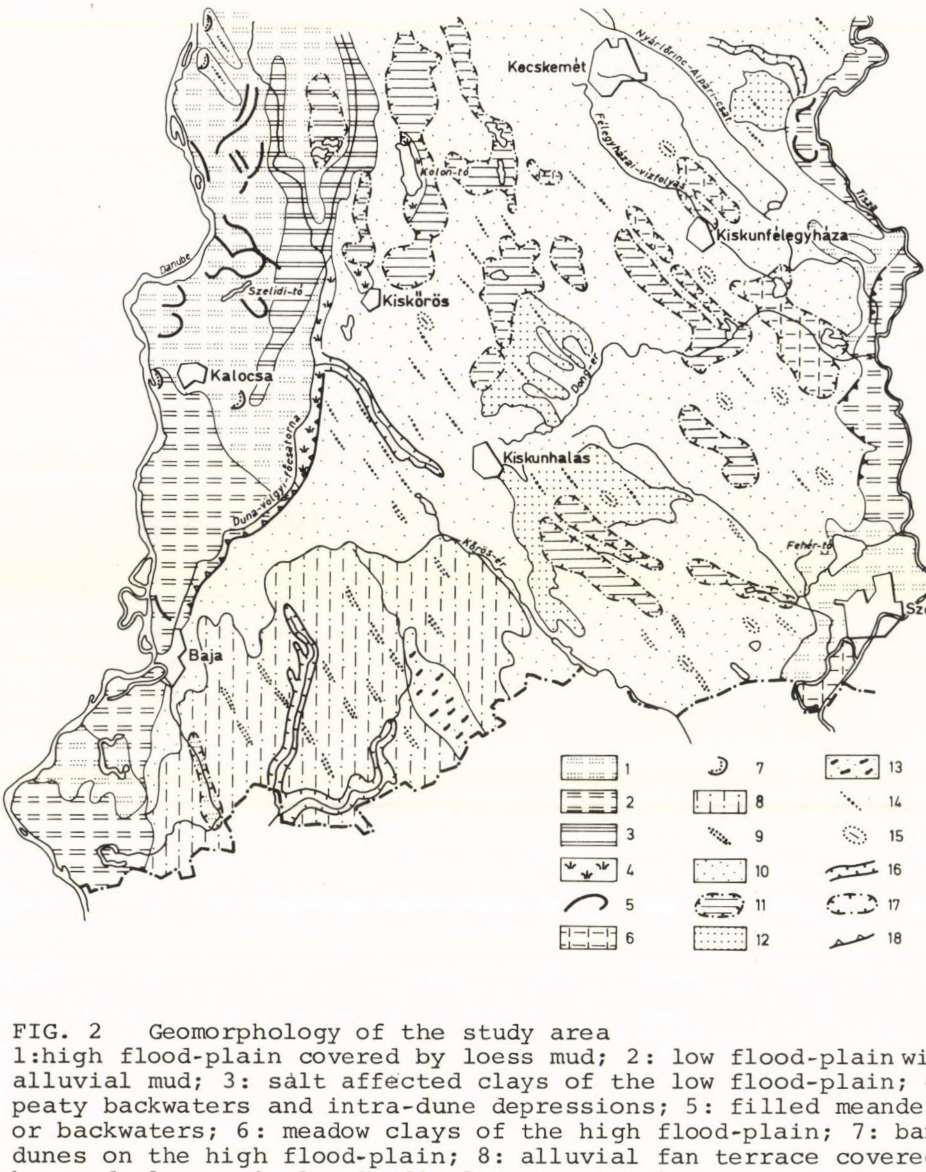

FIG. 2 Geomorphology of the study area
1:high flood-plain covered by loess mud; 2: low flood-plain with alluvial mud; 3: salt affected clays of the low flood-plain; 4: peaty backwaters and intra-dune depressions; 5: filled meander or backwaters; 6: meadow clays of the high flood-plain; 7: bank dunes on the high flood-plain; 8: alluvial fan terrace covered by sandy loess; 9: longitudinal dunes with loess cover; 1o: alluvial fan covered by blown-sand and cover sand; 11: salt affected intra-dune depressions with calcareous muds; 12: semibound surface with sand dunes; 13: sand dunes covered by chernozems; 14: region of stabilized sand dunes; 15: deflation depression; 16: erosion valley; 17: salt affected basins and small embanked basins; 18: inactive steep bank.

several cases buried humic horizons may also be found, all of which have favourable effect on the nutrient budget of the soil.

d/ In most of the sand soils the effect of hydromorphous processes can already be observed.

CONCLUSIONS DRAWN FROM THE PHYSICAL AND CHEMICAL FEATURES OF THE PROFILES INVESTIGATED

a/ Given the geological features of the Danube alluvium the soil profiles show the common feature of having a considerable calcareous content and pH-values above 8 are characteristic.

b/ The amount of calcium carbonate is generally highest at the base of the soils.

c/ Apart from soil profile 1 which is a loamy clay, all the other soils are of sand composition.

d/ The thickness and position of humic horizons are a reflection of the processes going on in these soils. For example, the blown-sand is characterized by a relatively thin A-horizon of low humus content, while the humic sands have a relatively thick superficial humus horizon. In the case of the general sand cover the humic horizon is overlain by a humus-free skeletal soil horizon at the surface. Stratified humic sand soils are characterized by the presence of A-horizons buried at different depths below the humic A-horizon at the surface. /TABLE I/.

MINERAL COMPOSITION AND FINE-DISPERSE FRACTION OF THE PROFILES INVESTIGATED[x]

P r o f i l e 1.

Clayey meadow soil. Mica predominates in this soil, the amount ranging from 27 to 4o%. Considerable amounts of quartz /14--38%/ are also present while the proportion of plagioclases varies from 2 to 24%. In all horizons calcite, dolomite and chlorite are also found. The relatively large amounts of mica and quartz relate to the fact that sand and clay were almost equally important as parent materials. /TABLE II, III/.

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[x] Analytical methods. The quantity of calcareous material was determined by the Scheibler-method. Hygroscopic moisture /hy/ as well as humus content were obtained from the potassium bichromate method while the pH-values were measured electrically. The mechanical analysis was carried out by pipette, by the use of a Na-pyrophosphate preparation. Once the carbonates and organic matter were removed, the mineral composition was investigated by means of X-ray diffraction and DTA in soil fractions of less than 2 microns.

TABLE I. Physical and chemical properties of the sand soils investigated

No of profile	Depth	Horizon	Ca CO_3	hy	H	H_2O	0,002	0,002	0,005	0,01	0,02	0,05	0,1	0,2	0,5	Physical A clay	Physical H sand
	m		%	%	%		mm ∅ gr. %										
	0-0,09	A	8	1,9	3,2	8,2	20,1	9,9	7,4	11,3	20,4	17,8	9,1	3,2	0,2	48,7	50,7
	0,12-0,20	B	7	2,0	3,2	8,3	19,9	9,7	6,9	13,7	20,8	16,2	8,8	3,0	0,1	50,2	48,9
1.	0,26-0,36	B-C	26	1,4	1,1	8,6	26,6	9,6	9,8	13,7	16,7	15,4	4,9	1,8	0,1	59,7	38,9
	0,47-0,57	C_1	31	0,7	-	8,6	15,7	6,7	6,5	15,2	28,5	22,2	3,2	1,3	0	44,1	55,2
	0,70-0,80	C_2	21	0,4	-	8,4	7,8	2,8	3,7	5,7	31,5	32,5	10,9	4,6	0	20,0	79,5
	0-0,08	I	12	0,3	0,2	8,1	0,1	0	1,2	0,2	1,0	5,7	37,0	51,5	2,3	1,5	97,5
5.	0,35-0,45	II_1	10	0,2	0	8,3	0,3	0	0	0,9	0	6,6	36,4	53,7	1,6	1,2	98,3
	0,70-0,80	II_2	14	0,2	-	8,4	0,8	0	0,3	0,1	0	7,1	45,7	44,1	0,9	1,2	97,8
	0,00-0,06	A_0	7	0,2	0,2	8,5	0,6	0,1	0,1	0,4	0,6	11,6	59,0	25,3	1,5	1,2	98,0
	0,17-0,27	A_1	6	0,2	0	8,5	0,6	0,5	0,1	0,5	0,2	11,9	61,3	22,2	0,3	1,7	95,9
19.	0,30-0,40	B	10	0,2	0	8,4	0,3	0,3	0,1	0,1	0,4	14,7	59,4	23,6	0,6	0,8	98,7
	0,49-0,59	A	8	0,3	0	8,4	1,1	0,4	0,1	0,3	0,4	12,6	61,5	23,1	0,4	1,8	98,0
	0,63-0,73	C	13	0,3	-	8,5	0,3	0,1	0	0,1	0,3	14,2	58,5	24,9	0,5	0,5	98,4
	0,00-0,10	A_{sz}	2	0,4	0,7	8,0	2,0	0,3	0,5	0,3	0,5	6,6	68,4	19,3	0,4	3,1	95,2
	0,15-0,25	A	2	0,4	0,6	8,2	1,5	0,4	0,1	0,7	0,6	11,0	66,5	17,8	0,7	2,7	96,6
25.	0,28-0,38	B	4	0,4	0	8,4	0,9	0,2	2,4	1,4	1,2	14,9	57,9	20,1	0,3	4,9	94,4
	0,42-0,52	B-C	5	0,4	0	8,3	2,7	0,4	0,8	0,9	0,7	13,6	66,8	13,1	0,3	5,8	94,5
	0,70-0,80	C	13	0,3	-	8,5	2,7	0,7	1,1	1,9	1,4	22,9	60,6	7,9	0,3	6,3	93,1
	0,15-0,25	A	3	0,3	0,5	8,3	0,9	0,3	0,1	0,5	0,6	10,6	56,9	28,9	0,7	1,8	97,7
	0,30-0,39	B	2	0,2	0,2	8,3	2,2	0	0,2	0,8	0,4	7,7	48,0	38,0	1,6	3,2	96,5
	0,39-0,49	A_1	1	0,3	0,6	8,2	1,3	0,5	0,5	0,3	1,2	13,4	56,1	25,8	0,5	2,6	97,0
20.	0,70-0,80	B_1	5	0,3	0	8,5	2,1	0	0	1,3	0,4	11,6	55,3	26,1	0,5	3,4	93,9
	1,15-1,25	A_1	8	0,4	0,6	8,3	2,6	0,3	1,0	2,3	4,1	24,2	40,8	22,0	0,5	6,2	91,6
	1,40-1,50	C_1	6	0,3	-	8,4	2,1	0,3	0,1	1,2	0,2	8,1	45,0	41,5	1,9	3,7	96,7
	1,50-2,00	C	9	0,2	-	8,4	1,4	0,1	0,5	0,6	1,6	21,2	54,9	18,4	0,2	2,6	96,3
	0,08-0,18	A	2	0,5	0,9	8,2	0,8	1,5	0,4	1,4	1,4	9,5	47,1	37,2	0,4	4,1	95,6
13.	0,35-0,45	B	6	0,5	0,2	8,4	1,9	1,1	0,7	1,2	1,8	18,1	51,4	23,0	0,1	4,9	94,4
	0,65-0,75	C	11	0,3	-	8,6	1,7	0,7	0,4	0,1	1,2	16,1	46,3	30,8	0,3	2,9	94,7

TABLE II Mineral composition of the sand soils investigated

Profile	Horizon	Quartz	Mica	Felspar K	Felspar Pl	Calcite	Dolomite	Chlorite	Montmor-illonite	Type
1	A	38	4o	-	8	3	3	8	-	Clayey mechanical
	B	3o	27	-	24	6	5	8	-	
	B-C	26	32	-	12	2o	5	5		meadow soil
	C_1	14	4o	-	2	18	6	2o	-	
	C_2	2o	4o	4	6	4	2o	6	-	
5	I	76	-		2o	2	2	-	-	
	II/1	77	-		8	11	4	-	-	Blown sand soil
	II/2	6o	-		32	6	2		-	
19	A_o	65	5	5	lo	6	4	5	-	
	A_1	61	lo	-	17	5	3	4	-	
	B	75	5	4	8	4	4	-	-	Cover sand soil
	A	62	4	-	22	8	4	-	-	
	C	51	5	19	8	lo	7	-	-	
25	A_{sz}	59	6		29	4	2	-	-	
	A	74	6		13	2	2	3	-	
	B	45	12	3	25	7	4	4	-	Humic sand soil
	B-C	48	lo	9	22	7	4	-	-	
	C	47	9	6	13	8	12	5		
2o	A	68	-	15	7	5	-	5	-	
	B	63	6	8	15	4	-	4	-	
	A_1	88	7		5	-	-	-	-	Stratified humic
	B_1	64	4		26	4	2	-	-	sand soil
	A_2	53	12	5	8	6	5	7	4	
	C_1	6o	5		23	5	3	4	1	
13	A	52	lo	12	12	4	2	4	4	
	B	54	9	lo	18	7	2	-	-	Humic hydromorphous
	C	73	6		6	7	8	-	-	sand soil

TABLE III Mineral composition of mechanical fractions of less than 2 microns in the sand soils investigated

Profile	Horizon	Quartz	Feldspar	Illite	Montmorillonite	Chlorite	Illite Montmorillonite	Illite Chlorite	Kaolinite	Type
1	A	2	3	71	3	10	8	-	3	Clayey mechanical meadow soil
	B	3	-	60	5	17	5	6	4	
	B-C	3	-	60	5	18	-	10	4	
	C_1	2	2	32	7	37	12	-	8	
	C_2	3	3	30	16	28	16	-	4	
5	I	8	3	17	15	24	15	13	5	Blown sand soil
	II/1	10	4	30	8	24	12	4	8	
	II/2	10	3	30	8	24	12	5	8	
19	A_o	6	3	60	-	10	8	9	4	Cover sand soil
	A_1	5	3	44	8	17	11	8	4	
	B	5	2	45	8	14	14	8	4	
	A	6	4	45	8	18	7	9	3	
	C	8	3	46		22	8	10	3	
25	A_{sz}	16	4	32	15	13	10	10	-	Humic sand soil
	A	7	3	39	15	10	12	9	5	
	B	7	4	34	13	16	11	11	4	
	B-C	4	3	28	14	21	17	8	5	
	C	5	3	38	11	13	10	13	7	
20	A	5	4	46		12	10	18	5	Stratified humic sand soil
	B	5	4	26	10	10	20	20	5	
	A_1	5	4	29		22	15	20	5	
	B_1	4	4	29	10	18	14	14	7	
	A_2	8	5	27	15	15	13	13	4	
	$C_{I/1}$	7	2	37	11	18	10	10	5	
	$C_{I/2}$	6	2	39	12	12	12	12	5	
13	A	4	3	60	-	10	8	10	5	Humic hydromorphous sand soil
	B	4	3	49	10	12	9	9	4	
	C									

In fractions of less than 2 microns clay minerals predominate. For instance in the A and B-horizons 85% and 8o% respectively of the fine-disperse fraction consists of clay minerals. This also verifies the soil's classification as a loamy clay. From among the clay minerals illite predominates /32--75%/, while kaolinite occurs in small quantities in all horizons /3--8%/. The high amounts of montmorillonite /3--16%/ and of the mixed-illite-montmorillonite /5--16/ relate to the presence of reduction processes that are characteristic of meadow soil formation.

