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LATEST PLEISTOCENE GEOHISTORY OF THE BÁCSKA LOESS AREA

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INTRODUCTION

The Bácska Loess Area is situated in the southern part of the Danube-Tisza Interfluve. A smaller part of it is shared by Hungary, the greater part by Yugoslavia *(Fig. 1)*.

The early Danube flowed still diagonally, in southwest direction across what is now the Danube-Tisza Interfluve, probably up to the Günz-Mindel interglacial. Thereafter it got into its present-day meridional valley. After the Günz-Mindel interglacial the Danube-Tisza Interfluve was abandoned by fluvial accumulation so that only eolian sediments, loesses and wind-blown sands could settle down on its

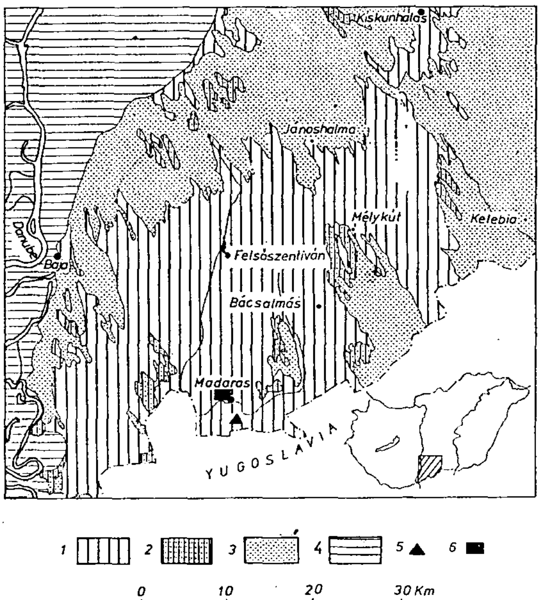


Fig. 1. Geological map of the Hungarian share of the Bácska Loess Area and of its surroundings 1. Typical loess, 2. Sandy loess, 3. Wind-blown sand, 4. Alluvium, 5. Site of the Madaras section, 6. Location of the large-scale geological map showing the *Katymár-Madaras* area (area shown in *Fig. 6*.)

surface. As a result of this, tens of metres, and in several places even more than a hundred m, of alternating wind-blown sand and loess can now be found in this area. In the northern part of the Bácska Loess Area, at Felsőszentiván, the eolian sediments attain 120 m in thickness. Farther south their thickness rapidly decreases, to become as little as 60 m in the vicinity of Madaras [I. MIHÁLTZ, 1953, B. MOLNÁR, 1961, 1970, 1973, 1975, E. KROLOPP, 1970, M. KRETZOI—E. KROLOPP, 1972].

The surface of the Danube-Tisza Interfluve is covered today predominantly by wind-blown sands, a minor part being shared by loess. Out of the loess-covered parts, the Bácska Loess Area is the largest and most important. The Hungarian share of the study area lies SSE of the Baja—Jánoshalma—Kiskunhalas line, reaching almost as far east as the Budapest—Kelebia (Belgrade) railway line. In southern direction it continues beyond the frontier, in Yugoslavia, being bounded by the Danube valley in the west. In the north and east, it borders on wind-blown sands, in the west it is flanked by the Danube's alluvial plain varying between 80 and 90 m in altitude. On the northern border there are the wind-blown sands of Illancs with their topmost point of 174 m altitude, representing, at the same time, the highest point of the Danube-Tisza Interfluve. The wind-blown sands to the east of the loess area have an altitude of 110 to 120 m a.s.l. The surface of the study area has an altitude of 130 m in the northwest and 120 m near the Hungarian—Yugoslav frontier.

The Hungarian part of the Bácska loess is characterized by low relative relief (weak relief energy), though the two channels of the Kigyós rivulet have heavily incised into the loess surface and thus have markedly furrowed the level loess surface. The geomorphological pattern is further complicated by the occurrence of loess-buried wind-blown sand bars of northwest-southeast direction, soaring remarkably above their level loess background.

The Hungarian share of the loess area lies close to the Hungarian—Yugoslavian border, thus its detailed geological investigation was delayed for a long time, despite the fact that, on account of the renewed large-scale geological mapping projects, both Hungary and Yugoslavia did feel an urgent need for an exact knowledge of the geological makeup of the study area and for the clarification of its latest Pleistocene geohistory. Notably, the fact is that a key to understanding the geology of the whole area is in its Hungarian part. The contact of both the wind-blown sands and the loesses of the Danube-Tisza Interfluve and their superposition can be studied best here. This question is discussed in the present paper and it is sought to fill the gap of knowledge still existing in this respect.

During our previous traverses we observed the occurrence of a great many of well-exposed geological sections in the Bácska Loess Area. Of these the exposures of Madaras and Katymár proved to be the best. The gastropod-rich loess covering the surface is exposed, together with the wind-blown sands underneath, at both localities.

At Madaras the loess is mined for brick (*Fig. 1,* Picture 1). In 1966, while extracting the raw material, the miners discovered a culture layer 170 to 180 cm above the floor of the mine pit, at about 8 m depth under the surface. Undertaking excavations to salvage the artifacts, V. T. DOBOSI unearthed a surface of 15.3 m² on which she found three fireplace spots. The fireplaces were covered by a thick ash and charcoal layer. The artifacts recovered included 33 flint implements, 188 flint splinters and an object identified, with some reserve though, as a bone implement. On the basis of the studied implements, V. T. DOBOSI considers the Madaras site and another prehistoric campsite discovered earlier at Ságvár, to the south of Lake Balaton, to represent two approximately identical sites of the eastern-gravetti culture.

Only two of the poorly preserved bone fragments recovered from the culture layer could be identified (*Equus* sp., det. by D. JÁNOSSY). In the charcoal J. STIEBER identified the presence of *Betula, Pinus,* of the group of *Pinus silvestris* and of *Pinus cembra.* Only two of the 128 charcoal fragments examined were remnants of deciduous trees, the rest having been, all, conifers. From these data, J. STIEBER in-

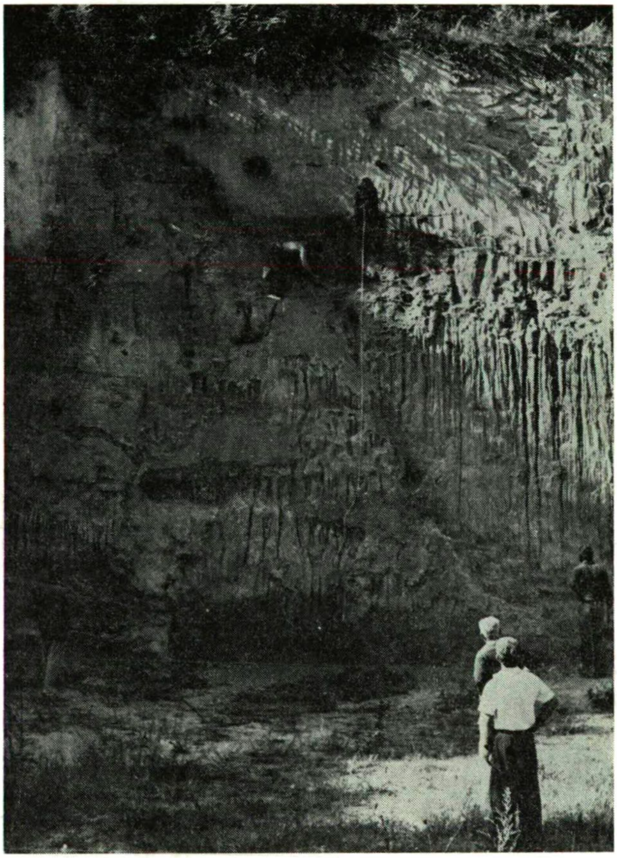
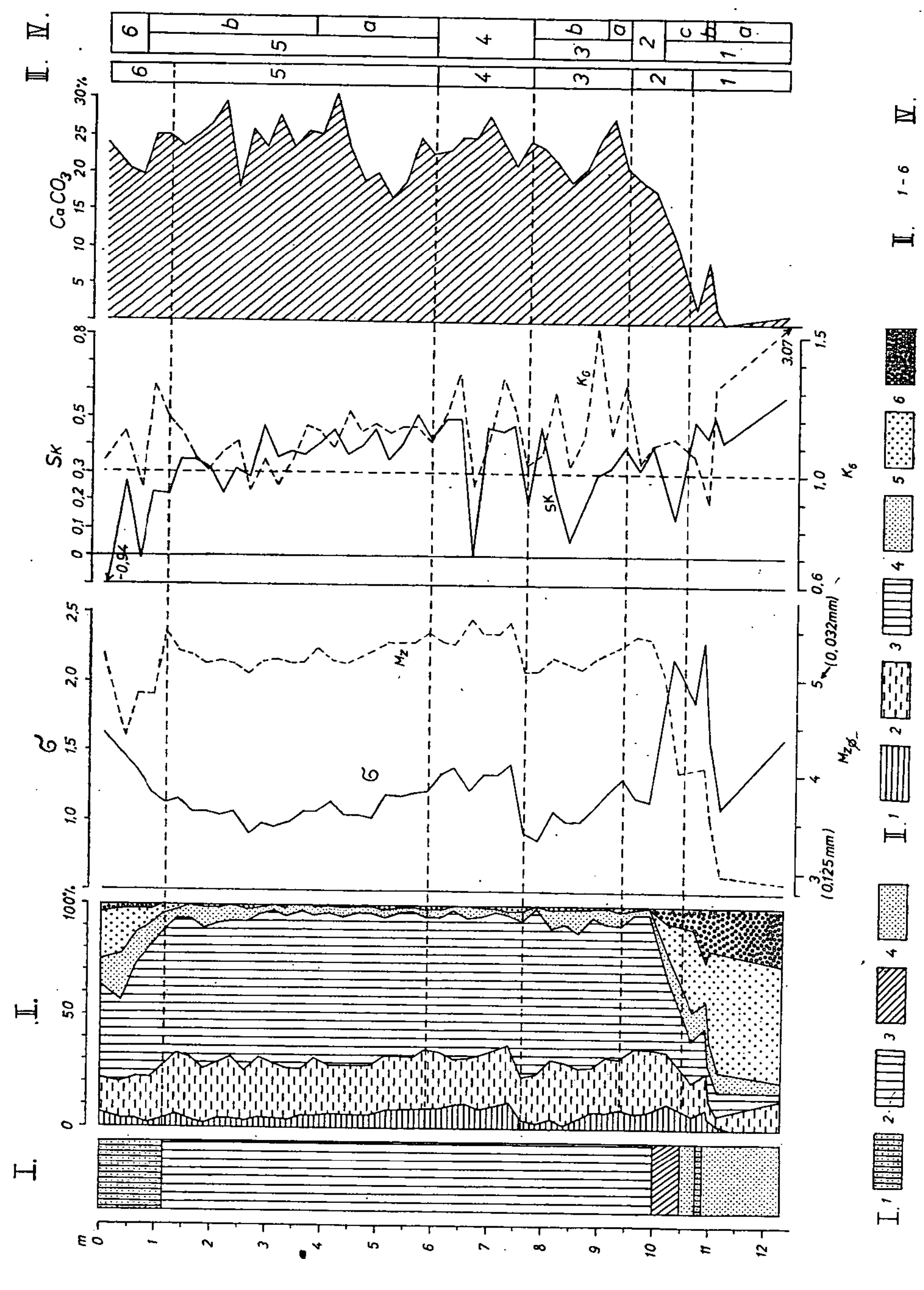


Fig. 2. The *Madaras* loess exposure

ferred mixed *Pinus cembra—Pinus silvestris* forests and an explicitely continental, cold climate [J. STIEBER, 1967]. The charcoal remnants were tested with the radioactive C^{14} method by M. A. GREY of the Niedersächsisches Landesamt für Bodenforschung, *Hannover,* FRG. He obtained for the site an absolute age of $18\,080 \pm 405$ years [V. T. DOBOSI, 1967a].

The miners had even earlier observed a bone-containing layer about 180 cm deeper than the 1966 mine pit floor and the examined culture layer, but no new result was yielded either by this layer, or by the horizon which V. T. DOBOSI dis-


I.
II.
III. IV.
CaCO3
Sk
Kσ
σ
Mz
Mzφ
(0,032mm)
(0,125mm)
30%
100%
m
1-6

covered some 70 cm above it and which contained some bones of poor preservation, locally totally dissolved, or by the few implements found in 1967. Only L. KORDOS did find in 1975, in the northern part of the exposure, in a horizon nearly identical with the already-known culture layer, two tooth plate fragments of a *Mammuthus* cf. *primigenius* BLUMENBACH and one metacarpus of an *Equus* sp., the proximal end of which was damaged. The size data of this latter find are the following: length $\pm$240 mm, distal width $\pm$55 mm, width of diaphysis 58 mm, height of diaphysis 27 mm. These remnants of a mammoth and of a horse of medium size are typical of the Mid-Würm glaciation.

In the light of the above results the Madaras section was selected for geological elaboration. The northern side of the Madaras brickyard has a hight of 9.8 m. This exposure was complemented with a trial pit of 1.5 m depth and a borehole of 1.0 m depth, so that a total of 12.3 m of geological section was studied and evaluated. While being studied, the section was visited by mapping geologists working on the Yugoslavian side of the frontier. Samples were taken at every 25 cm or at any change in lithology. They were then subjected to detailed sedimentological and paleontological analyses. The results can be reported as follows.

LITHOLOGICAL FEATURES OF THE MADARAS SECTION

46 samples were taken from the Madaras section. They were first macroscopically described, then analyzed hydrometrically (a method based on specific weight measurements) and by sieving. The results are shown by plotting techniques in *Fig. 3* (Columns I—II).

The section begins at its base with light yellow small sands. The share of the 0.1 to 0.2 mm sand fraction is more than 50%, that of the 0.2 to 0.5 mm one being more than 20—25%. This sand layer is overlain, between 10.8 and 10.9 m, by light yellow sandy loess with *Pseudomycelium* and, in the 10.5—10.8 m interval follow again small sands completely identical with the previous ones.

The sands are followed in the 10.0—10.5 m interval, by a brown humic, chernozem-like soil horizon developed on a loessy basis. From 1.25 m to 10.0 m there is typical loess of loose structure, a little even sandy, looking completely homogeneous to the naked eye. The loess fraction shares 60—70% in this interval. Of the coarser fractions, fine sand shares 3 to 7%, small sands 0.5 to 1.5%. Clays and fine silts are contained in 25 to 30%. The bulk of the section is constituted by loess attaining 8.73 m in thickness.

The topmost 0.0—1.25 m interval of the section is sandy loess. Within the loess the sand content increases continuously from the base to the top of the section, attaining its maximum, 44.0%, between 0.25 and 0.50 m.

Having read the necessary parameters from the cumulative curves of the laboratory analyses of the grain composition and then substituting the data into the formula proposed by D. L. IMAN, R. L. FOLK and W. C. WARD, the individual sedimentological statistical data were calculated. The results have been plotted as a function of depth *(Fig. 3)* [D. L. IMAN, 1952, R. L. FOLK and W. C. WARD, 1957].

Fig. 3. Sedimentological features of the Madaras section I. 1. Sandy loess, 2. Typical loess, 3. Loess-based, chernozem-like soil, 4. Small-grained wind-blown sand. II. 1. Clay (0.005 mm∅), 2. Fine silt (0.005—0.02 mm∅), 3. Loess fraction (0.02—0.06 mm∅), 4. Fine sand (0.06—0.1 mm∅), 5. Small sand (0.1—0.2 mm∅), 6. Medium sand (0.2—0.5 mm∅), III. Intervals distinguished on the basis of sedimentological studies. IV. Intervals distinguished on the basis of paleontological studies.

Medium grain size (*Mz*) expresses the mean value of the grain composition of the sediment. Its calculation is done as follows:

$$Mz = \frac{\varphi_{16} + \varphi_{50} + \varphi_{84}}{3}$$

Mz is one of the expressions of the mean trend of grain size distribution and its value is proportional with the kinetic energy of the depositing medium (sedimentary environment).

In the Madaras section the mean grain size varies between 2.89 and 5.63φ, *i.e.* from 0.38 to 0.022 mm. Least fluctuation occurs in the 1.25—10.0 m interval; notably, here the mean grain size is as low as 5.00—5.63φ, *i.e.* between 0.03 and 0.02 mm.

Consequently, at the time of deposition of the sediment the kinetic energy of the depositing medium was very well-balanced. Greatest changes in mean grain size are found there, where a material coarser than the loess, *i.e.* sand, also occurs, or there, where sedimentation was followed by transformation processes such as soil genesis. In other words, they are found in the basal and the topmost parts of the section.

The degree of sorting of the sediment, dispersion (σ), is calculated by using the following formula:

$$\sigma = \frac{\varphi_{84} - \varphi_{16}}{4} + \frac{\varphi_{95} - \varphi_5}{6.6}$$

σ means the deviation from the average of the kinetic energy of the sedimentary environment. The longer the value of the transportation energy remains unchanged, the better the sediment is sorted.

In the Madaras section this value is 0.87 to 2.31, *i.e.* the sediment varies between poorly and moderately sorted *(Fig. 3)*. In the lower part of the section, where sand and loess alternate, and where soil-generating processes were also involved in the postgenetic transformation of the sediment, the sorting is worse. Here the value of σ is between 1.56 and 2.31. In the 1.25—10.0 m interval it is rather stable, around 10.0—1.3, to show again an increase farther up the section.

It is interesting to compare the behaviour of the curves of *Mz* and σ. In the lower part of the section, from 9.25 downwards, the increase of the grain size is usually accompanied by worse sorting. In the 7.75—9.25 m interval, the loess, looking macroscopically somewhat more compact, is more moderately sorted. The two curves showing the variation of the grain size and sorting run almost parallel. In 6.0—7.75 m the grain size increases, while the sorting declines. In 1.25—6.0 m the contrary is the case, *i.e.* the grain size decreases, the sorting improves, but the curve remains invariably parallel. Between 0.0 and 1.25 m, however, again a decrease in sorting is associated with the increase of the grain size. Consequently, the two curves in this interval are not parallel, but largely convergent.

Skewness (*Sk*) expresses the asymmetry of the curve. Its direction is measured as related to the median. Its value is calculated as follows:

$$Sk = \frac{1}{2}\left(\frac{\varphi_{84} + \varphi_{12} 2\varphi_{50}}{\varphi_{84} - \varphi_{16}} + \frac{\varphi_{95} + \varphi_5 - 2\varphi_{50}}{\varphi_{95} - \varphi_5}\right)$$

A negative value of skewness, *i.e.* a curve skewed towards coarser fractions, has the meaning that the kinetic energy of the sedimentary environment was for a long time higher than the average kinetic energy. A positive value of skewness means a curve skewed towards the fine fractions, in other words, that the energy of the sedimentary environment must have been for a long time (or more frequently) less than the average.

In the Madaras section the skewness varies between -0.94 and $+0.59$ as extreme values. Looking at the plot of *Fig. 3*, one can readily see that the *Sk* curve is in most cases shifted towards positive skewness. In only two near-surface samples does it overstep, in a negative sense, the point 0 corresponding to a completely symmetrical curve, just touching it at 6.5 m.