P r o f i l e 5.

Blown-sand soil and skeletal soil sand. In the mineral composition of this soil, quartz predominates /6o--77%/ and considerable amounts of plagioclase /8--32%/ are also present. Only calcite /2--11%/ and dolomite /2--4%/ were found in addition. The soil is probably of Danube origin and its mineral composition consisting of 97 to 98% sand, is mainly determined by the primary parent. This suggests that soil formation processes have only slightly affected its mineral composition which is a characteristic feature of blown-sand soils. The proportion of fine disperse fraction is very low /o.1 to o.8%/, and does not affect the soil's characteristics. The considerable amount of montmorillonite /8 to 15%/ and mixed illite-montmorillonite /12 to 15 % in this fraction probably relate to the minor presence of reduction process in the source area of the parent material.

P r o f i l e 19.

Cover-sand soil The proportion of quartz is very high /51 to 75%/, and considerable amounts of feldspar are also found /12 to 27%/. In addition smaller quantities of mica /4 to 1o%/, calcite /4 to 1o%/ and dolomite /4 to 7%/ were present. From a mineralogical point of view, this soil, which contains 96 to 98% sand, can be considered as a quartz-feldspar sand. In the low disperse fraction amounting to o.3 to 1.1% illite predominates /44 to 6o%/. The small amounts of montmorillonite /8%/and mixed illite-montmorillonite /7 to 14%/ relate to the presence of reduction processes in the source area of the soil.

P r o f i l e 25.

Humic sand soil. In its mineral composition quartz plays the predominating role /45 to 74%/ although the proportions of feldspars /13 to 31%/ and clays are higher than in the blown sand or cover-sand soils. The clay content ranges from 1.2 to 1.5% in the blown sand soils, from o.5 to 1.7% in the cover-sand soils and from 2.7 to 6.3% in the humic sand soils, which suggests that the weathering has been somewhat stronger in this last mentioned type. In the fraction of less than 2 microns considerable amounts of montmorillonite /11 to 15%/ illite-montmorillonite /1o to 16%/ and illite /28 to 39%/ are found.

P r o f i l e 2o.

Stratified humic sand soil. The quantity of clay in this soil is higher /1.8 to 6.2%/ than in the cover-sand and blown-sand soils, and indicates that more intensive weathering has taken place. None the less quartz /53 to 88%/ and feldspars /5 to 26%/ predominate. In the fine disperse fraction illite is again the most common clay mineral /26 to 46%/,although montmorillonite /o to 12%/, the mixed illite-montmorillonite /lo to 2o%/ and kaolinite /4 to 7%/ are also significant.

P r o f i l e le.

Humic hydromorphous sand soil.The clay quantity is again higher than in the blown-sand and cover-sand soils /2.9 to 4.9%/, suggesting more intense weathering processes, although quartz /52 to 73%/ and feldspar /6 to 24%/ remain dominant. In the fine disperse fractions illite is again the most important clay mineral /49 to 6o%/, with montmorillonite /o tl lo%/, illite-montmorillonite /8 to 9%/ and kaolinite /4 to 5%/ being less important.

CONCLUSIONS TO BE DRAWN FROM THE EVIDENCE OF MINERAL COMPOSITION

a/ Clay content is closely related to soil formation processes and varies from 2o to 59% in meadow soils, from 1.2 to 1.5% in blown-sand soils from o.5 to 1.7% cover-sand soils, from 2.7 to 6.3% in humic sand soils, from 1.8 to 6.2% in stratified humic sand soils and from 2.9 to 4.9% in hydromorphous humic sand soils. The clay content of the clayey meadow soil is thus seem to be substantially greater than in the other five soil profiles, and fairly well characterizes the mechanical differences between them.

Clay content, however, is not identical in the various sand soils, it being only a half to one third of the amount in the blown-sand and cover-sand soils when compared with the more humic sand soils. This fact suggests two conclusions:

1/ Weathering has been in the humic sand soils more intense than in the blown-sand and cover-sand soils.

2/ The small amount of clay in the blown-sand and cover-sand soils does not affect their characteristics. By contrast, the affect on the humic sand soils although the clay content remains below 7%, is considerable because of the high adsorption capacity of the clay minerals.

b/ While the presence of montmorillonite and illite-montmorillonite in the meadow soils relates to the preserve of reduction processes during soil formation, the existende of these minerals in the sand soils suggest reduction processes of the source area of the parent material.

c/ In the fine disperse fractions illite-type clay minerals generally predominate.

d/ Calcite, which occurs in most of the soils, is derived from alluvium of the Danube.

e/ The small amount but significant role of the clay fractions occurring in the sand soils suggests that amelioration can be achieved by applying fine disperse materials of high adsorption capacity.

SUMMARY

1/ In order to characterize the sand soils of the Danube-Tisza Interfluve five profiles were selected containing blown sands, cover sands, humic sands, stratified humic sands and humic hydromorphous soils. For the sake of comparison one loamy-clay meadow soil was also investigated.

2/ The sand soils are varied, and in most profiles the effect of cultivation could be observed.

3/ The thickness and position of humic horizons strongly affect the soil characteristics.

4/ In certain sand soils the effect of groundwater can be observed.

5/ The relatively small amount of clay in the humic sand soils plays an important role since the clay minerals strongly affect the water and nutrient budgets due to their high adsorption capacity.

6/ The fertility of sand soils is determined not only by their genetic horizons but also gy the physical, chemical and mineral characteristics of the underlying sediments.

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COHERENCY BETWEEN THE WATER SUPPLY AND WATER LEVEL FLUCTUATION IN QUATERNARY UNDERGROUND AQUIFERS

RÓNAI, A.

It is evident that the Quaternary underground fresh water bearing layers are supplied from atmospheric sources. We know also that in unconfined aquifers the seasonal supply is a function of fluctuation in water level. The question is whether or not this correlation exists in confined aquifers and if so to what depth it is effective /RÉTHÁTI,L.1978, TÓTH,J.1963/.

It would be hard to find a more suitable territory for the investigation of underground water movement than the Great Hungarian Plain. In this vast basin the thickness of the Quaternary sediments exceeds 6oo m, and below them follows the Pliocene sequence of sands and clays, with a thickness of 3ooo-5ooo m. Within this vast complex various aquifers have been topped by many tens of thousands of artesian wells and by many thousands of gas- and oil exploratory boreholes /RÓNAI A.1975/.

In the Hungarian part of this lowland area the Hungarian Geological Institute has established a network of artesian check wells, far from the places of commercial water extraction, in order to observe the natural fluctuations of the water level at different depths. At the selected points geological key borehole were put down and the cores of the profiles minutely analysed. The best water bearing layers were pumped and tested hydrodynamically, geochemically and geophysically. Following these experiments groups of 2,3 and 4 separate wells were bored for checking water movements at different depths. The deepest well achieved a depth of 11oo m and taps an Upper Pliocene sequence, although the majority tap Quaternary aquifers at depths ranging from 5o--1oo m to 5oo--6oo m /FIG.1./

The check-wells of the Hungarian Geological Institute are sitated far from towns and large industrial establishments so that substantial water extraction from underground sources associated with these does not disturb the natural regime of the water level. The check-wells serve only experimental purposes and there is no water extracted from them.

The natural causes for the fluctuations in piezometric water

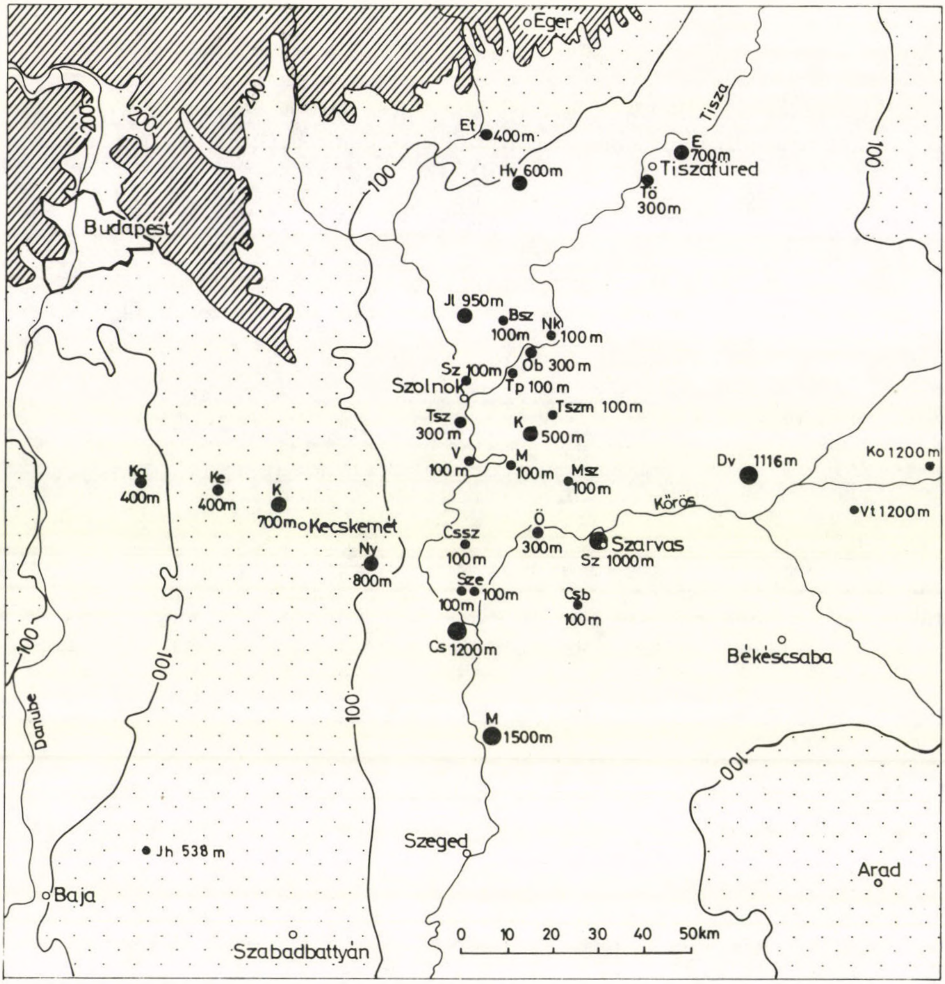

FIG.1: Geological research boreholes in the Great Hungarian Plain. Undertaken by the Hungarian Geological Institute 1965--198o.

level are as follows:

1. P e r i o d i c   f l u c t u a t i o n s caused by tida forces of 12 hours periodicity. Such fluctuation are of the order of a few centimeters.

2. F l u c t u a t i o n s caused by atmospheric pressure changes, occurring is weakly cycles and amounting

to a few decimeters.

3. S e a s o n a l   f l u c t u a t i o n s caused by the natural recharge and discharge of the aquifers, of yearly periodicity and attaining several meters.

4. L o n g e r   p e r i o d   f l u c t u a t i o n s in the natural recharge and discharge of the aquifers the shortest observed cycle so far being of the order of 9--14 years.

5. E x t r a o r d i n a r y   f l u c t u a t i o n s caused for example, by large scale flooding and earth-quakes. FIG.2, 3, 4, 5.

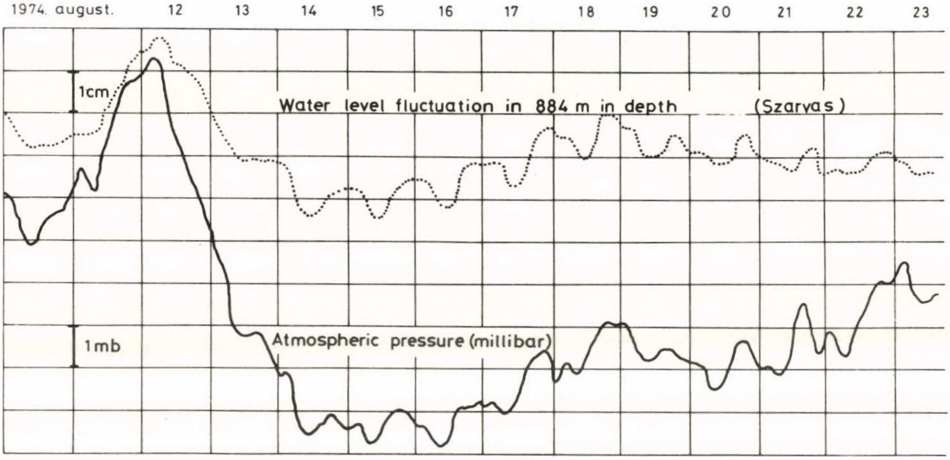

FIG.2: Artesian water level fluctuations caused by earth tide and atmospheric pressure changes

WATER LEVEL FLUCTUATIONS BY DEPTH BELOW THE SURFACE

The most important feature observed in the check wells concerns the size of fluctuations as a function of depth /p.3/.Generally the changes in level caused by tidal and athmospheric pressure differences appear only at greater depths and not in shallow aquifers, while the range of fluctuation also increases with depth.

More complicated is the interdependence between seasonal and longer period water level fluctuations and the depth of unconfined layers. This condition is influenced by surface morphology by the granulometry of the water bearing layer, by general underground water circulation, by the proximity of the catchment area, by the volume of discharge and recharge in the aquifer and last but not least by pressure conditions.

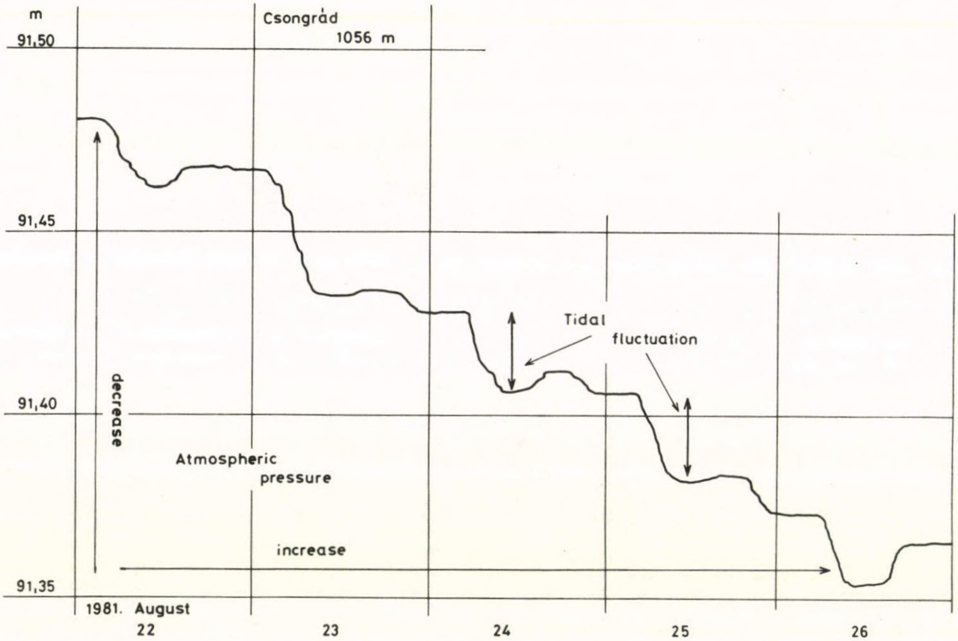

FIG.3: Changes in atmospheric pressure and fluctuations of water level

Two kinds of pressure situation can be observed in the Quaternary and Pliocene sedimentary sequences of the Great Hungarian Plain. Below the sand hills at higher elevations there is a negative pressure gradient, which means that the piezometric head of the water bearing layer decreases with depth. By contrast, the pressure gradient is positive in the lower lying clay-covered regions, which means, that the piezometric head of the water bearing layers increases with depth. This situation demonstrates the large extent of the circulation of underground water. In the catchment areas the water moves downwards to a certain depth, as occurs at higher elevation where the surface is made up of permeable rocks or sediments /FIG.6,7,8,9/.

In the lower lying parts of the plain, water tends to move upwards.

The inflexion point of the negative pressure anomaly lies at a depth of 3oo--5oo m in the catchment areas of the Great Hungarian Plain, below what the pressure becomes positive.

Seasonal fluctuations of water level follow the same pattern as in the shallowest phreatic aquifers, rising at the beginning

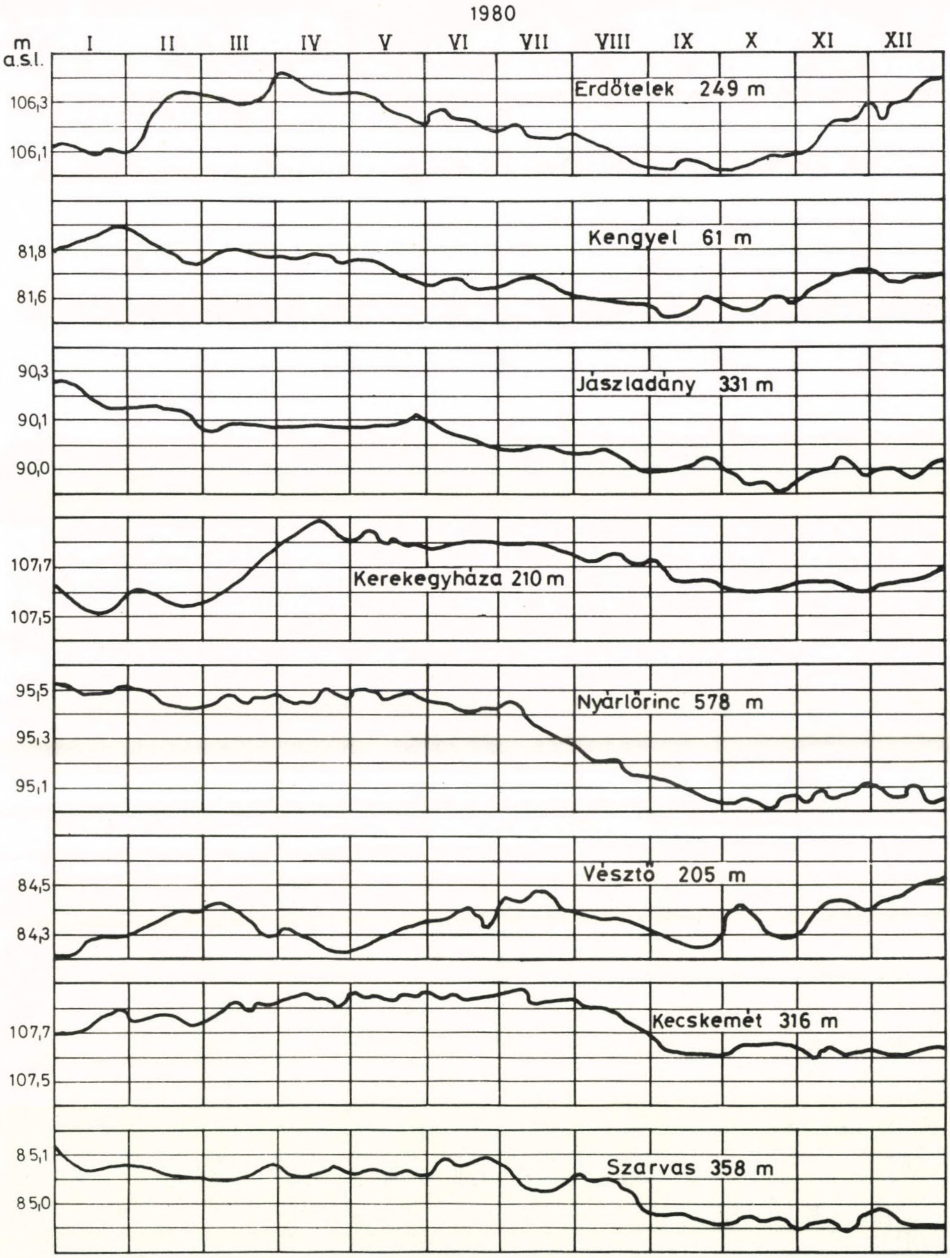

FIG.4: Water level fluctuations caused by atmospheric pressure and earth tidal effects by depth

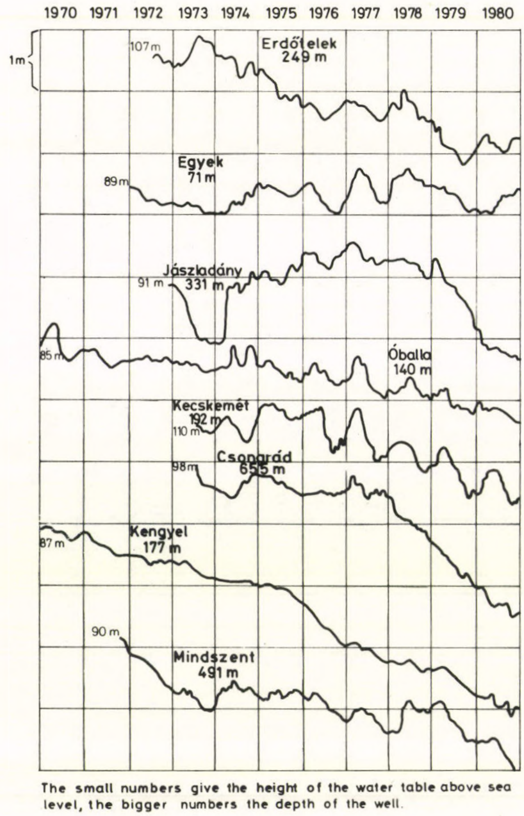

FIG.5: Water level fluctuations in artesian check-wells caused by the Romanian earth quake 4. March 1977.

of spring and then sinking to reach their lowest point at the end of September and in October, again to be followed by a rising phase. With few exceptions /as for instance at Vésztő/ this is the law at every depth. The range of fluctuation was o.3 to o.6 m in 198o, but this varies from year to year, and during really wet years can reach as much as 3--4 m. In FIG.6. the wells at Kerekegyháza, Nyárlőrinc and Kecskemét are situated in areas with negative pressure gradients; the others are characterized by positive pressure gradients.

Longer period fluctuationsshow a general diminution in amplitude from 197o to 198o, amounting to some 2 to 3 m during the lo years period. There are exceptions, however, as in wells at Jászladány and Egyek.

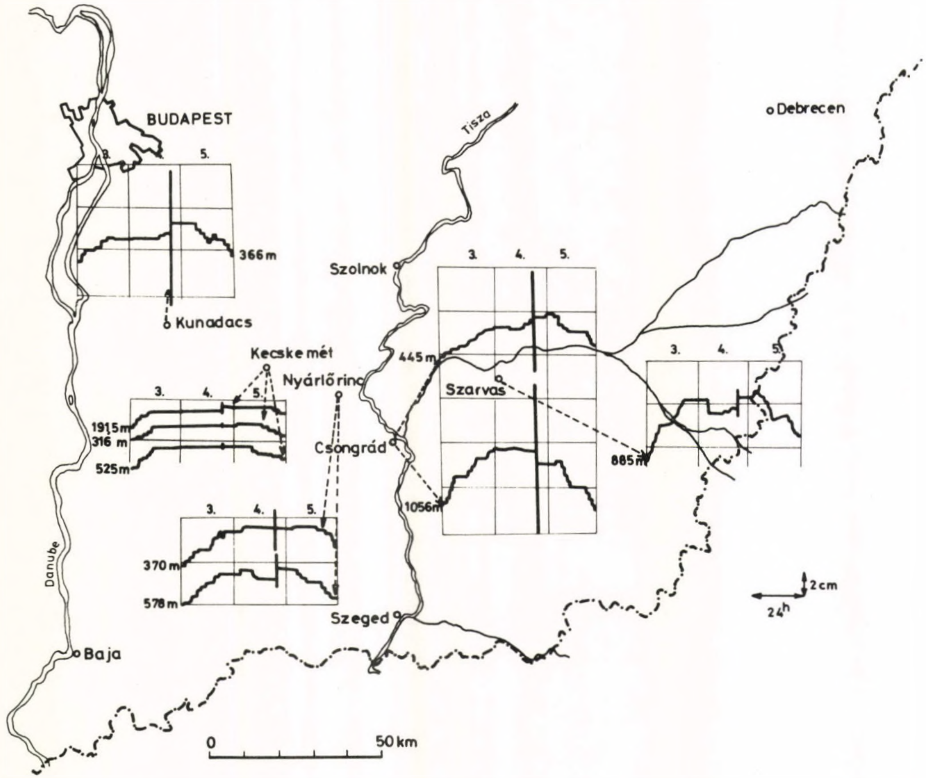

FIG. 6 Positive and negative pressure gradients in the aquifers of the Great Hungarian Plain

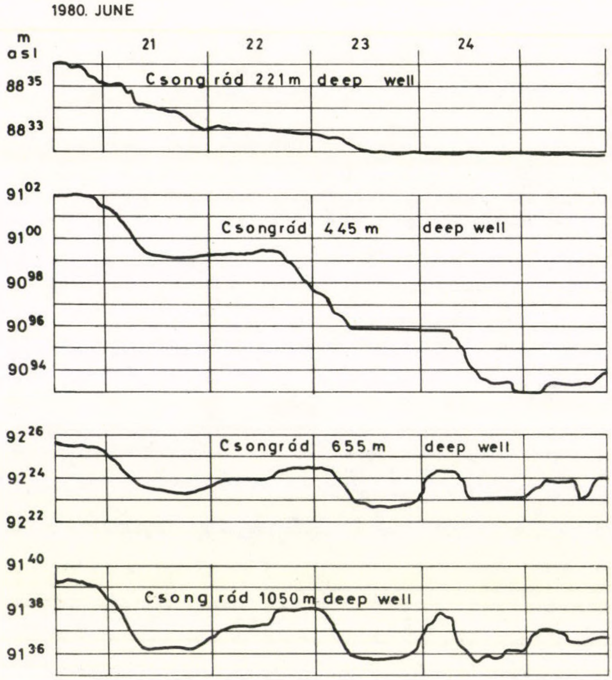

FIG.7: Seasonal water level fluctuations in artesian aquifers, 198o.

Seasonal and longer period fluctuations of the artesian water level grow in amplitude as a function of depth in regions with positive pressure anomalies and diminish in amplitude in areas where the pressure gradient is negative. In FIG.8 the Kecskemét well lies in a region with a negative pressure gradient: in all the others the gradient is positive. At the Dévaványa, Szarvas observation stations we have no winter data, as the piezometric head is lo--16 m above the surface. As recordings are registered at these stations on a tower above the general level of the terrain, we have to drain the water from the tower during winter to prevent freezing.

ARTESIAN WATER LEVEL FLUCTUATIONS BY GRANULOMETRY AND AQUIFER YIELD

FIG.lo, 11, 12.

The amplitude of the fluctuations in the same well range with large limits from year to year from a few dm, to 2--3 m. Where the annual fluctuations follow a diminishing trend the depletion of the aquifer is indicated.