In the lower half of the section, in the 6.5—12.3 m interval, the skewness heavily oscillates with values within the 0.01—0.59 range. This means that the energy of the depositing medium was more often and with some fluctuation less than the average kinetic energy.

Between 1.25 and 6.5 m the skewness is very stable, showing a slow upward decrease with values of 0.22 to 0.50. Thus the kinetic energy of the sedimentary environment must have been less than the average for an abnormally long time, though with smaller oscillations compared to the preceding interval.

Finally, in the 0.0—1.25 m interval the sediment yields curves bearing witness to a subsymmetrical grain composition so that again a curve stretch of higher oscillation can be observed on the plot concerned.

Curtosis (K_G) expresses how much a frequency curve is pointed. The relation of 90% of the sediment to the middle-range 50% is examined. Properly speaking, nothing else than the sorting ratio of the grain size distribution in the middle range of 50 to 90% is dealt with. Its value is calculated by the aid of the following formula:

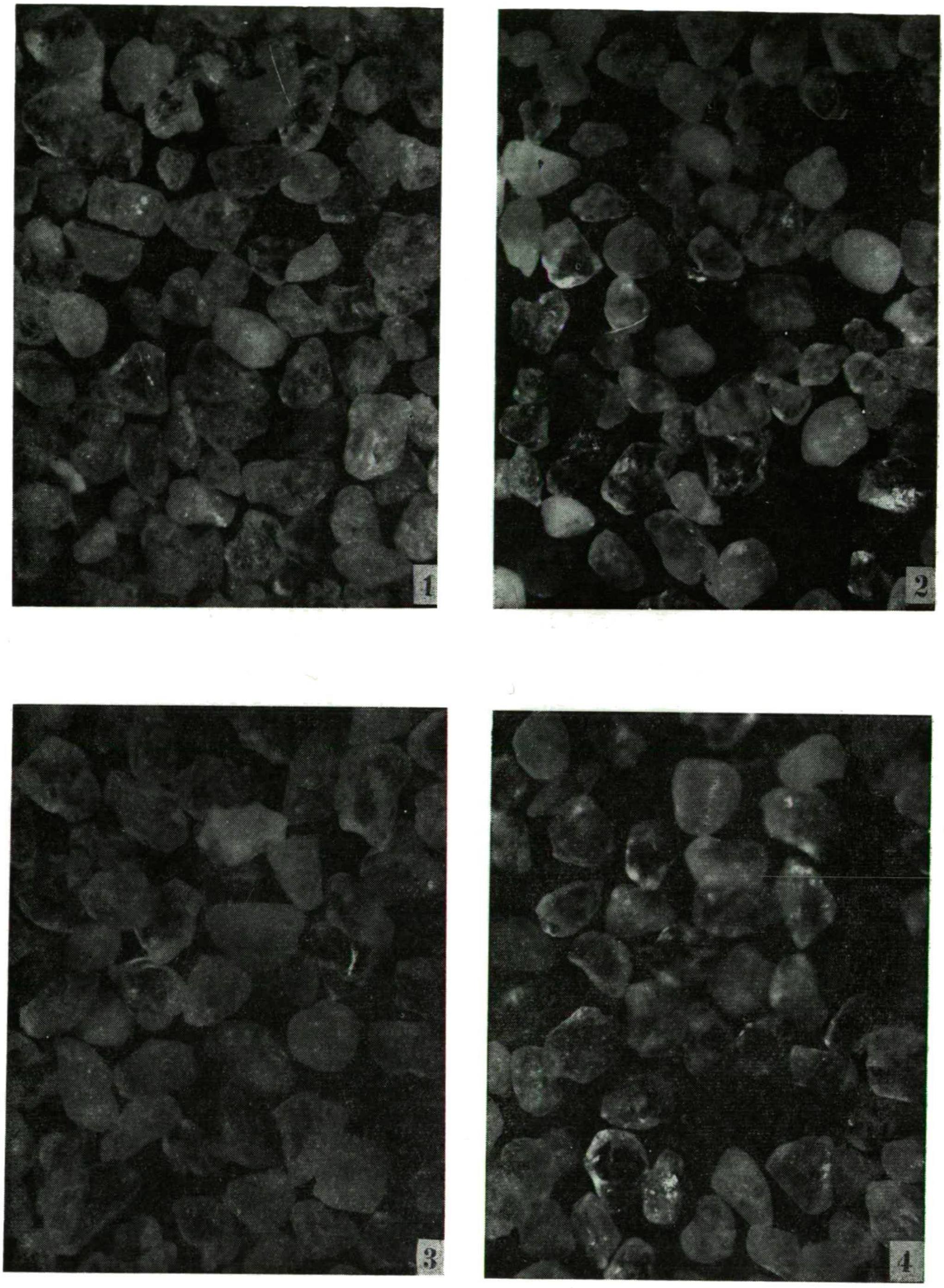
$$K_G = \frac{\varphi_{95} - \varphi_5}{2.44(\varphi_{75} - \varphi_{25})}$$

If the K_G value of the curve equals 1, the distribution is normal and the fluctuations of the kinetic energy of the sedimentary environment affected only sediments of a grain size corresponding to the 50% range of the curve. If the value of curtosis is greater than 1, the oscillations of the velocity did for a long time not exceed 50% of the average velocity.

In the Madaras section the values of curtosis are in the 0.90—3.07 range, but, of the striking value, 3.07, of the sample taken from the greatest depth be disregarded, so they prove to be as low as 0.90 to 1.53. In the majority of the cases the value of curtosis is greater than 1, which means that the amplitude of oscillations of the sedimentary environment at the time of sedimentation did for a long time not exceed 50% of the average velocity.

Comparing the curtosis and asymmetry curves of *Fig. 3*, one can see the major changes in the behaviour of the two curves to be subparallel, except for a few cases (e.g. at 1.0 or 9.0 m).

The collected samples were analyzed for calcium carbonate content by being treated in hydrochloric acid. The calcium carbonate content of the Madaras section varies between 0.0 and 31.0%. However, according to the values obtained, two substantially different vertical ranges can be distinguished. In the 10.0—12.3 m interval the calcium carbonate content is between 0.0 and 12.0%, in the 0.0—10.0 m interval it is substantially greater, ranging from 17.0 to 31.0%. The smaller carbonate content of the lower depth range is due to the occurrence here of a soil layer developed predominantly on sands and loesses. The carbonate that used to be in the soil and


1
2
3
4

the thin loess layer of the 10.8—10.9 m interval was lost to leaching, while the sands have, as a rule, a lower carbonate content compared to that of the loess. The 0.0—10.0 m interval shows high calcium carbonate values of 20 to 25% which are generally characteristic of the loesses of the Danube-Tisza Interfluve.

The shape of the quartz grains of the sands occurring in the lower part of the section and at a depth of 2 m under the surface in the same mine pit, 20 m north of the section under study, was examined by the CAILLEUX-method [A. CAILLEUX 1952]. The quartz grains of the sand dune outcropping from below the loess blanket 1 km west of the exposure were also examined. The results are summarized in Table 1. As can be seen, the rather fine, 0.1 to 0.2 mm, grains corresponding to

TABLE 1

Results of grain shape analyses obtained by the Cailleux method for 0.1 to 0.2 mm quartz grains from wind-blown sands interbedded with and underlying the loess at Madaras

Locality		Grain type		Photographs
		NU (%)	RM (%)	
The Madaras	10.9—11.0 m	19.0	81.0	Plate I, Fig. 1.
section	11.3—12.3 m	20.0	80.0	Plate I, Fig. 2—3
Sand lens lying at 2 m depth under the surface		14.0	86.0	Plate I, Fig. 5.
Sand outcropping from below the loess blanket at 1 km distance to the west from the exposure		14.0	86,0	

NU = Sharp-edged, splintery grains; RM = Rounded, mat grains.

the predominant sand fraction still consist, themselves, mainly of rounded grains of mat surface. The samples were also photographed under a stereomicroscope (Plate I, *Figs. 1—4*). On the photographs predominantly rounded grains can be seen. According to A. CAILLEUX, the above results and observations prove convincingly that both the sands underlying the loess and those interbedded with it, represent wind-blown sands.

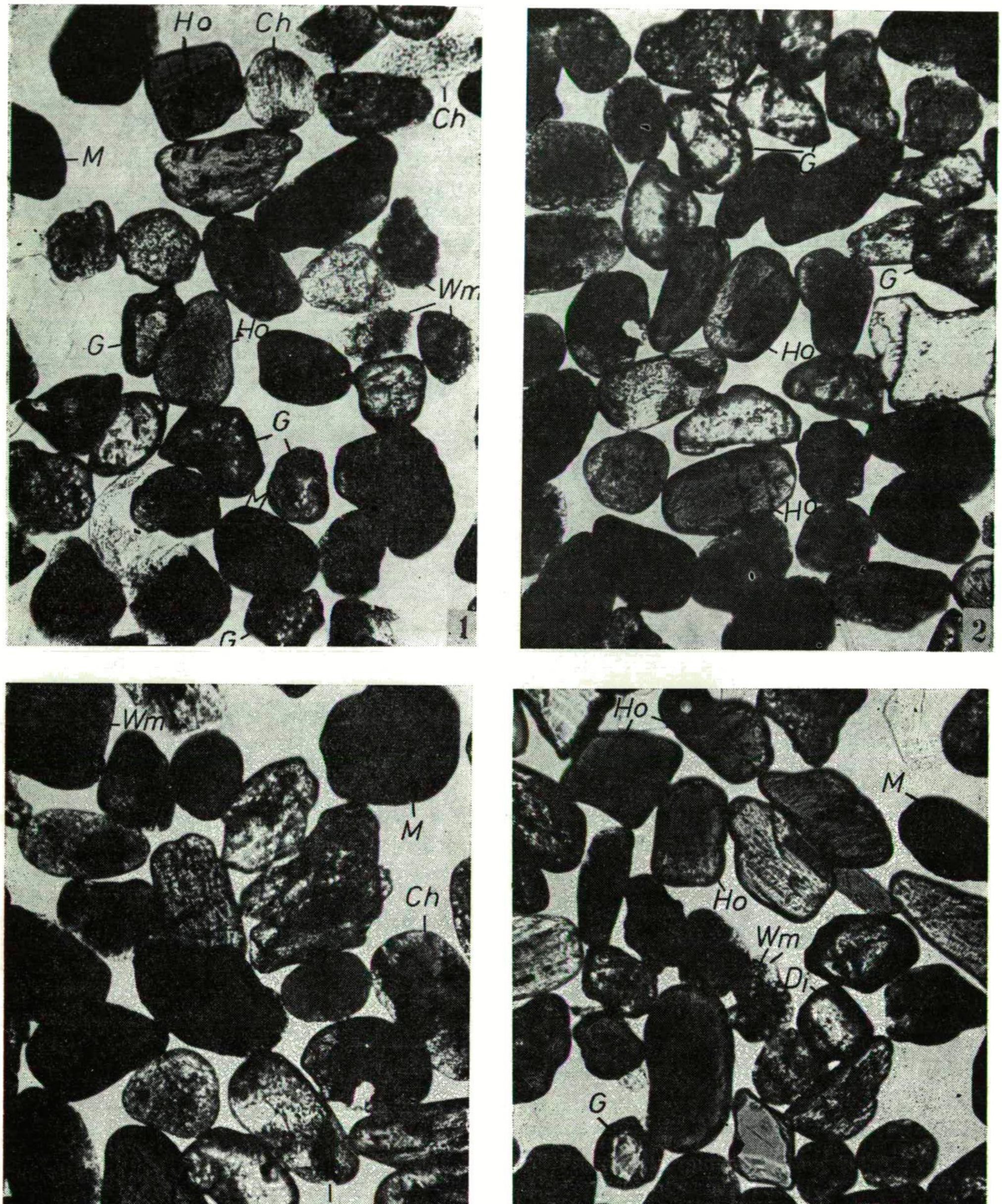
These same samples were analyzed for heavy minerals as well. As proved by the results, the sands must have been blown out of the Danube valley by the winds, thus originating from a Danubian source area, a fact corroborated by the photographs made under the mineralogical microscope (Plate II, *Figs. 1—4*). It is pre-

PLATE I

Stereomicroscopic images of 0.1 to 0.2 mm quartz grains from wind-blown sands interbedded with or underlying the loess at *Madaras*

1. The *Madaras* section: 10.9—11.0 m
2. The *Madaras* section: 11.3—12.3 m
3. The *Madaras* section: 11.3—12.3 m
4. Sand lens of the Madaras exposure

PLATE II



dominantly garnets, well-rounded common hornblendes, magnetites and weathered minerals that are visible on the photographs. Each of these implies a Danubian origin [B. MOLNÁR 1961, 1964, 1966, 1970].

Having a look at *Fig. 3* summarizing the most important results, one can easily recognize, even in intervals seeming to be homogeneous to the unaided eye, that the 12.3 m section consists of several distinct parts differring from one another as far as the sedimentological features, *i.e.* the mechanism of accumulation, the changes in its energy and the postgenetic transformations of the material are concerned. The individual parts show up the following characteristics:

1. The 10.5—12.3 m interval comprises wind-blown sands and an interbedded, thin sandy loess layer. It is characterized by coarser grain size, poorer and rapidly changing sorting, a heavy positive asymmetry, a striking value of curtosis and a very low amount of calcium carbonate. All these indicate that the energy responsible for the deposition of the sediment must have been most diversified of all parts of the section. The observed sedimentological features reflect even otherwise shock-like changes in sedimentary energy. The interval can be further split up into an upper and a lower wind-blown sand and an interbedded sandy loess horizon.

2. The 9.25—10.5 m interval is characterized by a granulometric composition much finer than the former, by a rapidly improving sorting associated with the refinement of the grain size, by a positive skewness smaller than that of the previous interval, by a substantially smaller and more equilibrated curtosis as well as by a calcium carbonate content increasing from the base to the top of the sequence at a rapid rate. Thus the energetic conditions that were involved in the deposition of the sediment must have been much more steady than they were in the case of the previous interval. The interval under consideration can be split up into two additional parts. In the lower part there appears a loess-based chernozem-like soil suggestive of a warmer climate, while the upper part includes typical loesses the origin of which is indicative of a climate turning colder.

3. In the 7.75—9.25 m interval there is such a loess facies in which clay and fine silt decrease in quantity, while the fine sand content increases. The dynamics of the sedimentary environment must have been equilibrated, the sorting gradually improving from base to top. The values of the asymmetry and curtosis of the sediment, however, are markedly variable. Consequently, the sedimentation that took place in this interval must have evolved under the conditions of rather steady dynamics due to minor climatic changes. The sedimentation characteristics do not enable us to distinguish further subintervals within it.

4. Between 6.0 and 7.75 m, the quantity of clay and fine silt shows a sudden increase. Fine sand though decreasing in content, is characterized by an increasing

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PLATE II

Heavy minerals recovered from the 0.1 to 0.2 mm fraction of the wind-blown sands interbedded with and underlying the loess at Madaras. The pictures were photographed under mineralogical microscope, at parallel nicols, the minerals having been mounted in nitrobensene with an optical refringency of 1.552. Abbreviations of mineral names shown on the images: Di: Diopside, M: Magnetite, Ch: Chlorite, Ho: Hornblende, G: Garnet, W: Weathered mineral.

1. The Madaras section: 10.9—11.0 m
2. The Madaras section: 11.3—12.3 m
3. The Madaras section: 11.3—12.3 m
4. Sand lens of the Madaras exposure

mean energy of the sedimentary environment. The sorting of the sediment is weaker compared to that of the previous interval. Asymmetry and curtosis show invariably a wide range of variation, though the trend of this variation is unidirectional in both cases, as proved by the parallel run of the two corresponding curves in *Fig. 3*. Consequently, the energy responsible for sedimentation must have been a little greater, but somewhat more equilibrated and steady, on the average, than in the previous interval. The sedimentological features of the interval do not enable any further division.

5. The 1.25—6.0 m interval is characterized by a very steady and well-balanced average energy of deposition, by a good sorting, a rather considerable, though steady, positive skewness, a steady curtosis and a high carbonate percentage. It is this five-metre interval in all of the Madaras section that indicates the most steady sedimentation conditions. Notably, very steady, cold climatic conditions, typical of loess sedimentation, must have prevailed at the time of deposition. In the light of changes in asymmetry and curtosis the interval can be split up into two subintervals. Between 3.75 and 6.0 m, though markedly steady, both asymmetry and curtosis show a somewhat higher value than is the case with the 1.25—3.75 m subinterval.

6. In the 0.0—1.25 m interval the sand content of the loess increases rapidly and the average energy of sedimentation also increases. The value of this second characteristic feature, however, showed a less rapid change, as manifested by sorting, asymmetry and curtosis alike. In *Fig. 3* all the curves of sedimentological features pertaining to this interval show unsteady variations with rapid changes and striking differences in the sedimentary conditions they reflect.

PALEONTOLOGICAL RESULTS OBTAINED FOR THE MADARAS SECTION

Sedimentological analyses were coupled with parallel paleontological studies on the material of the same samples. About 4 kg of sediment per sample was washed through a 0.8 mm mesh sieve on the location. The paleontological material consisted, irrespective of a very small number of vertebrate remains and charcoal remnants, predominantly of mollusc shells. Since the sediment was washed in equal quantities for each particular sample, it was possible to compare the numbers of gastropod shells found in the individual samples. If the number of specimens obtained at washing was below the minimum necessary for processing (hundred specimens), so additional, larger quantities of material were subject to washing. In such cases, the material washed was doubled and the resulting number of specimens was halved.

The total number of taxons recovered from the 12.3 m sequence was 39. Considering that we are dealing predominantly with loess strata, this figure is considerable. Only in the case of the so-called wet-land loesses of the Great Hungarian Plain can a similar, though even richer, number of taxa be observed [M. ROTARIDES, 1931].