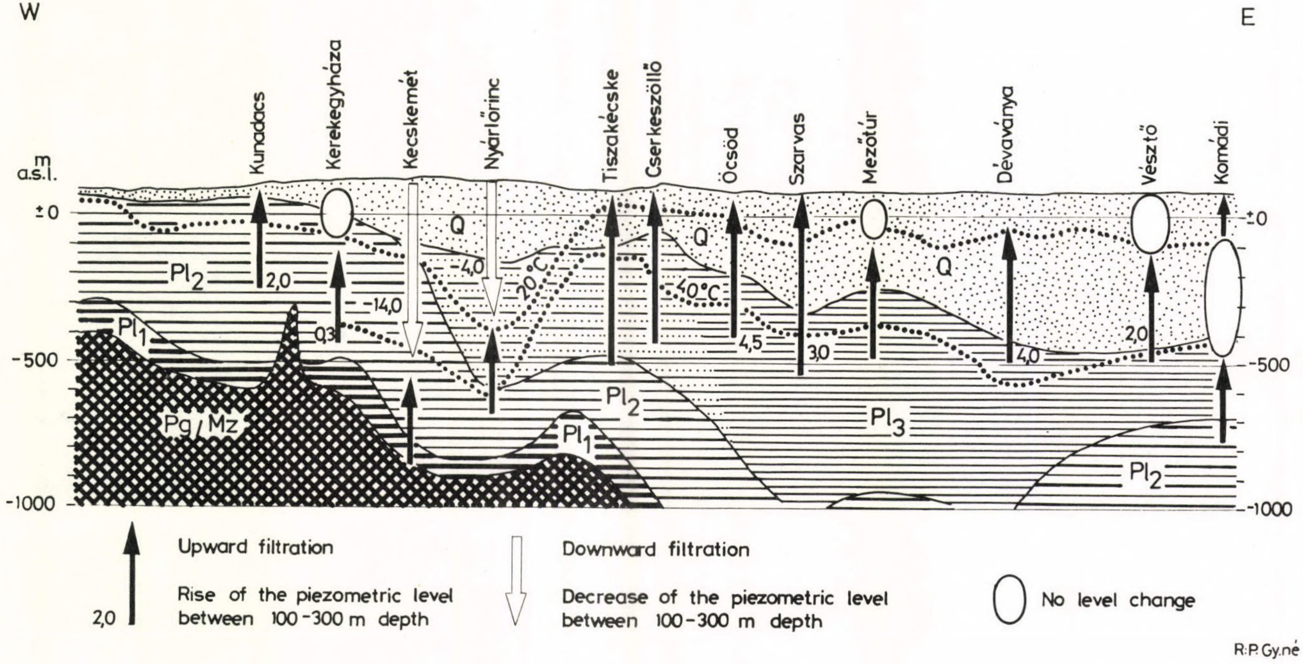

FIG.8: The range of seasonal water level fluctuations at different depths

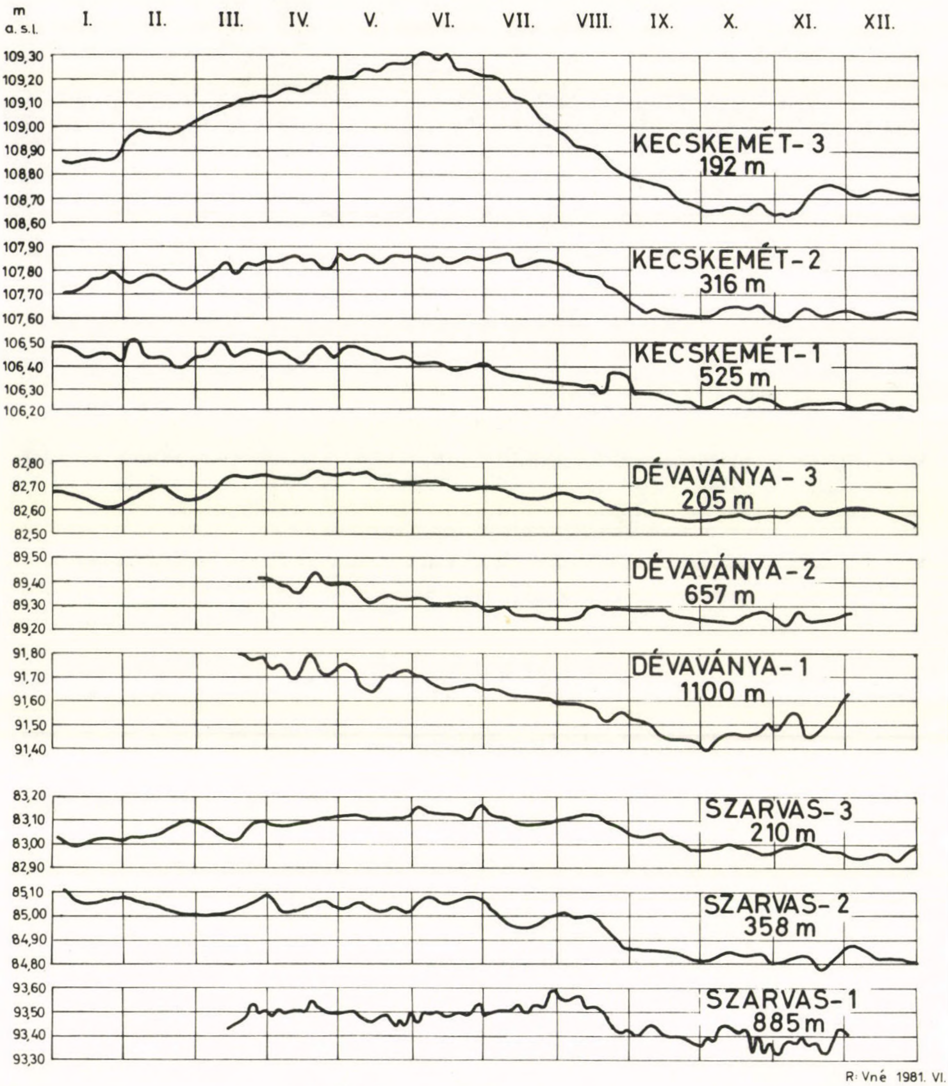

FIG.9: Longer period water level fluctuations in artesian aquifers

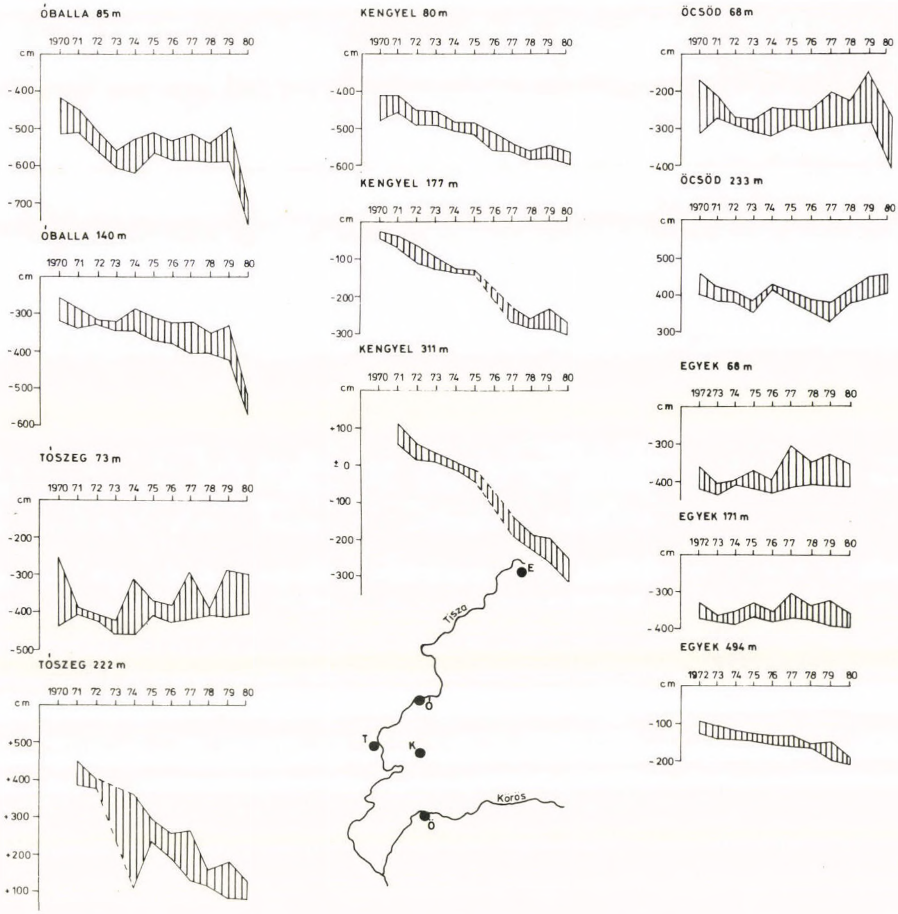

FIG.1o: Longer period fluctuations of ground water level at different depths between 197o and 198o

The range of water level fluctuation is a function of the granulometry of the water bearing strata in non-confined aquifers. The finer the granulometric composition of the water bearing strata, the higher is the amplitude of the oscillations assuming identical recharge. In the deeper, confined aquifers the relation is more complicated and it is not easy to establish a simple relationship characterizing the granulometry of an extensive aquifer. We can use medium grain size, determine an uniformity index and can also give the range of grain size in terms of weight. Nevertheless none of these parameters is precise enough to give a good base for comparing different aquifers.

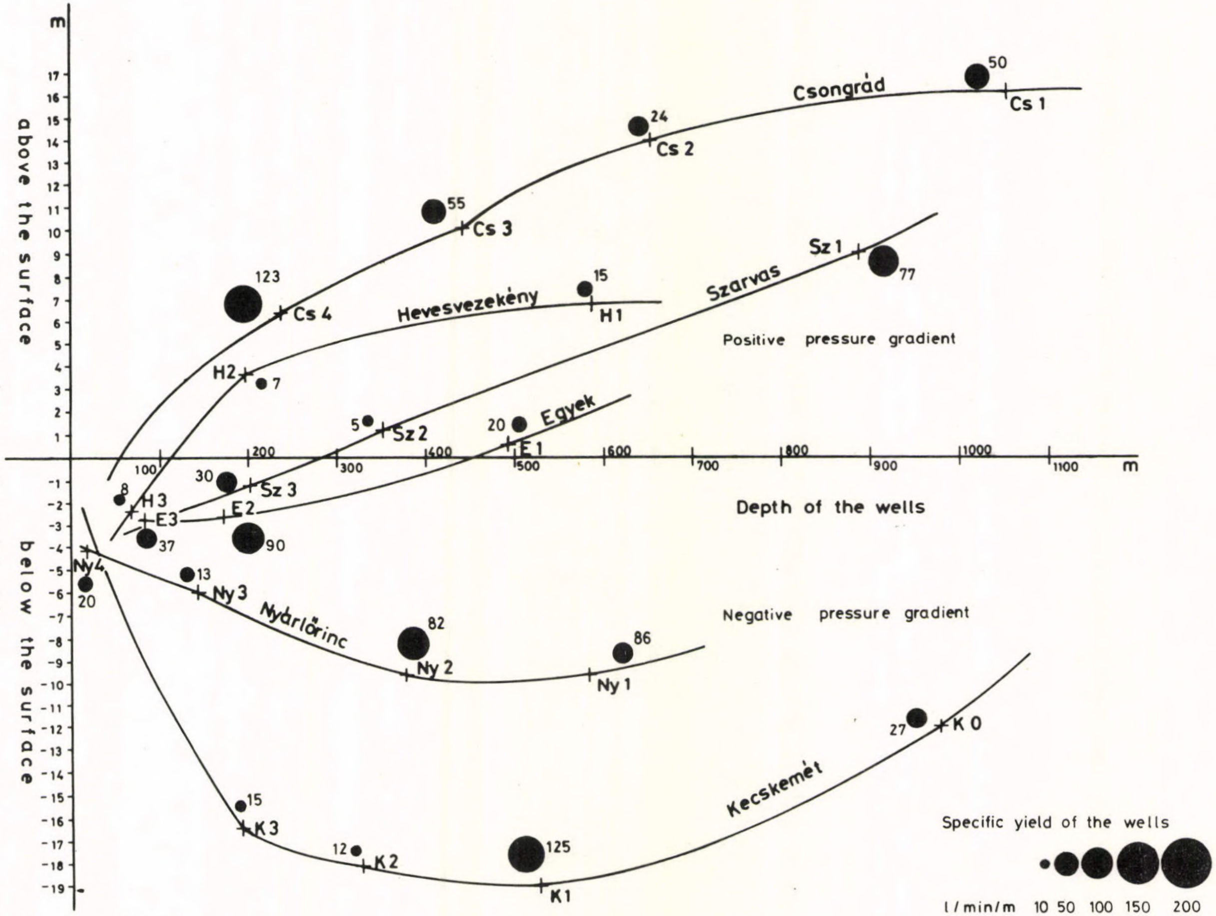

FIG.11: The relationships between pressure, depth and yield

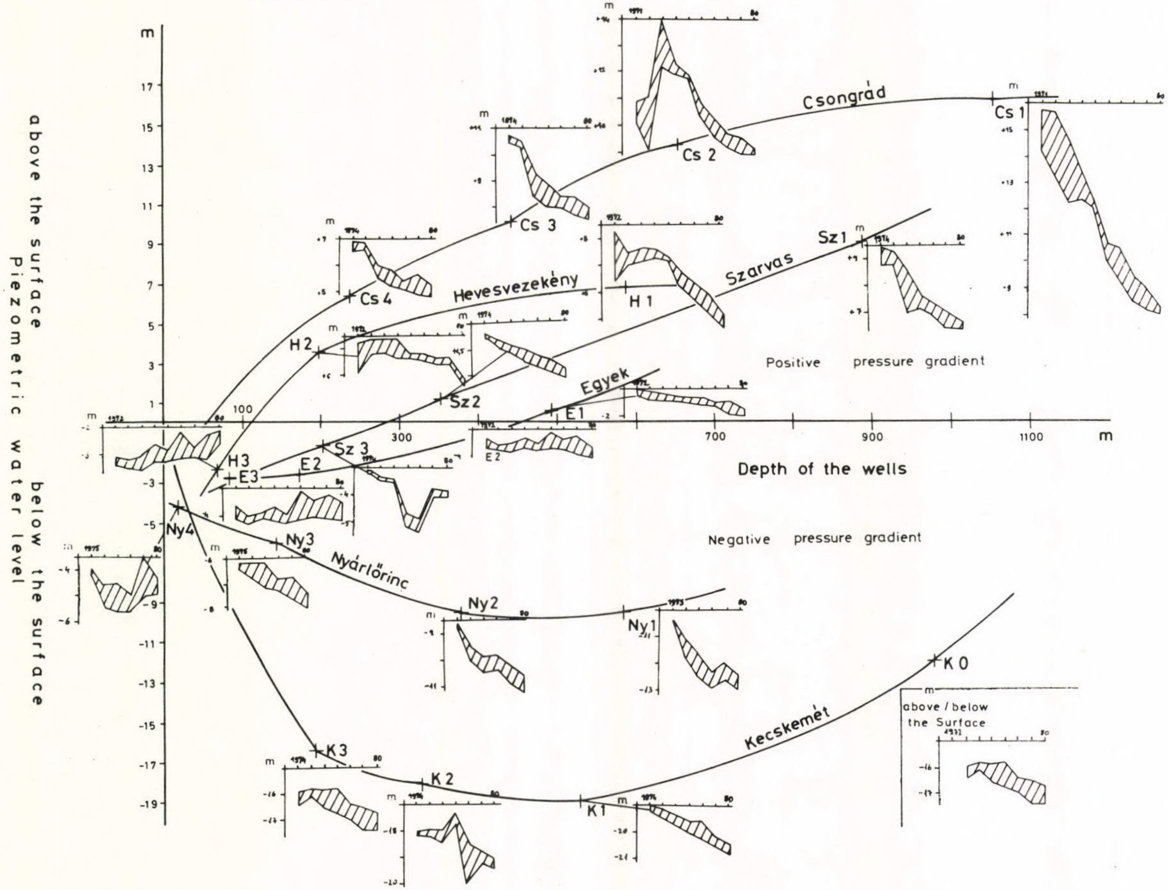

FIG.12: The relationships between depth, pressure and water level fluctuations

Specific well yield is used instead the granulometry of the water bearing stratum, to provide information on the productivity of an aquifer. In this way a comparison can be made between the well yield and the range of seasonal water level fluctuations. It is still difficult, however, to compare the productivity of different water bearing strata with the use of this index, because it also depends on so many factors, such as the execution of the well, the size of the liner, and the slot size of the screen.

It is to be emphasized that pressure conditions always have a role to play in the amplitude of water level fluctuations in addition to the granulometry and the yield of the aquifer.

Due to the complexity of the factors involved it is difficult to make comparative investigations comparing the recharge and discharge of aquifers with the amplitude of water level fluctuation in different wells. Nevertheless the size of these movements in a single aquifer, where pressure conditions, depth and granulometry are the same, is a strict function of the waterbudget of the aquifer.

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RIVER CHANNEL AND FLOOD PLAIN EVOLUTION OF THE GREAT PLAIN SECTION OF THE DANUBE, BASED ON MAP EVIDENCE BETWEEN 1782 AND 1950

SOMOGYI, S.

INTRODUCTION

Regarding surface evolution, the temperate zone being predominantly under the effect of the erosional and depositional activity of rivers forms one of the climatic-morphological regions of the Earth. The rate of surface development in this zone, however, has been heterogeneous and great differences can be observed according to the density, discharge and regional position of the drainage networks. The processes of erosion and deposition are most rapid in the beds and flood plains of the rivers. Hence a knowledge of the processes of the recent past are of primary significance both for hydrologists and for geographers. It is important for the prediction of the expected bed displacement, for the design of the bank side buildings, for taking into consideration changes in navigable water, from the point of view of landscape evolution, landscape ecological investigation and for the utilization of flood plains and rivers. The results of such investigations may be utilized by hydrography, the interface between hydrology and physical geography, because valuable information is obtainable for the details of the regularities of rivers and of the other superficial waters. Data on "recent" erosional and depositional activity, however, are also important from the paleogeographical point of view, because conclusion may be drawn about the intensity of the surface shaping processes of a river in earlier geological periods.