One of the causes responsible for the high number of taxa — though by far not the single cause — is that specimens of water-dwelling species (Tables 2—3) have also been recovered from the lower part of the sequence (10.5—12.3 m). These are species of great ecological tolerance living in standing water bodies or in waters of low kinetic energy. They may live and thrive even in minor ponds and pools including hardly any vegetation and they are able to survive even shorter or longer periods of drought when their habitat runs dry. Their sporadical occurrence can be explained by the presence of the so-called “semlyéks”, *i.e.* intermittent minor

Quantitative occurrence of the molluscanfauna in the Madaras profile

TABLE 3

Serial number	Depth in m	*Vallonia enniensis* (GREDL.)	*Vallonia tenuilabris* (A. BR.)		*Chondrula tridens* (MÜLL.)		*Clausilia dubia* DRAP.		*Clausiliidae indet.*		*Vitrea crystallina* (MÜLL.)		*Euconulus fulvus* (MÜLL.)		*Nesovitrea hammonis* (STRÖM)	
		pc.	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%
44	0—0,25		17	14,4	1	0,8	5	4,2			1	0,8	5	4,2		
43	0,25—0,50		5	5,2	11	11,5					2	2,1	1	1,0		
42	0,50—0,75		33	20,8	3	1,9	4	2,5					13	8,2	2	1,3
41	0,75—1,0		138	18,6	3	0,4	15	2,0			17	2,3	78	10,5	10	1,3
40	1,0—1,25		53	11,9			12	2,7			5	1,1	12	2,7	5	1,1
39	1,25—1,50		71	13,3			26	4,9			3	0,6	65	12,2	6	1,1
38	1,50—1,75		138	23,4			13	2,2					70	11,9	15	2,5
37	1,75—2,0		73	17,4			24	5,7					50	11,9	7	1,7
36	2,0—2,25		78	16,9			12	2,6					42	9,1	10	2,2
35	2,25—2,50		34	11,8			50	17,3					86	29,8	4	1,4
34	2,50—2,75		20	2,5			5	0,6					56	6,9	19	2,4
33	2,75—3,0		109	12,9			15	1,8			1	0,1	64	7,6	27	3,2
32	3,0—3,25		314	52,6	1	0,2	36	6,0					87	14,6	7	1,2
31	3,25—3,50		203	29,0			20	2,9			5	0,7	118	16,9	15	2,1
30	3,50—3,75		81	15,0			6	1,1			4	0,7	39	7,2	7	1,3
29	3,75—4,0		116	19,9			24	4,1			9	1,5	94	16,2	1	0,2
28	4,0—4,25		4	0,7			22	3,7			66	11,4	57	9,6	8	1,4
27	4,25—4,50		12	1,6	1	0,1	2	0,3			73	9,7	34	4,5	24	3,2
26	4,50—4,75		2	0,3			6	0,8			105	14,5	36	4,9	19	2,6
25	4,75—5,0						9	0,8			129	11,4	43	3,8	18	1,6
24	5,0—5,25		158	8,1			2	0,1			161	8,3	100	5,1	26	1,3
23	5,25—5,50		44	2,6			1	0,1			201	11,9	103	6,1	19	1,1
22	5,50—5,75						4	0,2			297	13,3	117	5,2	25	1,1
21	5,75—6,0		1	0,1			11	0,7			109	6,6	92	5,6	39	2,4
20	6,0—6,25		2	0,2	43	4,2	9	0,9			1	0,1	29	2,8	27	2,6
19	6,25—6,50		1	0,2	35	8,0					1	0,2	3	0,7	14	3,2
18	6,50—6,75		+	+	25	8,9					1	0,4			14	5,0
17	6,75—7,0		5	0,9	50	8,8			1	0,2	3	0,5	3	0,5	27	4,8
16	7,0—7,25				47	3,9					38	3,2	1	0,1	66	5,5
15	7,25—7,50				43	5,4					11	1,4			40	5,0
14	7,50—7,75				7	1,7					17	4,1	1	0,2	4	0,9
13	7,75—8,0										43	7,7	6	1,1	15	2,7
12	8,0—8,25		10	2,2	1	0,2					22	4,9	13	2,9		
11	8,25—8,50		37	4,6							13	1,6	67	8,4	11	1,4
10	8,50—8,75										9	3,4	78	29,5	6	2,3
9	8,75—9,0		2	0,1	5	0,2					65	3,0	69	3,2	128	5,9
8	9,0—9,25												1	0,1		
7	9,25—9,50				17	5,0							2	0,6	2	0,6
6	9,50—9,75				30	7,9					5	1,3			5	1,3
5	9,75—10,0				11	3,5										
4	10,0—10,50				4	6,3									1	1,6
3	10,50—10,80				4	7,7	+	+							2	3,8
2	10,80—10,90															
1	10,90—11,30				+	+										
0	11,30—12,30	1							+	+						

Serial number	Depth in m	*Vitrina pellucida* (MÜLL.)		*Semilimax semilimax* (FÉR.)		*Limacidae indet.*		*Discus ruderatus* (FÉR.)		*Punctum pygmaeum* (DRAP.)		*Bradybaena fruticum* (MÜLL.)		*Helicopsis striata* (DRAP.)		*Trichia hispida* (L.)		*Arianta arbustorum* (L.)		*Helicidae indet.*	
		pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%
44	0—0,25									6	5,1					24	20,3				
43	0,25—0,50					4	4,2			1	1,0					17	17,7				
42	0,50—0,75					1	0,6			3	1,9					33	20,8				
41	0,75—1,0					2	0,3			35	4,7					279	37,7				
40	1,0—1,25							3	0,7	7	1,6					197	44,6				
39	1,25—1,50							1	0,2	38	7,1					228	42,7				
38	1,50—1,75									1	0,2					149	25,3				
37	1,75—2,0															120	28,6				
36	2,0—2,25															165	35,8				
35	2,25—2,50							1	0,3							90	31,1				
34	2,50—2,75															549	68,2				
33	2,75—3,0					4	0,5									220	26,0				
32	3,0—3,25					3	0,5			1	0,2					118	19,8				
31	3,25—3,50							2	0,3	5	0,7					149	21,3				
30	3,50—3,75							1	0,2	3	0,6					96	17,8				
29	3,75—4,0			1	0,2			8	1,4	26	4,5					255	43,8				
28	4,0—4,25	41	6,9	3	0,5	4	0,7	3	0,5	128	21,6					151	25,5	18	3,0		
27	4,25—4,50	31	4,1			3	0,4	2	0,3	323	42,9					131	17,4	5	0,7		
26	4,50—4,75	83	11,5	3	0,4	3	0,4	1	0,1	230	31,9					91	12,6	7	1,0		
25	4,75—5,0	123	10,9	6	0,5			1	0,1	449	39,8					91	8,1	15	1,3		
24	5,0—5,25	211	10,8	7	0,4			2	0,1	878	45,2					101	5,2	27	1,4		
23	5,25—5,50	148	8,8			1	0,1	11	0,6	955	56,7					89	5,3				
22	5,50—5,75	153	6,9							1434	64,3					112	5,1	2	0,1		
21	5,75—6,0	49	3,0			1	0,1			1262	76,6					24	1,5				
20	6,0—6,25	8	0,8			24	2,4			93	9,1					100	9,8	3	0,3		
19	6,25—6,50					34	7,7			3	0,7					91	20,7	7	1,6		
18	6,50—6,75					27	9,6			2	0,7					45	16,0	3	1,1		
17	6,75—7,0	1	0,2			20	3,5			16	2,8	2	0,4	13	2,3	36	6,9	2	0,4		
16	7,0—7,25					16	1,3			190	15,9	24	2,0			54	4,5	2	0,2		
15	7,25—7,50	1	0,1			24	3,0			27	3,4	7	0,9			73	9,1	7	0,9		
14	7,50—7,75					17	4,1					2	0,5			34	8,2	2	0,5		
13	7,75—8,0					28	5,8									343	61,4				
12	8,0—8,25					7	1,6									25	56,0				
11	8,25—8,50					4	0,5			19	2,4					466	58,3				
10	8,50—8,75									8	3,0					23	8,7	2	0,6		
9	8,75—9,0					89	4,1			368	17,1					352	16,4	8	0,4		
8	9,0—9,25					65	5,5			1	0,1			24	2,0	4	0,3				
7	9,25—9,50					6	1,8			20	5,9			1	0,3	1	0,3			1	0,3
6	9,50—9,75					7	1,9			14	3,7	5	1,3			1	0,3				
5	9,75—10,0					4	1,3	+	+					14	4,4						
4	10,0—10,50					3	4,7	+	+			+	+	+	+			+	+		
3	10,50—10,80					1	1,9	+	+					5	9,6						
2	10,80—10,90																			+	+
1	10,90—11,30													+	+					+	+
0	11,30—12,30															+	+				