LITERATURE

The activity of rivers may be followed for the most part from an investigation of the rate of meander development and bed displacement, and by the determination of the quantity of alluvium transported. Such investigations were performed by many of the pioneer investigators. At the turn of this century the statistical evaluation of meanders was elaborated by the Americans BOWMANN and JEFFERSON and first applied to the Tisza river by PÉCH, J. /1898-19o7/ and by VUJEVIC, S. /19o6/. In his study of the Tisza Valley /LÁSZLÓFFY, W. 1932/ applied the same method and evaluated his findings in his report published on the laboratory experiments of Wicksburg. The most recent investigations concerning the recent bed changes of the Tisza were preformed by KÁROLYI, Z. /196o/. Statistical analysis were applied by PÉCSI, A /1939/, FODOR, F. /1953/ and GÁBRIS, Gy./197o/ in the case of other rivers. The connection between meander evolution, bed displacement and alluvial transport was, however, investigated only by LÁSZLÓFFY, W. /1932/ and KÁROLYI, Z. /1959, 196o/. In addition to these investigations of the process of alluviation during the past decades were also available /BOGÁRDI, J. 1955/.

Possible charges in the bed of the Danube, however, have not received as much attention as those of the Tisza, except for the valuable studies of KÁROLYI, Z. /1957, 1958, 1959, 196o/ which deal with the alluvial conditions of the river. The author has tried to fill this omission in his study of the bed changes of the Danube which he carried out over a number of years. First the reach of the Danube Valley at Sárköz between the mouth of the Sió /1498 km/ and Báta /1468 km/ was investigated. This choice was made because there was reason to believe that the bed-forming energy of the river is most effective in this reach. It is well-known from former investigations /TŐRY, K. 1952; KÁROLYI, Z. 1958; SOMOGYI, S. 196o/ that in the reach around Gönyü the bed changes and the flood plain evolves, according to the regularities in the formation of the alluvial fan. Between Gönyü and Paks the bed consists of gravel originating from the Late Pleistocene aggradation which decreases the erosional activity of the river and also hinders lateral displacement /LÓCZY, L. 1881; GÓCZÁN, L. 1955; MAROSI, S. 1955; PÉCSI, M. 1959; SOMOGYI, S. 1967/. South of Paks, however, the lithology of the bed and the river alluvium are mainly of fine sand /BOGÁRDI,J. 1955/. This fact proves that the channel cutting activity of the river has not yet reached the Late Pleistocene gravels that lie at a deeper level here; nor does the river transport coarser alluvium from the upper reach. On the basis of this the reach in question can be regarded as a freely and typically meandering section /KÁDÁR, L. 1954; SOMOGYI, S. 1967/.

METHODS

One method of investigating bed changes is through the observation of recent downcutting, siltation and channel and bank erosion. In view of the fact that such observations require complicated and expensive measurements over a long period it was impossible to adopt this method. Furthermore in the course of the last seventy years numerous artificial interventions have taken place aiming at the improvement of navigation, which strongly influences the general picture based only on recent surveys. An historical investigation of the problem was thus preferred.

Eight series of maps of acceptable detail are available for the Sárköz reach of the Danube, for this purpose. These are as follows:

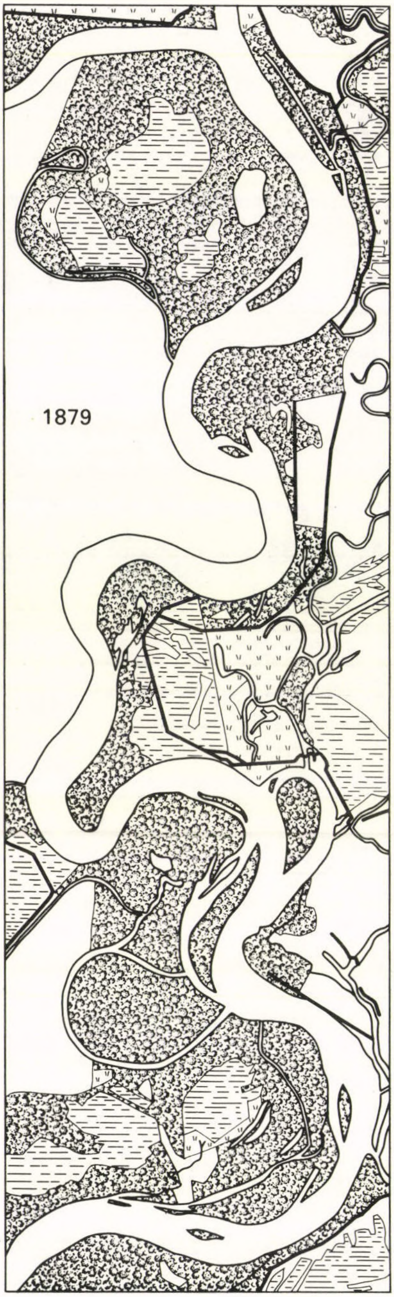
- The first national military survey of 1782-1784.
- The mapping of the Danube undertaken by the Residential Council in 1828.
- The second national military survey of 1858-1859.
- The first /civil/ cadastral survey of 186o-1879.
- The third national military survey of 1881.
- The correction of the first cadastral survey by the Hydrographical Department of the Ministry of Agriculture carried out between 1897 and 19o3.
- The mapping of the Cartographical Office of the River Forces of 1924-1927.
- The correction of the third national military survey in 195o with the use of aerial photographs.

At the suggestion of the topographer EDVY, Gy. a former research fellow at the Cartographical Office of the River Forces, it was decided to redraw all the existing maps at the same scale to ensure numerical comparability and also where possible to eliminate errors made during the course of earlier surveys. This enormous work was prepared with meticulous care by EDVY, Gy. who sacrificed his time to undertake this work.

The scale chosen for the elaboration is 1:25 ooo, because the two most recent surveys were performed at this scale; additionally this was the most convenient scale for recalculating the other maps. The elimination of errors in earlier surveys was the most awkward and difficult task of the whole work. Great help was given by the precision and large scale /1:2 88o/ of the first cadastral survey, and the accurately measured network of survey reference points established then is still to be found in the National Surveying and Triangulation Office. Earlier and later surveys may be reconstructed in accordance with these reference points by measuring any displacement that can be observed. The greater the time difference between a given survey and the first cadastral survey the greater the deviation and more difficult the reconstruction. The rearrangement of the first military survey proved to be the most difficult task because in this case identifiable reference points were relatively rare. It is to be noted that the first cadastral survey, as the starting basis, was elaborated first, but a proper arises in that the two banks of the river were surveyed at different times such that there is relatively little time difference between the previous and subsequent surveys /FIG. 1/.

Excluding these data the time differences between the individual surveys are the following:

I. Military survey 1783	
Danube-mapping: 1828	45 years
II. Military survey: 1858	3o years
III. Military survey: 1881	23 years
II. Cadastral survey: 19oo	19 years
Survey of River Forces: 1925	25 years
Correction of the third Military Survey: 195o	25 years



DISCUSSION

Our investigation has embraced the whole reach of the Sárköz Danube but in this paper only a 7 km long section will be demonstrated. The section mentioned above is important in that the evolution of a meander without any human intervention, as well as the effect of the cut-off performed in the last years of the previous century can be seen /FIG. 2,3/.

Comparing the single surveys the first fact which is conspicious is that this reach has considerably changed in length. Currently measuring 12 km and 15 km before regulation, the rate of displacement of the bed was 13o m/year in case of shortening, and 6o to 13o m/year in case of lengthening. The rate of change in length depends on the particular phase of bend evolution, with an increase in the radius of curvature the lenght of the arch is ever growing. The rate of displacement of the meander shows an increasing tendency only up to a certain point, thereafter the centrifugal force decreases, because of the increasing length of the arc /VUJEVIC, 19o6; LÁSZLÓFFY, W. 1932/. On this basis we tried to assign each phase of meander evolution traceable in the Sárköz reach to the theoretical scheme of evolutionary stages determined by BOWMANN. The measured numerical values, of course, could only correspond to those of the theoretical scheme if there were no any disturbing factors, but as a result of these the differences in certain cases may be rather considerable. /TABLE 1/

FIG. 1 Cadastral survey No. I of 1879 from the Sárköz reach of the Danube /legend see in FIG. 2/.

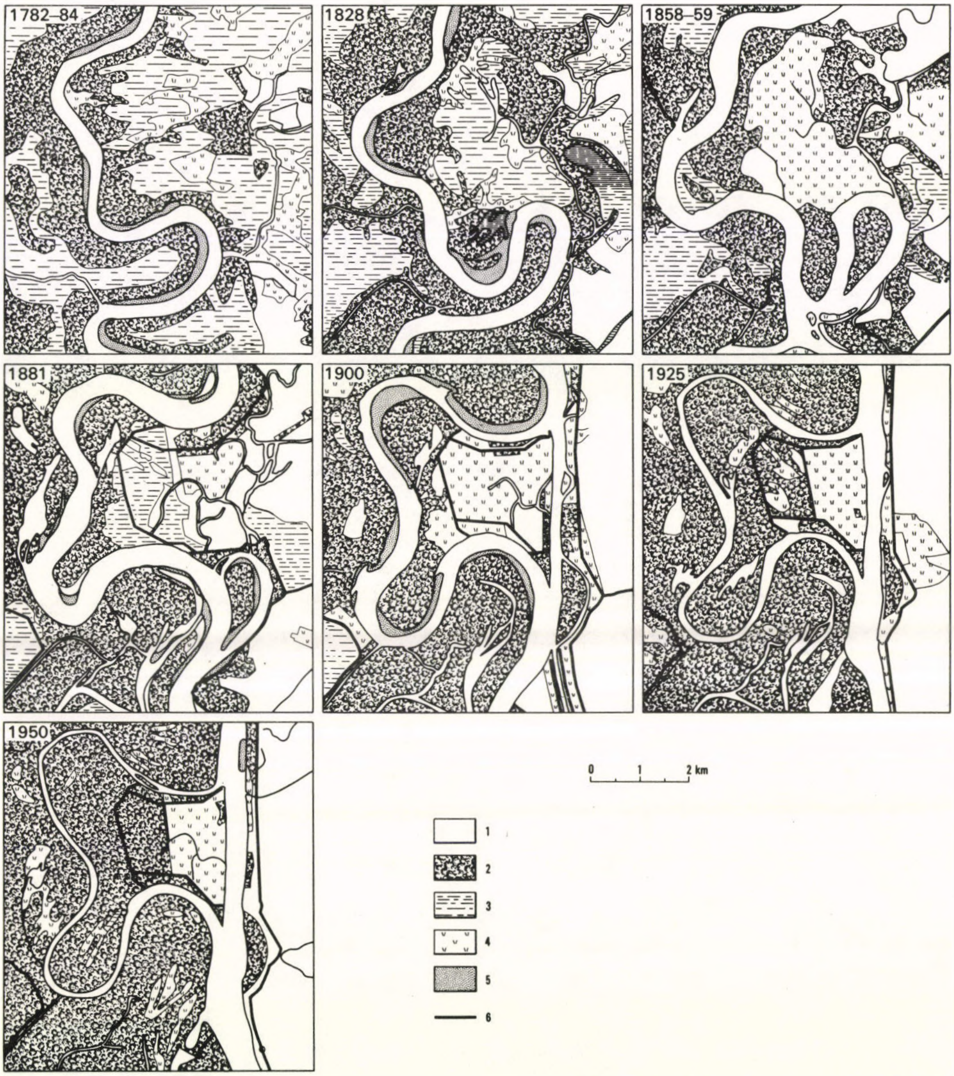


FIG. 2 Profiles of the maps of the Sárköz reach of the Danube reconstructed to the same scale
1: ploughland; 2: forest; 3: marshy-boggy area; 4: waterlogged meadow; 5: zone shallow; 6: dam.

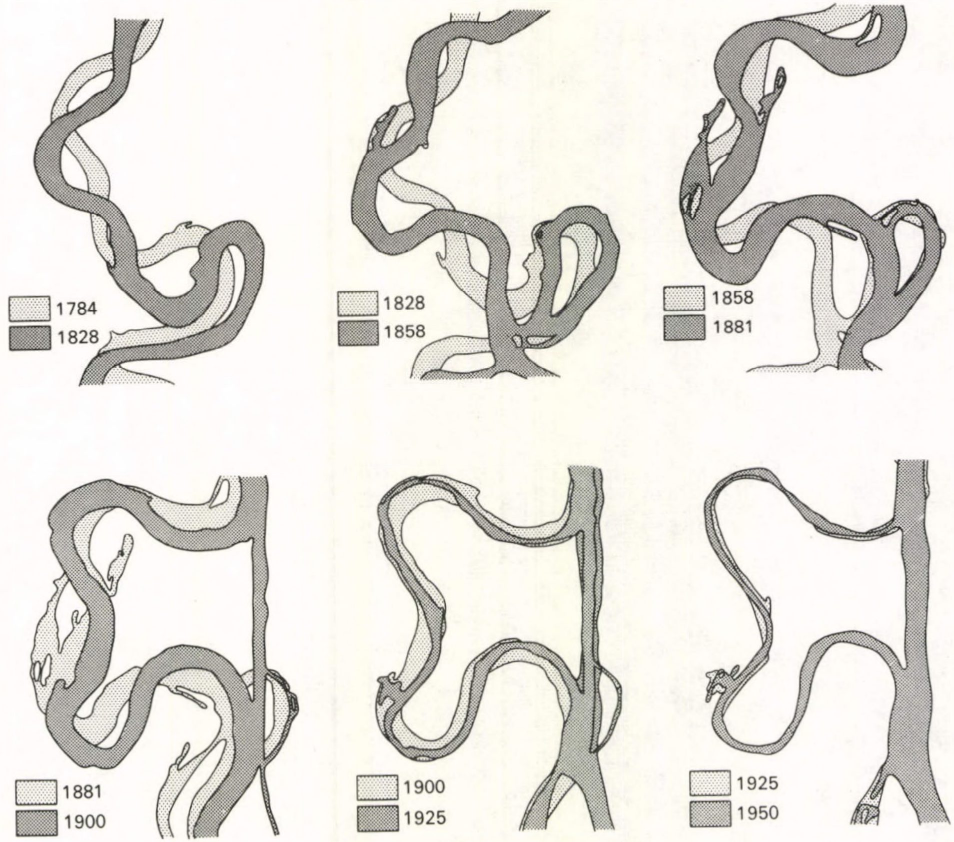


FIG. 3 Channel displacement of the Danube's Sárköz reach projected onto each other from the different dates.