Quantitative occurrence of the molluscan fauna in the Madaras profile TABLE 2

Species

Serial number	Depth in m	*Sphaerium corneum* (L.)		*Pisidium* cf. *henslowanum* (SHEPP.)		*Pisidium* sp.	*Valvata cristata* MÜLL.	*Valvata pulchella* (STUD.)		*Planorbis planorbis* (L.)	*Anisus spirorbis* (L.)	*Succinea elegans* RISSO	*Succinea oblonga* DRAP.		*Cochlicopa lubrica* (MÜLL.)		*Cochlicopa* cf. *lubricella* (PORRO)	*Vertigo pygmaea* (DRAP.)		*Vertigo alpestris* ALD.		*Granaria frumentum* (DRAP.)		*Pupilla muscorum* (L.)		*Pupilla triplicata* (STUD.)		*Pupilla sterri* (VOITH)		*Columella columella* (MART.)		*Orcula dolium* (DRAP.)		*Vallonia pulchella* (MÜLL.)		*Vallonia costata* (MÜLL.)	
		pc.	%	pc.	%	pc.	pc.	pc.	%	pc.	pc.	pc.	pc.	%	pc.	%	pc.	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%	pc.	%
44	0—0,25												1	0,8										10	8,5	24	20,3	1	0,8	2	1,7	1	0,8			20	16,9
43	0,25—0,50												6	6,6										4	4,2	17	17,7			2	2,1					26	27,1
42	0,50—0,75												24	15,1										9	5,7	4	2,5			6	3,8					24	15,1
41	0,75—1,0												39	5,3										42	5,7	4	0,5	3	0,4	62	8,4	4	0,5			10	1,3
40	1,0 —1,25												62	14,0										24	5,4					49	11,0					13	2,9
39	1,25—1,50												33	6,2										10	1,9			2	0,4	51	9,6						
38	1,50—1,75												110	18,6										52	8,8			2	0,3	40	6,8						
37	1,75—2,0												91	21,7										34	8,1					20	4,8	1	0,2				
36	2,0 —2,25												61	13,2										57	12,4					18	3,9					18	3,9
35	2,25—2,50												17	5,9										1	0,3					4	1,4					2	0,7
34	2,50—2,75												115	14,3										26	3,2					10	1,2	4	0,5			1	0,1
33	2,75—3,0												174	20,6										45	5,3			1	0,1	181	24,0	1	0,1			3	0,4
32	3,0 —3,25												19	3,2										4	0,7	1	0,2			6	1,0						
31	3,25—3,50												91	13,0										4	0,6					86	12,3					1	0,1
30	3,50—3,75												151	27,9	1	0,2								96	17,8					55	10,2						
29	3,75—4,0												25	4,3	2	0,3								12	2,1	+	+			5	0,9	1	0,2			3	0,5
28	4,0 —4,25												1	0,2	8	1,4								19	3,2	2	0,3					2	0,3			55	9,3
27	4,25—4,50												2	0,3	10	1,3								34	4,5	5	0,7			3	0,4	4	0,5			53	7,0
26	4,50—4,75														42	5,8								55	7,6	1	0,1					9	1,2			29	4,0
25	4,75—5,0														19	1,7								140	12,4							23	2,0	1	0,4	60	5,3
24	5,0 —5,25														17	0,9								118	6,1							46	2,4			89	4,6
23	5,25—5,50														16	0,9								15	0,9	5	0,3					50	3,0			26	1,5
22	5,50—5,75														8	0,4								56	2,5							1	0,1			20	0,9
21	5,75—6,0																							2	0,1	32	1,9			4	0,2					21	1,3
20	6,0 —6,25																							13	1,3	345	33,8									323	31,7
19	6,25—6,50																							51	11,6	8	1,8			1	0,2					191	43,4
18	6,50—6,75																							29	10,3	3	1,1									132	47,0
17	6,75—7,0																							49	8,6	30	5,3									310	54,6
16	7,0 —7,25														13	1,1								92	7,7	5	0,4									649	54,2
15	7,25—7,50														5	0,6								116	14,5	5	0,6									439	55,0
14	7,50—7,75														2	0,5								71	16,9	73	17,5									188	44,9
13	7,75—8,0																							74	13,2	2	0,4									47	8,4
12	8,0 —8,25																							86	19,2	2	0,4									55	12,3
11	8,25—8,50																							100	12,5	12	1,5			14	1,8					56	7,0
10	8,50—8,75																							15	5,7	115	43,6			2	0,8					7	2,7
9	8,75—9,0												60	2,9	1	0,1								495	23,0	58	2,7			3	0,1					443	20,6
8	9,0 —9,25																							223	19,0	785	66,5									77	6,5
7	9,25—9,50																					8	2,4	17	5,0	148	43,7									116	34,2
6	9,50—9,75																					36	9,6	3	0,8	84	22,3									186	49,5
5	9,75—10,0														1	0,3						3	0,9	3	0,9	269	85,4									10	3,2
4	10,0 —10,50							1	1,6									1	1,6	1	1,6	6	9,4	16	25,0									26	40,6	5	7,8
3	10,50—10,80	4	7,7	1	1,9					+					3	5,8		1	1,9			3	5,8	1	1,9	11	21,2							14	26,9	5	9,6
2	10,80—10,90																									+	+										
1	10,90—11,30					1																				2								2			
0	11,30—12,30					7	1	1		+	+	1					+	1				1		3		3										1	

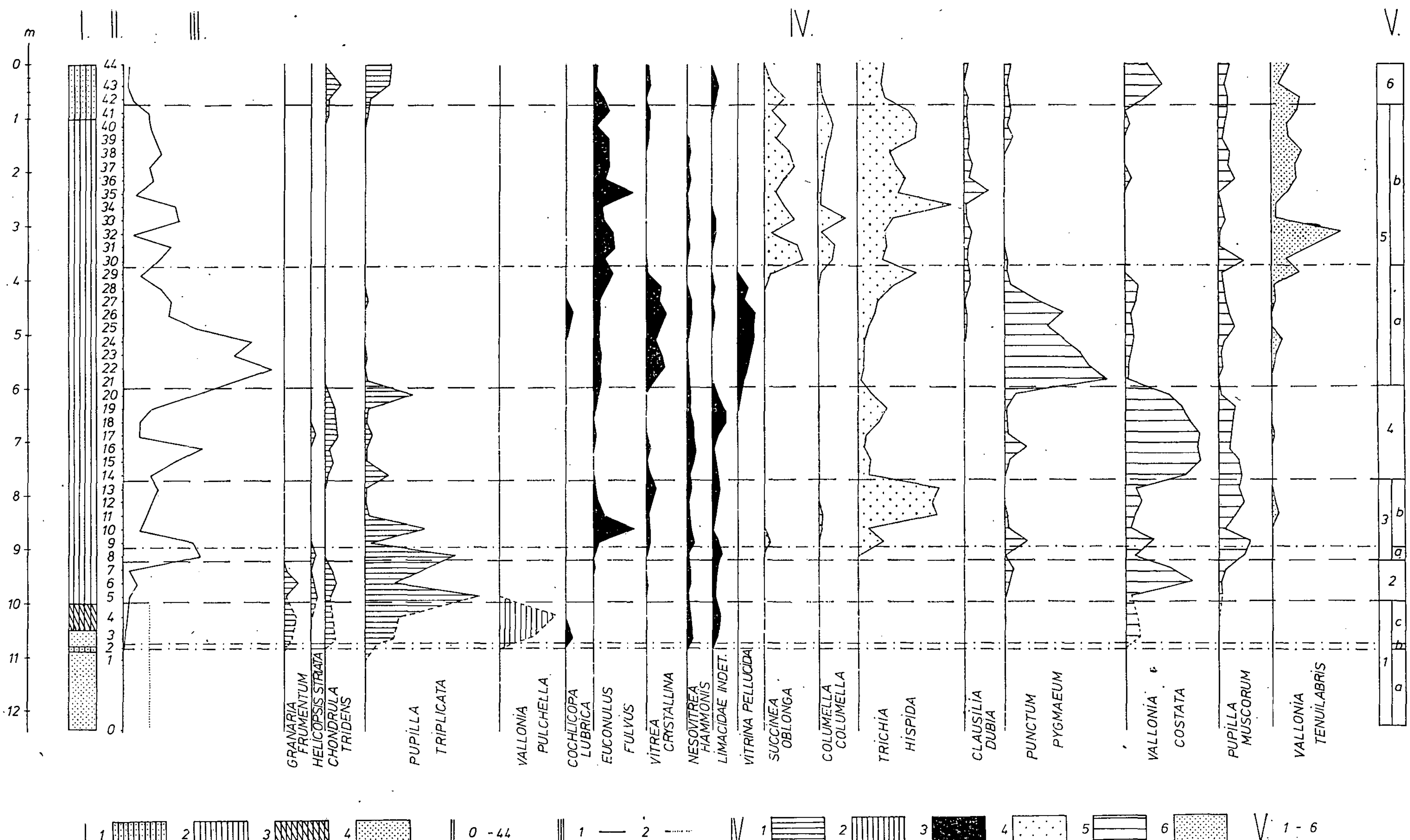

Fig. 4. Results of the paleontological study of the Madaras section
I. Same as in Fig. 3. II. Number of samples analyzed (Agrees with the number of samples figuring in Tables 2—3). III. Number of mollusc specimens recovered from the samples. 1. Diagram on the number of specimens, 2. The presence of water-dwelling species. IV. Curves of abundances of the comparatively more frequent species (1 mm=2%). V. Malacologically distinguished intervals. 1. to 6. Indication of single ecological types.

water pools, occurring even at present, as a result of the accumulation of water in more humid periods between sand dunes.

Between 0.0 and 10.5 m the fauna consists exclusively of terrestrial species (Tables 2—3). Most of the species found here are "loess snails" of high ecological valency, their habitats being land surfaces carrying a sparse vegetation. Much smaller is the number of those species living in bush and sparsely wooded areas, real forest-dwelling forms being totally absent in the fauna.

The quantitative study of the mollusc fauna has been based upon a total of about 30 thousand specimens selected from the washing residue. This quantitative analysis has showed rhythmical changes in the percentages of elements of different environmental and climatic demand. Given the subjectivity involved in the classification by various specialists of the gastropod species according to the character of the vegetation, the temperature and moisture demand of the animal, etc., we have relied first of all on the behaviour of the curves of abundances of the species in subdividing the sedimentary sequence on the basis of the mollusc fauna [E. KROLOPP, 1965, 1966, 1969]. Notably, it is obvious that curves of the same or similar behaviour imply that the species under consideration must have reacted in the same way upon environmental changes *(Fig. 4)*. On the basis of the detailed qualitative and quantitative examinations of the mollusc material of the samples the sedimentary sequence can be subdivided into the following intervals:

1. The 10.0—12.3 m interval is characterized by the appearance of water-dwelling and terrestrial faunas. The majority of the species living on land surface are highly thermophile *(Granaria frumentum* (DRAP.), *Pupilla triplicata* (Stud.), *Vallonia enniensis* (GREDL.), *Chondrule tridens* (MÜLL.), *Helicopsis striata* (DRAP.), cold-favouring elements being absent. Unfortunately, the sediment contains very few gastropod shells, so that even after the material had been rewashed only two samples could be quantitatively evaluated. Accordingly three subintervals can be distinguished:

1a) Between 10.9 and 12.3 m both water-dwelling and terrestrial forms occur in a very low number of specimens.

1b) The 10.8—10.9 m subinterval is characterized by a very poor fauna, so that only a few terrestrial forms were recovered as shell fragments.

1c) Although the 10.0—10.8 m subinterval shows a little richer fauna, the specimens per sample were in every case below a hundred in number, the calculated value of abundance thus being just informative (part indicated by broken line in *Fig. 4*). Beside thermophile forms, there is a remarkably high percentage of *Vallonia pulchella* (MÜLL.), a species very rare in loess-dwelling faunas and suggesting, again, a mild climate. The terrestrial species included some hydrophile elements as well.

2. In the 9.25—10.0 m interval the hydrophile elements are already absent. The thermophile species are still present, though with abundances smaller compared to the previous interval. The high frequency of *Pupilla triplicata* (STUD.), a species of similarly more or less high heat demand, and the great abundance of *Vallonia costata* (MÜLL.), a form, enduring even a drier climate and so of high ecological tolerance, are conspicuous features.

3. The 7.75—9.25 m interval comprises a characteristic "loess fauna". The total number of specimens recovered from the samples is considerably greater compared to the preceding intervals. Figuring only with a low number of specimens in the foregoing, *Pupilla muscorum* (L.) attains here a considerably high value of abundance. Beside it, *Pupilla triplicata* (STUD.), a species of even greater heat demand, is still present. *Vallonia costata* (MÜLL.) and *Trichia hispida* (L.) show diametrically opposite variations in abundances. Similar changes in the populations of other species typical of different, drier, environments or, on the contrary, characterized by a higher moisture demand, respectively, can be observed. The following subintervals can be distinguished:

3a) Between 9.0 and 9.25 m there is a transitional zone, where the number of specimens of *Pupilla triplicata* (STUD.), a more or less thermophile species, is still high.

3b) In the 7.75—9.0 m subinterval the abundance of thermophile elements, first of all, of *Trichia hispida* (L.), increases. Cold-indicating *Vallonia tenuilabris* (A. BR.) also appears. This is the depth range from which the artifacts and other archeological finds have been recovered.

4. In the 6.0—7.75 m interval the psychrophile elements decrease in abundance compared to the previous interval, while *Vallonia costata* (MÜLL.) enduring even a drier climate shows an increasing number of specimens. Some thermophile species also appear.

5. Between 75.0—6.0 m — especially in the lower one-third — a very high total number of specimens is characteristic. The fauna is a typical "loess fauna" in which, however, psychrophile elements occur in considerable number, too. The high frequency of *Vitrina pellucida* (MÜLL.) is noteworthy. Notably, this species is known from the loess sections thus far processed from just one or two localities, being represented by a few specimens only. *Semilimax semilimax* (FÉR.) is similarly rare in the loess. The following two subintervals have been distinguished:

5a) Between 3.75 and 6.0 m the very high total number of specimens is associated with the characteristic predominance of *Punctum pygmaeum* (DRAP.).

5b) The fauna of the 0.75—3.75 subinterval is characterized by the predominance of psychrophile and cold-enduring species (*Succinea oblonga* DRAP., *Columella columella* (MART.), *Euconulus fluvus* (MÜLL.), *Trichia hispida* (L.). Cold-indicating *Vallonia tenuilabris* (A. BR.) also occurs in considerable number of specimens.

6. Between 0.0 and 0.75 m, the abundance of psychrophile species decreases in relation to the previous interval. Thermophile elements highly tolerant of drought appear, showing particularly high abundances in the 0.25—0.50 m depth range. Otherwise, the total number of specimens decreases.

In the light of the quantitative study of the mollusc fauna the ecological conditions of the individual intervals can be characterized as follows:

1. At the time of the deposition of the lower part of the sedimentary sequence concerned the climate seems to have corresponded to the present-day one or possibly more inclined to the extremes. Intermittent pools (semlyék") seem to have formed in the more humid periods in which even a water-dwelling fauna appeared for a short span of time. There did not exist, however, any considerable forestrial vegetation. In the 10.8—10.9 m interval, in compliance with loess formation, the fauna suggests a drier climate.

2. The fauna of the 9.25—10.0 m interval indicates a climate turning drier.

The decrease in the number of species is indicative of the decline of vegetation as well.

3. The fauna of the 7.75—9.25 m interval is suggestive of a cool and humid climate and a grassy or, at most locally, bush-strewn vegetation.

4. In the 6.0—7.75 m interval the sedimentation seems to have taken place under a climate that was a little drier and warmer compared to the previous case.

5. The fauna of the 0.75—6.0 m interval is indicative of a cool, humid and then explicitely cold climate. The land surface was grown with grass locally dotted with shrubs.

6. It was only at the time of the 0.0—0.75 m interval that the climate was warmer. However, the vegetation is even here deprived of any features that might be indicative of forests, being of grassland or bush character.

The reconstruction of the one-time climate is valid primarily to the growing season, *i.e.* that lasting from spring to autumn. Notably, the life of gastropods is most heavily influenced by the temperature and precipitation conditions of these seasons. They survive the period from the autumn to the spring mainly in an inactive state, thus being less affected by the corresponding climatic influences.

The analysis of the behaviour of the curves of gastropod abundances from Madaras has enabled us not only to reconstruct how the environment looked like at sedimentation and to subdivide the sequence malacologically, but it has called attention to a couple of peculiarities which may be relied on subsequently when studying other latest Pleistocene geological sections. So it is worthy of mention that in intervals, where the fundamental ecological factors appear to be uniform, the curves of abundances obtained for *Punctum pygmaeum* (DRAP.) and *Trichia hispida* (L.) may *quasi* replace each other. It is obvious that the ecological requirements of the two species are not completely identical, this being that feature enabling us to distinguish further subdivisions within single major intervals. In addition, it is also peculiar that the curves of psychrophile species of smaller population run parallel.

The washing residue of samples has yielded, in addition to molluscs, some vertebrate fossil remnants as well. L. KORDOS has given the following description of bone remains of this kind:

In the 10.9—11.3 m interval there was a fragment of the lower incisor of 1 specimen of a small-sized vole (? *Microtus*). The 8.75—9.0 m interval yielded one upper incisor fragment and and another tooth fragment belonging to *Sorex araneus* L. In the same interval there were, in addition, one M^1 and one M^3 of *Myodes glareolus* (SCHR.) and fragments of the lower incisors of 2 small-sized voles (? *Microtus*) *Arvicilidae indet*. The 8.50—8.75 m interval produced one bone splinter of *Micromammalia indet.*, 7.25—7.50 did so 2 fragments of egg shells of *Aves indet.*, 5.75—6.0 m yielded *Myodes glareolus* (SCHR.), one M_2 (?) fr. and, finally, 5.50—5.75 was found to contain 12 specimens of 3—4 mm size of bone splinters belonging to a *Mammalia indet.*

None of the vertebrate finds indicates an extremely cold climate, but it suggests rather a humid environment of lush vegetation. Unfortunately enough, the finds are of no exact chronological value.

Relying on the mollusc fauna thus far available, the vertebrate remains and other earlier data, we can attempt at giving the following chronology of the Madaras sequence:

The wind-blown sands at the base of the sequence could have settled in a mild climatic phase. However, the time of deposition could not correspond to the Riss—Würm interglacial, but might be identified only with one of the "interstadials" distinguished within the Würm glacial [E. KROLOPP, 1973]. If it is identified with the $Würm_1$—$Würm_2$ interstadial, then on evidence of malacological studies of loess exposures in the neighbourhood of the Mecsek Mountains it seems to be presumable that the loesses of the subsequent cool and then totally cold climates represent a younger part of the Würm, *i.e.* the $Würm_2$ and $Würm_3$ stadials. As can be determined, however, erosion has removed all the sediment that used to cover the land surface originally. Thus it seems to be not at all improbable that a part of the loess layer that would correspond to the $Würm_3$ stadial is already missing from the section. The warm spell observed in the final part of the Madaras section would, more sandy in facies as it is, thus represent a $Würm_2$—$Würm_3$ warming up of the climate, or mean a minor mild phase within $Würm_3$ — an assumption that seems to be very plausible when the general geochronological evolution of the Bácska Loess Area, to be presented later, is taken into consideration.

Putting the interval boundaries obtained sedimentologically and paleontologically for the Madaras section side by side, it will be seen that the boundaries will coincide in most cases (*Fig. 3,* items III and IV). Where there is a difference, as for instance in the 1st and 6th intervals, this is due to the fact that changes in the conditions of sedimentation are followed with some delay by the corresponding changes of the fauna. In other words, a new biotope will not be formed until and unless the sedimentary environment has changed, succeding, in some way, to it: a process associated, in certain cases, with some time shifts. Excepting this, the variations of the sedimentological characteristics and the character of changes in the mollusc fauna are in a good harmony with one another.

For example, as implied by the sedimentological characteristics, the 1st interval showed a wide range of changes in the kinetic energy of sedimentation. A diversified hydrophile and terrestrial faunal assemblage appeared in the same interval. The sedimentological features in the 2nd interval are more steady than in the first one, while the fauna is characterized by features suggestive of a drought-inclined climate and by the reduction of the number of species. The 3rd interval witnessed a steady sedimentation, though disturbed by minor climatic changes. The fauna suggests a cool and humid environment. In the 4th interval the sediment was deposited by kinetic energies a little greater but a little even more steady than the former. The trend of becoming more steady is indicated in the fauna by the predominance of species characteristic of a climate that was drier and warmer than that of the previous interval. In the fifth phase the depositional energy was most steady and best balanced within the entire section under study. This fact is indicated in the fauna by the appearance of species suggestive, especially in the upper part, of a cooler climate. Finally, in the 6th interval the kinetic energy responsible for sedimentation increased to such an extent that it became unsteady with rapid, shock-like changes in its dynamics. In the fauna, this change is indicated by the appearance of thermophile species.

LATEST PLEISTOCENE GEOHISTORICAL EVOLUTION OF THE BÁCSKA LOESS AREA

The latest Pleistocene history of the Bácska Loess Area can be illustrated and explained by relying on the earlier geological surveys undertaken by I. MIHÁLTZ and L. MOLDVAY, on the relevant studies performed by B. MOLNÁR and on the Madaras section processed as well as on the observations made during field traverses by the present writers [in: I. MIHÁLTZ, 1953, B. MOLNÁR, 1961, 1970, 1975).