TABLE 1 Characteristic values of meander evolution by stage of development /after LÁSZLÓFFY, W./

		I.	II.	III.	IV.	V.
R	/Radius of curvature of current-line/	=	= 1 = 1	$\frac{1}{2}$ = o,5	$\frac{1}{2}$ =o,7o7	= 1 = 1
H	/Length of arc between inflexion points/	= 1 = 1	$\frac{1}{3}$ =1,o5	= $\frac{1}{2}$ =1,57	= $\frac{3}{2}$ $\frac{1}{2}$ = 3,33	$\frac{5\ \ 1}{3}$ =5,23
I	/Relative descent/ $\frac{l}{H}$	= 1	o,95	o,64	o,3	o,19
m	/Height of arc perpendicular to chord/	= o	o,27	1	3.14	3,72
P = $\frac{I}{H}$	/Centrifugal force/	= o	o,95	1,28	o,42	o,19

TABLE 2 Data on the development of river bed along the Sárköz reach of the Danube

/A = Strongly developed river meander/

Date	L m	h m	H m	β	m m	α	R m	Y m	D m	M m	M/D	River bed axis displacement in m	Stage of development
1783	13 25o	3 61o	5 75o	3,2	2 4oo	1,3	75o	6	1 95o	2 65o	1,4	W 625 E 175	IV
1828	16 ooo	1 4oo	8 ooo	5,6	2 75o	1,3	5oo	9	1 25o	3 25o	2,6	S 1255 E 15o W 2oo S 75o	V
1858	12 ooo	25o	6 5oo	2,6	2 75o	11	575	8	1 5oo	3 2oo	2,1		
/B = Weakly developed river meander/													
1783	13 25o	875	1 125	1,3	4oo	o,46	45o	1o	1 6oo	1 6oo	1		I
1828	16 ooo	2 4oo	4 ooo	1,6	1 45o	o,5	85o	5,3	1 825	1 825		W 275 E 175 S 875	
1825	12 ooo	1 6oo	3 5oo	2,2	1 5oo	o,43	7oo	6,4	1 9oo	2 375	1,2	W 55o W 2oo S 175o	III
1881	16 ooo	1 55o	4 75o	3	2 ooo	1,3	575	8	1 5oo	2 375	1,6	S W 26o	
19o3	18 5oo	1 ooo	4 5oo	4,5	2 ooo	2	575	8	1 9oo	3 1oo	1,6	S 875 E 35o E 175	IV
1925	7 ooo											S 375	V
195o	7 ooo											E 35oo E 2ooo	

Legend: L = length of the reach measured in the current; h = length of the chord /distance between the inflexion points/; H = Length of arc between the inflexions; m = height of arc; R = radius of curvature of the current lie; M = width of the meander; D = diameter of the meander; $= \frac{H}{h}$; $= \frac{m}{h}$; $Y = \frac{4\ 5oo}{R}$

To enable a better comparison in the TABLE 2 the evolution of two meanders was followed for which the characteristic numerical values introduced by literature were determined. The sharp bend formed in 1783 in the southern part of the reach in question was captured over a period of 7o years. Its capture was followed quite closely the second military survey in 1858. According to the theoretically determined stages this meander reached the IVth stage in 1783 and the Vth evolutionary stage in 1828. All meanders reaching this stage have the potential for capture, which took place in the care of this meander sometime at the beginning of the 185os. To obtain some idea about the development of a young meander the evolution of one such form was followed from 1783 on. This meander lies in the northern part of the reach. It began to develop in 1783, the first evolutionary stage, reached the third stage in 1828 and the fifth stage by the end of the century, whereafter the potential for capture existed. The meander was, however, then eliminated during the process of river regulation, but it may be assumed that had natural evolution progressed, it would have been captured in around 1925, the time of the next survey. By following the evolution of the two meanders, it is possible to assess the length of life of a Danube meander from its inception capture, which on the basis of the Sárköz experience would seem to be around 15o years.

The changes in the characteristic numerical values of meanders, of course, relate to numerous other factors about meander development, but on this occasion they will be neglected. The reader is only referred to the fact that in spite of the different disturbing factors the value, expressing the relationship between the arc height /m/ and the chord /h/, i.e. the straight line between the two inflexion points, proved to be the most regularly changing value.

Our statements concerning the evolutionary stages agree with the calculations of PÉCSI, A. /1939/. According to him the value of , expressing the relationship between length of the arc and the chord is a function of the age of the meander. When is less than 1.57, the meander is young, when it is between 1.57 and 2, the meander is of middle age, and where is greater than 2, the meander is old.

Referring to JEFFERSON /19o2/ it is used to be supposed that the oscillation of meanders, i.e. the distance of the envelope, may increase by a factor of 18 /this value is indicated as M in the table/. According to our data in the Sárköz reach of the Danube, where in different times the width of the water surface was 3oo to 35o metres, the increase was only up to tenfold and instead of continued expansion after the fourth stage the meander deformed, or doubled.

What caused this remarkable phenomenon? It is known from the geological-geomorphological research of the area /PÉCSI, M. 1959/ that in the structure of the Sárköz only the upper 15 to

2o metres is composed of finegrained recent alluvium; beneath this gravels can be found which also have a thickness of around 15 to 2o metres, which relate to the period of subsidences during the Upper Pleistocene. When the radius of curvature of a meander begins to decrease and at the same time the centrifugal force increases, the under-cutting power of the current becomes stronger. It is known from the be surveys that depressions of 18 metres depth can be found below the zero level in the meanders. In these places erosion removes the fine-grained recent alluvium and meets the deeper-lying coarser-grained layers. With its available energy, however, the river cannot erode at the same rate. Therefore the lateral evolution of meander development becomes slower, and seems to have ceased, by contrast in the upper part wher down-cutting is less the displacement continues at a constant rate. In this way further meanders form which spread over the deepest-cut "main" meander and distort it. It is in this way that the bowl and sack-line meanders of the Sárköz reach come into existence.

It can also be observed that displacement in a north-south direction always exceeds lateral east-west displacement because in this case the effects of centrifugal force and gravitation coincide with each other. For instance, between1783 and 1828 the maximum lateral displacement was 8oo metres i. e. 18 m per year while displacement in a north-south direction reached over 1 2oo metres, i. e. 28 m per year /TABLE 3/.

TABLE 3 Maximum bed displacement

Intervals	Lateral displacement	Displacement in a NS direction
1783 - 1828	8oo m /18 m/year/	1 275 m /28 m/year/
1828 - 1858	66o m /2o m/year/	1 o5o m /35 m/year/
1858 - 1881	1 2oo m /5o m/year/	85o m /38 m/year/
1881 - 19oo	3oo m /16 m/year/	375 m /16 m/year/

Comparing these data meanders at different stages of evolution are not separated, although the change in centrifugal force has a significant influence because only the differences between the two tendencies needs to be emphasized. It is obvious that the rate of lateral displacement is in all cases less than the displacement in a north-south direction, with the exception of the period 1858 to 1881; in this case no displacement took place but the main meander was abandoned.

It is very interesting to observe the effect of bed displacement on the whole river course. This problem is answered in the last but one column of the table, where the oscillation in the direction of flow demonstrable from the Sárköz reach, is summarized /this is the difference between successive east west movements/.

Similar displacementsin an east and westerly direction follow one another from time to time. Namely, however much the river meanders, the axis and main direction of flow remains constant in the same plane. This means that the river is really of graded stream character, it neither down cuts appreciably nor is alluviation substantial. It can also be stated that assymetrial tectonic effects have not act on the river during the past two centuries because if this had occurred the unidirectional movement would have taken place.

Let us now consider the question of erosion for which the length and displacement of the bed serve as the basis of the investigation /FIG. 4/. For instance, we know, that the length of the bed was 13 25o metres in 1783. The main displacement value /the mean value of both lateral and vertical displacements/ was about 1 ooo metres, but since there were bank sections where displacement was less, an average displacement of 13 metres per year can be calculated assuming a total displacement of 6oo metres up to 1828. Assuming an average uniform bed depth of lo m the river washed away 13 25o x 6oo x lo cu. metres of material from the whole section of the reach, i. e. 79 5oo ooo cu. m., which corresponds to a yearly average of 1.8 million cu. m. Of course, the overwhelming majority of the material washed away is newly deposited by the river, but the increase in the amount of alluvium is none the less considerable. In the more recent shorter bed the increase in the amount of alluvium between Fajsz and Baja was estimated by BOGÁRDI, J. /1955/ to have been 8 million tons, i. e. more than 4 million cu. m. From these facts the considerable wash from the bank is obvious and this can also be observed in the artificial cut-off of the reach extending over a distance of more than three kilometres where the value reached 7 m per year between 19o3 and 1925. Recalculating these values, this means the wash and transport of about 7o ooo cu. m rock per kilometre per year. Erosional bank wash along the Sárköz reach of the Danube /TABLE 4/.

Comparing the surveys of 1925 and 195o it is obvious that the evolution of the so-called Rezét cut-off had finished for the most part 1925. The further widening of the bed is hindered by bank-protecting stones and dams, which are artificial and cover a considerable length. As a result of this no significant bank displacement can be observed between 1925 and 195o. Siltation and the narrowing of the bed became ever stronger processes.

The rate of narrowing of the backwater between 19o3 and 1925 surpassed lo m per year and this continued to be substantial after 1925 as well. The reason why it is only the strip near the bank that silts up and nto the whole section was answered by CHOLNOKY, J. in 19o7. Naturally, the results presented above do not mean the termination of the evaluation. Further possib-

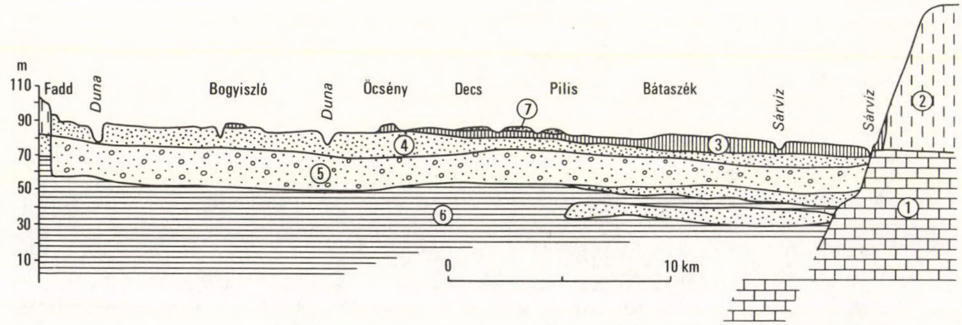


FIG 4 Geological profile between Fadd and Báta /SÜMEGHY, J. 1948/.
1: limestone; 2: loess; 3: alluvial silt; 4: fluvial sand; 5: gravelly sand and sandy gravel; 6: Upper Pannonian clay; 7: blown sand.

TABLE 4 Erosional bank wash along the Sárköz reach of the Danube

Interval year	Length of bad m	Bank-width washed away m	Annual total wash million cu.m	Mass of rock washed away million cu.m
1783 - 1828	13 25o	6oo	79.5	1.8
1828 - 1858	16 ooo	42o	67,2	2.2
1858 - 1881	12 ooo	48o	57.6	2.5
1881 - 19oo	16 ooo	21o	33.6	1.5
19oo - 1925	7 ooo	15o	1o.5	o.55
1925 - 195o	7 ooo	75	5.3	o.2

ilities for investigation are given by the study of the changes in the flood plain and its transformation. Comparing the various maps it is obvious - besides the facts mentioned above - that the evolution and extinction of meanders are regionally also separated. The succession of vegetation types is determined by the ecological conditions. Our aim is to extend the investigations to neighbouring river sections in the near future.

SUMMARY

The rate of bed displacement can be registrated only by means of precise geodetic network, the organization and maintenance of which has been an exacting task. The movement of recent beds is restricted by human investigation, as well. Thus the values of displacements determined on the basis of ancient mapping

possess considerable significance since these reflect more or less the natural state. The essence of the method is as follows: based on the coordinates of reference points of the maps constructed in different time intervals, scales and projections, the map of the bed and accompanying valley are drawn again in the same scale and projection. In this way the value of horizontal displacement of the bed can be exactly measured.

Applying this method a part of the Danube's Hungarian section was reconstructed on the basis of eight maps including a bed evolution of roughly 17o years. At the Sárköz reach the natural disjunction of a curvature as well as the formation of an other can be observed, the latter being cut at the beginning of this century. The rate of bed displacement depends of the stage of curvature evolution, this being characterized in the table by indices based on the length, chord, length of arc, arc height, radius of curvature, and on the wideness and diameter of it. These data relate to the fact that at this reach of the Danube, i. e. between Budapest and the Dráva mouth, the lifetime of a curvature from its formation up to its disjunction lasted to about 15o years in natural state. Nowadays this cannot be followed since a lot of economic interests requires the stabilisation of the bed in the same state. Out of the relationships referring to the state of curvature evolution the coefficient expressing the relationship between the arc length and chord of the curvature proved to be most characteristic. It can be also observed that the displacement down the river always exceeds that of the lateral movement since in this case the effects of gravitation and centrifugal forces coincide.

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ENGINEERING MORPHOLOGICAL INVESTIGATIONS OF THE CELLARS IN THE HISTORICAL TOWNS OF HUNGARY

Mrs. SZENTIRMAI, L. - SCHEUER, Gy.

INTRODUCTION

In historical times cellars with many different aims and designations were constructed beneath several of historical towns of the country, for instance beneath Pécs, Szekszárd, Szentendre and Eger /FIG. 1/. The stability of these cellars has, however, been threatened by the rapid and dynamic evolution of the towns and since the 196os cellar collapses have become increasingly frequent with consequent damage to overlying buildings, roads and public utilities. Immediate precautions have therefore been needed to present such collapses endangering life and material security.

FIG. 1 Sketch plan showing the towns endangered by cellar collapse

In this connection multipurpose city plans have been drawn up with a view to landscape and environmental protection, and including the geomorphological, geological and engineering geological aspects of this problem. The discovery of a solution to the problem of cellar collapses was hindered by the fact that the areas so affected coincide with historical town centres, and primary attention was given to saving building valuable from the historical and town-scape points of view. Thus, a reasonable and deliberate program was needed to carry out these substantial and divergent operations.

Efforts were made to reestablish some equilibrium partly by means of a selective filling-in of the cellars, and partly by fortifying them so as to achieve some functional accommodation to the towns life.

It is the task of the Surveying and Soil Prospecting Enterprise to coordinate these activities. Within the framework of the investigations into cellar stability large-scale research and investigations have been started which require the specialist cooperation of geomorphology, engineering geology and geology in addition to the documentation, archival and archeological activities. The results of the engineering-morphological and engineering-geological investigations are outlined below.

FORMATION AND CLASSIFICATION OF CELLAR SYSTEMS

The creation of cellars and cellar systems began in the Middle Age according to archival and historical data, but the most dynamic period of construction proved to be the 18th and 19th centuries when they most fitted in with the economic life of the towns concerned. Their principal functional role was the storing of wine, but there are also examples of cellars which were created to produce building material or were aimed at defensive or military purposes. During historical times were not only the cellars enlarged or interconnected, but certain branches were cut off or were haphazardly filled in and forgotten about. It is this last category that has caused most damage, and the search for unknown cellars consequently, proved to be an important task.

In case of the towns cited above the total lenght of known cellars exceeds 4oo km and beneath certain of them veritable cellar labirynths exist /FIG. 2/, that are overlain by buildings, roads and public utilities.

According to in situ observations the natural and geomorhological conditions of such cellars are variable, but a classification has been achieved using their most characteristic features what has been most helpful in pointing the way to a practical solution to the problem. This calls attention not only to the fact that there are different cellars /FIG. 3/, but also to the fact that any technical intervention must be tailored to the divergent aspects. The principals behind the classification of the different types of cellar are given in FIG. 4. TABLE I.provides

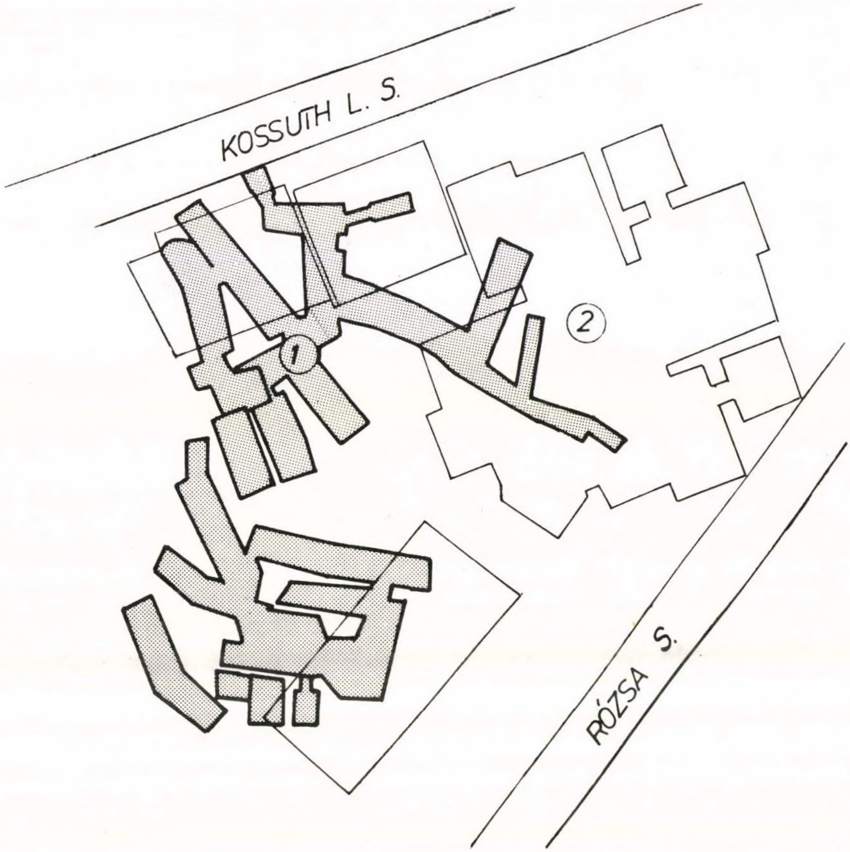

FIG. 2. Block plan of the city of Pécs showing discovered cellars
1: cellars; 2: buildings.

a classification according to the form of occurrence, while TABLE II. is based on the types of geomorphological site where the cellars were constructed.

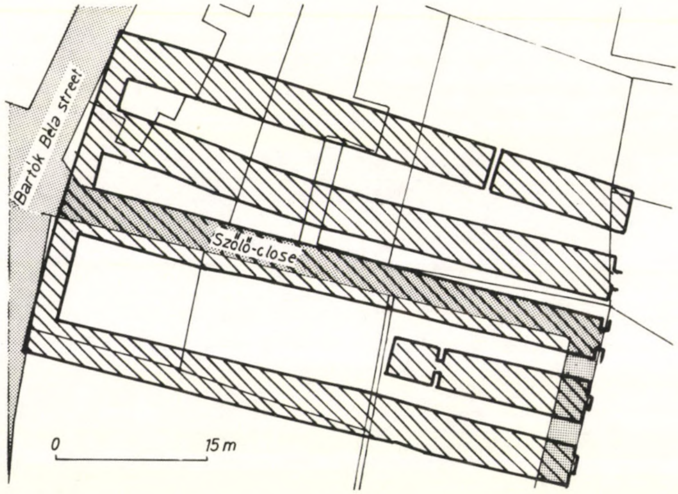

FIG. 3 Branched cellar at Szentendre in Szerb-street

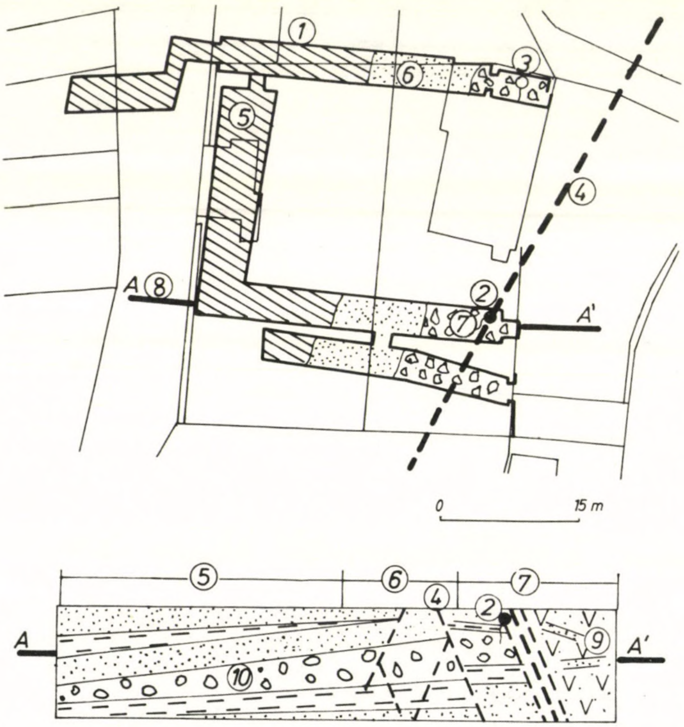

FIG. 4 Theoretical classification of cellars and cellar systems in the historical towns of Hungary

CLASSIFICATION ACCORDING TO THE SHAPE, DIMENSION AND FORM

design		
	1	simple
	2	branched
	3	cellar systems

dimension		
	1	small
	2	medium
	3	big
	4	huge (above 200 m)

internal height		
	1	low
	2	common
	3	high

internal shape		
	1	vaulted
	2	arched
	3	flat
	4	irregular
	5	mixed

profile of cellar		
	1	small (less than 1,5 m)
	2	common (1,5 to 3,0 m)
	3	big (3 to 6 m)
	4	huge (above 6 m)

TABLE I Classification of cellars according to design

GEOMORPHOLOGICAL ASPECT

CELLAR ENTRANCE MAY OPEN IN		
	1	hill-side
	2	in flat region or gently slope (up to 5°)
	3	top of hill or mountain
	4	natural vertical exposure
	5	artificial vertical exposure

TABLE II Geomorphological classification of cellars

ENGINEERING-MORPHOLOGICAL AND ENGINEERING-GEOLOGICAL

OBSERVATIONS ON THE STABILITY OF CELLARS

The studies dealing with the stability and collapse of cellars /KLEB, B. 1978; GÁLOS, M.. KERTÉSZ, P., KÜRTI, J. 198o; NAGY, J. et al. 198o/ have shown that the sudden increase in damage since the 196os is closely related to urbanization. Cellar collapses occurred previously, as well, but only rarely and locally. The increase in the amount of damage primarily affects public utilities, like the sewage system and piped water networks as well, as roads.

Due to the infiltration of water and the lack of drainage, the rocks in which the cellars are cut have gradually become wet. Consequently, weathering has intensified and stability has considerably decreased. For example, the processes at work have reduced the strength of rhyolite tufa by two-thirds. Due to the change of physical properties the rocks are no longer able to bear the load, and sporadic but always systematic cellar collapse follows. As a result of the rupture of watermains and sewers a large number of cellar collapses usually occur in a given area within a short period of time.

Observations and investigations have shown that cellar collapses take on definite forms and types which are affected by geomorphological, geological and petrophysical properties, in addition to the general nature of the cellars concerned. Obviously, different geomorphological collapse forms are associated with stratified as opposed to unstratified rocks. Consequently, the fundamentals which affect and determine the dimensions of collapses have been grouped together in TABLE III.

On the basis of this classification it can be stated that not only were cellars constructed in different rock types, but that the factors determining the location and dimensions of collapses are highly varied in form. According to the observations most collapses take place along definite, i. e. preformed surfaces. In the case of stratified rocks the bedding planes form such surfaces since these either lack strength completely or they are less or it is always stronger than the rest of the strata, and separation follows if the weight of rock exceeds this force. This type of separation may occur on a relatively minor scale in a cellar roof causing small collapses, but where distances of 1 to 2 m are involved general collapse follows. Other types of performed surface are the fault lines produced by tectonic movement where again adhesion is reduced and where the effect of water or other factors may induce them to become separation surfaces depending on their direction and dip, thus producing cellar collapses. Accordingly, cellar collapse may occur along bedding planes, along fractures and faults, and along non-preformed planes.

It is therefore clear that the cellars which are most likely to collapse, are those cut in weakened stratified rocks in which

GEOLOGICAL ASPECT

age

ROCK TYPE	
1	Sarmatian limestone
2	Miocene volcanic strata
3	Miocene marl, sandstone
4	Upper Pannonian cemented sand
5	Pleistocene travertine
6	Pleistocene sediments
7	loess

rock formation

ROCK SHAPE	
1	stratified
2	banked
3	bulky
4	mixed

THE STRATIFICATION MAY BE	
1	regular
2	wedging
3	thickening
4	lenticular
5	nodular
6	disturbed

STRATA SEQUENCE MAY BE	
1	homogeneous unstratified
2	homogeneous stratified
3	of interbedding
4	of different formation with stratification (clay, sand)

rock state

ACCORDING TO STRENGTH	
1	loose
2	loosely cemented
3	partially cemented
4	cemented
5	solid (excavable even by hand)
6	very solid
7	solid but fractured
8	solid, separated along planes

ROCK STATE	
1	fresh
2	locally weathered
3	weathered
4	fractured

structural conditions

DIP OF STRATA AS COMPARED TO THE CELLAR	
1	horizontal
2	outward dipping
3	inward dipping
4	vertical
5	angle subtending

FRACTURES MAY BE	
1	vertical
2	steep (more than 45°)
3	flat (less than 45°)

ACCORDING TO THE NUMBER OF FRACTURES	
1	single
2	several parallel
3	complicated several fractures intersect each other

ORIENTATION OF FRACTURES OF CELLAR	
1	longitudinal
2	transversal
3	diagonal

TABLE III Geological classification of cellars fractures and moisture are present /FIG. 5/.Cellar collapses are only dangerous if these react on the surface and from this point of view subcrustal or shallow cellars are the most dangerous.

In summary it can be stated that in stability tests on each cellar the detailed description of engineering-morphological and engineering-geological features is the primary task since it is only on this basis that conclusions can be drawn about the degree of danger, and the need for intervention.

TOWN CELLAR SYSTEMS

During the last few years decades damage to buildings caused by cellar collapses in several of the historical towns of Hungary has been such as to bring occasionally the town's life to a halt. Particularly affected have been Pécs, Szekszárd, Szentendre and Eger, and to a smaller extent Budapest.

a/ P é c s

Cellar collapses have been most widespread causing heavy building damage, fracturing of public utilities and road subsidence. According to the surveys that have been carried out the historical city is the most endangered part. Most of the cellars are cut into Upper Pannonian stratified loosely bound silty sands and sandstones which were easily excavated by hand while others are cut into Pleistocene fluvial and slope deposits. The low groundwater table at a depth of 1o to 2o m also favoured cellar building.

Originally these cellars were used for the storage of wine and other foodstuffs as well as for defence and due to numerous collapses are now in a largely ruined state. Most were unknown before their collapse. The rise in the level of the groundwater table substantially contributed to the damage, and previously dry cellars were inundated. Even in the still water-free cellars deterioration has occurred due mainly to water seepage from public utilities. This process has also been promoted by the stratification of the rocks and their low strength. Although the most urgent remedial activities are now finished, research remains in progress.

b/ S z e k s z á r d

Cellar damage in the town has only affected those districts situated on dissected slopes. The flat areas covered by alluvial sediments by contrast, were unfavourable for cellar construction either because of a high groundwater table, i. e. 2 to 4 m below the surface, or because of the existence of loose sands, and gravels. The excavation of cellars proved to be more favourable in the hill-sides since these regions are composed of a considerable thickness of loess which is easily excavated, is stable, and is dry while the groundwater table lies at greater depths. In this region nearly all the houses were vaulted /FIG.6/.

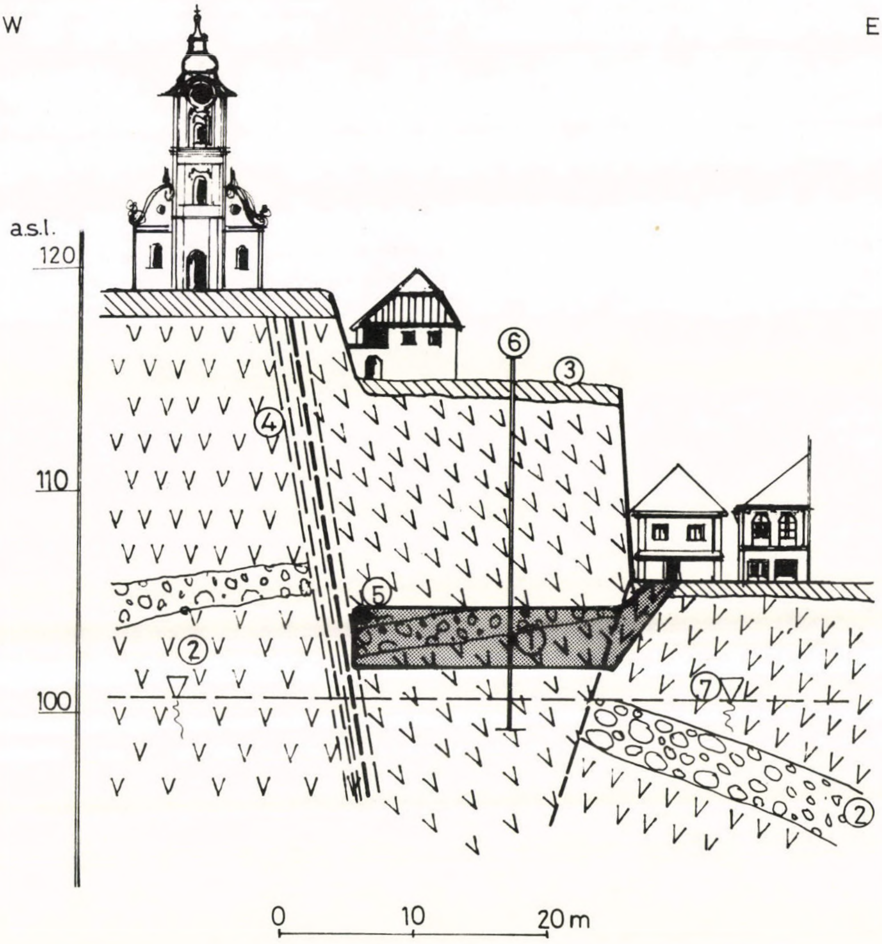

FIG. 5 State test of a cellar at Szentendre

1: the cellar; 2: site of continuous water infiltration; 3: site of periodically occurring water; 4: fracture zone; 5: stable cellar; 6: unstable cellar section; 7: cellar section with collapse; 8: site of the profile; 9: tufa, tuffaceous sand, sandstone; lo: mixed sequence of stratified gravels, clays and sands.

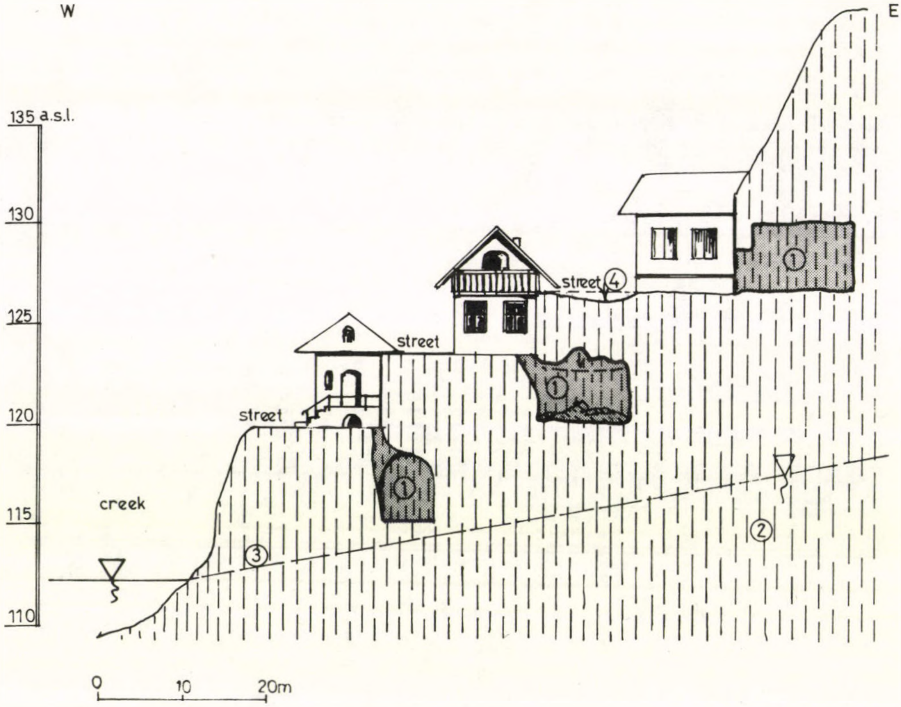

FIG. 6 Engineering-morphological sketch profile at Szekszárd 1: cellars; 2: loess sequence; 3: groundwater; 4: road subsidence caused by partial cellar collapse.

Due to water seepage from public utilities and poor drainage the loess strata have locally been moistened, and have lost their stability causing collapses that have endangered overlying establishments. Survey work and damage preventing activities are now in processes.

c/ S z e n t e n d r e

The morphological, geological and hydrogeological fundamentals of this provincial town located on the Danube north of Budapest were extremely favourable for the building of cellars. The dissected relief, the easily exploitable Miocene volcanic tufas as well as a low groundwater table favoured the creation of cellar system beneath to town and environs. As for as it is known the central part of the town is a veritable labirynth of cellars which were built for wine storage and which nowadays are mostly abandoned /FIG. 7/. Recently engineering-morphological and engineering-geological research has gone on parallel with the re-

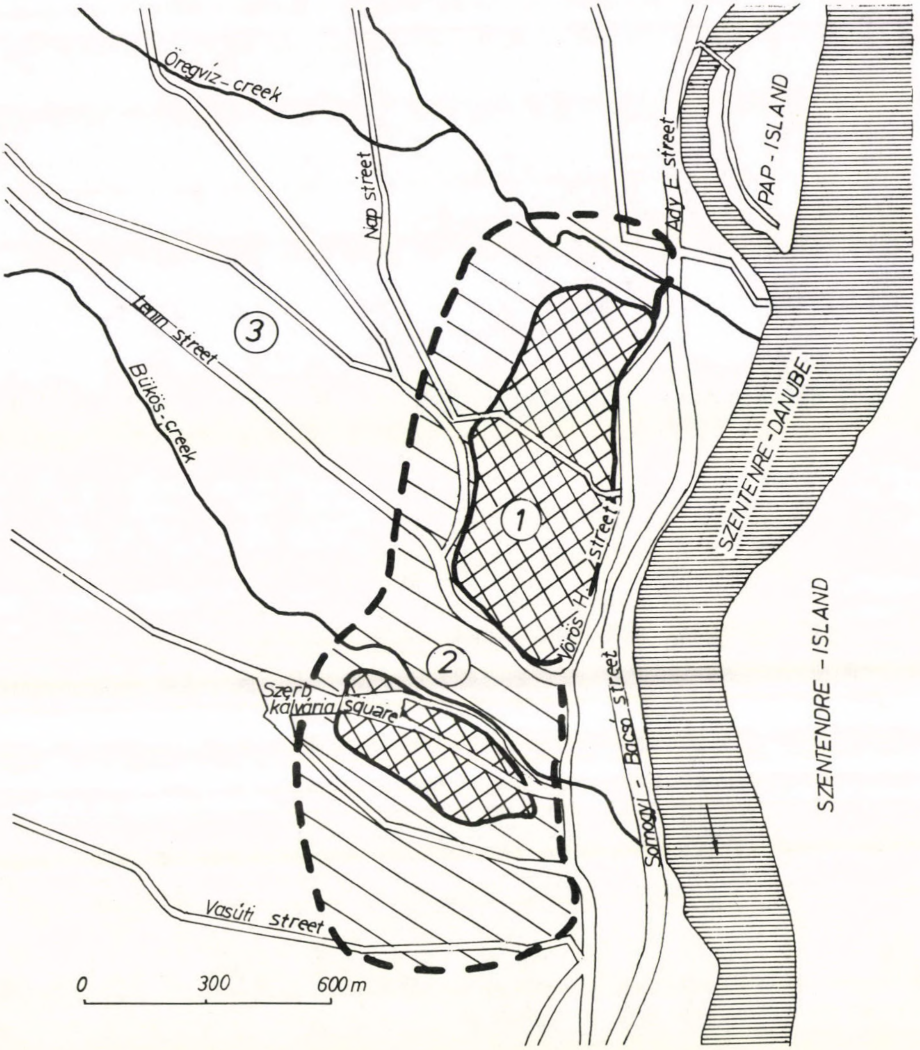

FIG. 7 Block plan showing the cellar system of the town of Szentendre
1: locations of greatest concentration of endangered cellars; 2: average cellar density; 3: local cellar systems.

inforcement of dangerous cellars. The most recent situation of cellars is shown in FIG. 8.

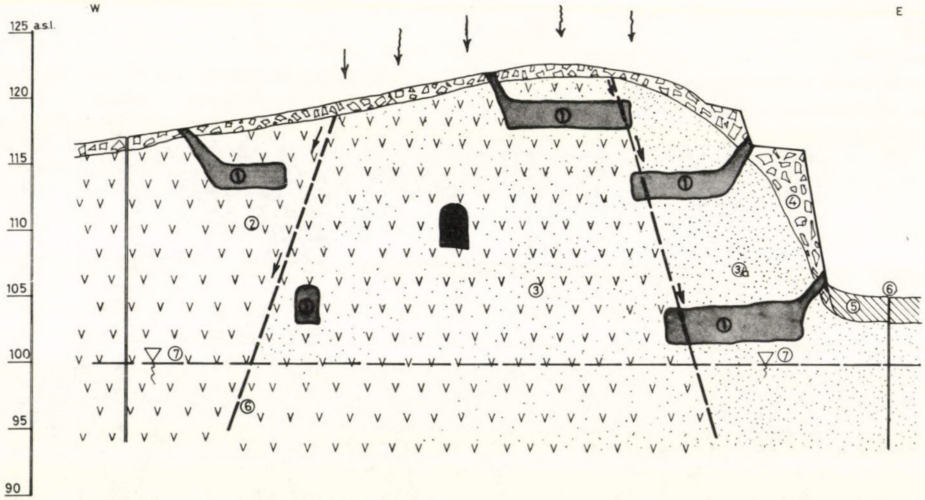

FIG. 8 Engineering-morphological profile at Szentendre
1: cellar; 2: Miocene tufa sequence; 3: packing; 4: fault, 5: spring; 6: well; 7: groundwater table.

d/ E g e r

In this town, deu to the substantial viticulture and wine production of surrounding areas huge cellars and labirynth-like cellar systems were developed, similar to those in Szentendre. Cellar collapses have also caused substantial problems. As a result of research started in 1969 it may be stated that the densest cellar network is found beneath the town itself. Nevertheless, in the suburbs and in the neighbouring vineyards numerous cellars are to be found forming local cellar series which are still in use. Most cellars were cut into Miocene rhyodacite tufas, marls and sandstones, but some are found into Quaternary travertines and other sediments. The deterioration of the state of the cellars has been caused first of all by the increase in the water content of the rocks in addition to other factors. In the historical parts of the town intense packing and reinforcing operations have been carried out in order to protect the buildings.

e/ B u d a p e s t

In certain districts of the capital, for instance, in Kőbánya and Budafok, fairly minor damage has been caused by the partial collapse of abandoned cellars and bentonite mines. Most of the underground caves and cellars are found in Sarmatian limestone. Any danger has either been eliminated or is in progress of being eliminated.

SUMMARY

Following the large number of cellar collapses at the end of the 196os geomorphological, geological and engineering methods of assessment as well as damage prevention and reconstruction procedures have been developed. As a result direct damage can now be prevented, and significant historical buildings protected and significant historical buildings protected and everyday life safeguarded.

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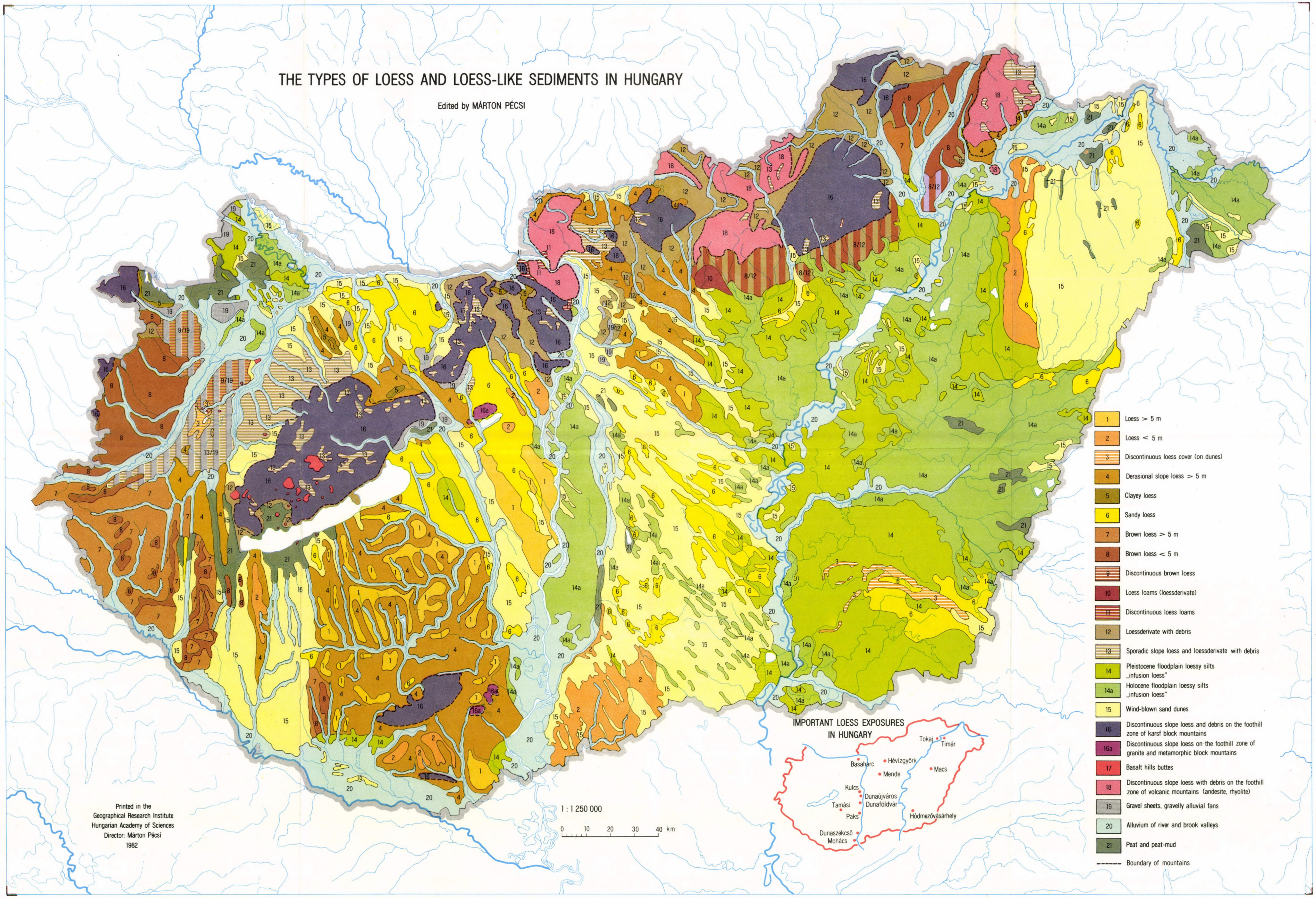
THE TYPES OF LOESS AND LOESS-LIKE SEDIMENTS IN HUNGARY
Edited by MÁRTON PÉCSI
1 Loess > 5 m
2 Loess < 5 m
3 Discontinuous loess cover (on dunes)
4 Derasional slope loess > 5 m
5 Clayey loess
6 Sandy loess
7 Brown loess > 5 m
8 Brown loess < 5 m
9 Discontinuous brown loess
10 Loess loams (loessderivate)
11 Discontinuous loess loams
12 Loessderivate with debris
13 Sporadic slope loess and loessderivate with debris
14 Pleistocene floodplain loessy silts „infusion loess"
14a Holocene floodplain loessy silts „infusion loess"
15 Wind-blown sand dunes
16 Discontinuous slope loess and debris on the foothill zone of karst block mountains
16a Discontinuous slope loess on the foothill zone of granite and metamorphic block mountains
17 Basalt hills buttes
18 Discontinuous slope loess with debris on the foothill zone of volcanic mountains (andesite, rhyolite)
19 Gravel sheets, gravelly alluvial fans
20 Alluvium of river and brook valleys
21 Peat and peat-mud
Boundary of mountains
IMPORTANT LOESS EXPOSURES IN HUNGARY
Tokaj
Tímár
Basaharc
Hévizgyörk
Mende
Macs
Kulcs
Dunaújváros
Dunaföldvár
Tamási
Paks
Hódmezővásárhely
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