As shown in the introductory part, the eolian sequence of the Bácska Loess Area shows a N—S and E—W directed reduction in thickness. The northern part of the study area was explored by the Szentes—Baja section studied by I. MIHÁLTZ and L. MOLDVAY down to 30 m depth, and examined in detail over the Baja—Felső-szentiván—Jánoshalma stretch *(Fig. 1)*. In this northern area the following geological formations have been encountered down to a depth of 30 m:

At 30 m depth, loess has been uncovered throughout the section under study. It is overlain by wind-blown sands in 5 to 10 m thickness. The wind-blown sands are followed, in turn, by a three-membered loess horizon divided by wind-blown sand layers of 1 to 3 m thickness. Two of the three loess subhorizons, *i.e.* the upper and the lower ones, are present throughout the study area, whilst the middle one is absent in a number of places. I. MIHÁLTZ assigned the upper three loess subhorizons and the wind-blown sand layers between them, to the Würm. In the west the topmost loess surface is overlain by Holocene wind-blown sands. The thick windblown sand layer underlying the three-membered loess horizon can be assigned to the Riss—Würm interglacial, while the loess occurring at 30 m depth might belong to the Riss glaciation already.

The same geology can be expected to occur in the more southern Hungarian share of the Bácska Loess Area, the only difference being, at the most, that the role of the interbedded wind-blown sand layers may be reduced, to become totally absent in several places over the Yugoslavian part of the area.

Thus the Madaras section has exposed, even on the basis of the above considerations, a part of the loesses of Würm age. The wind-blown sand occurring at the base of the section, was deposited, as shown in the light of the fauna, in a span of time characterized by a rather mild climate. This interval has been identified with the Würm$_1$—Würm$_2$ interstadial. With a climate turning colder, loess sedimentation started. This was the time when the thin layer of the Pseudomycelium-bearing, sandy loess of the 10.8—10.9 m interval was formed. However, the transition into the colder climatic phase seems to have been characterized by some oscillations,

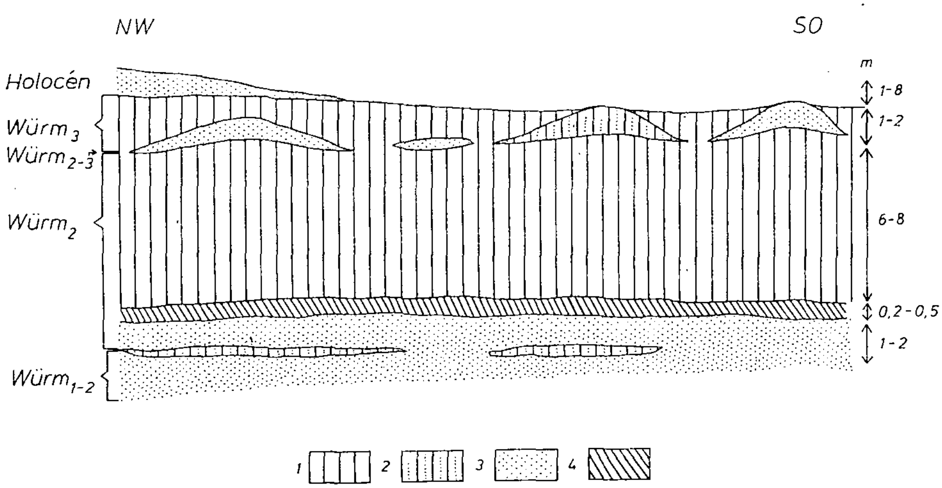

Fig. 5. Idealized sketch of the Latest Quaternary history of the Bácska Loess Area. 1. Typical loess, 2. Sandy loess, 3. Wind-blown sand, 4. Soil horizon.

as the thin loess layer is first overlain by wind-blown sands, to be then followed again by loess in which, however, a kind of chernozem soil was formed. It was only after this that a virtually longer cold loess deposition period followed, resulting in the formation of 8—9 thick loess layers. The initial grading of the climate into a colder one and its periodical oscillations are readily shown and reflected by changes in the fauna as well.

Fig. 5 shows the Latest Quaternary (since the Würm$_1$—Würm$_2$ interstadial up to the present) geohistory as demonstrable on an idealized sketch in NW—SE direction. At the base there is a thin, hardly 1—2 m, layer of wind-blown sands deposited in the Würm$_1$—Würm$_2$ interstadial. In some places, as could be seen at Madaras as well, a thin Pseudomycelium-bearing loess appears in the wind-blown sand layer. This is followed by a chernozem-like soil which is rather common throughout the study area, being present, e.a., even in the section at Katymár.

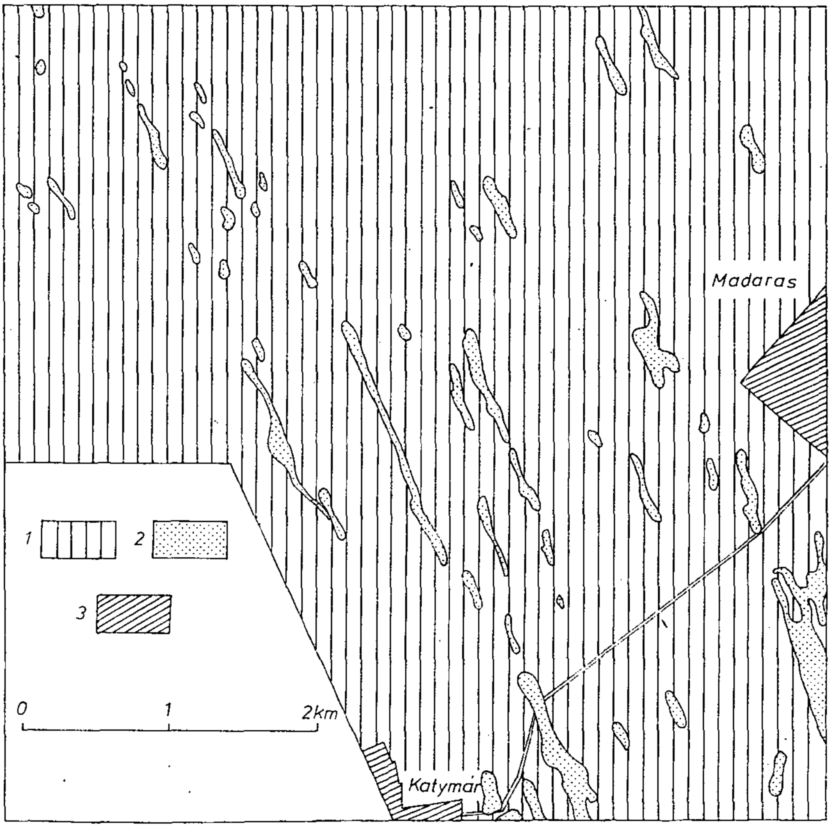

Fig. 6. Large-scale geological map of the Katymár-Madaras area.
1. Typical loess, 2. Wind-blown sand, 3. Settlement

The soil horizon has been overlain, in 6 to 10 m thickness, by typical loesses of the Würm$_2$ stadial. In the Würm$_2$—Würm$_3$ interstadial the one-time loess surface was blanketed by wind-blown sand brought by the predominant winds from the northwest. This wind-blown sand appears in the majority of the cases as a lens or as minor sand dunes. Its material is not always sand, but all types of transition from sand to loess may be represented. Consequently, it is represented by sandy loess or loessy sand. Where the loess overlying it and of later origin was removed by erosion, the wind-blown sand is exposed in the form of northwest-southeast trending bars of sand dunes, as can be seen on the large-scale geological map of the Katymár—Madaras area *(Fig. 6)*. In the Katymár exposure the wind-blown sands of the Würm_2—Würm_3 interstadial are present in the form of a thin sand layer *(Fig. 7)*.

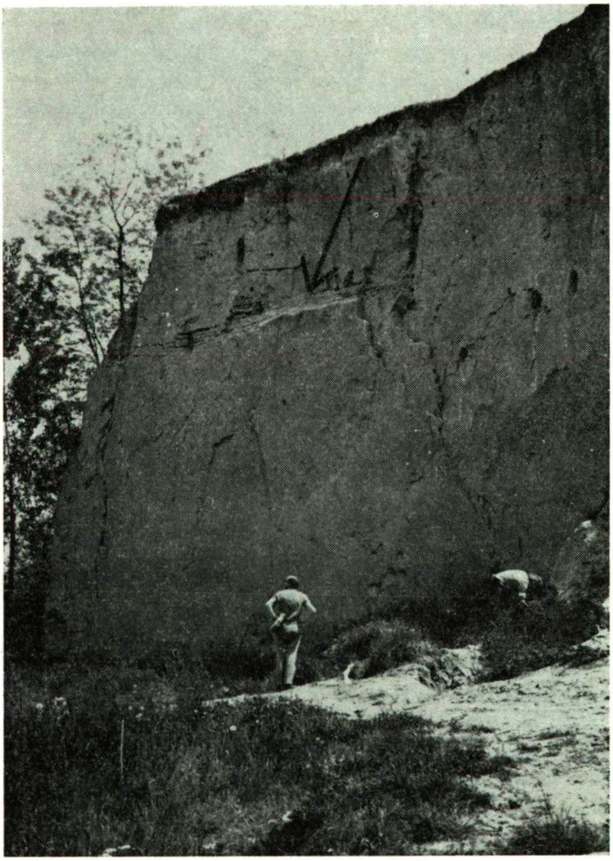

Fig. 7. The Katymár exposure.

Thus the loess of the last stadial (Würm_3) must have developed already on a surface covered by bars of sand dunes. In Holocene time winds coming from the northwest deposited again eolian sands in the northwest part of the Bácska Loess Area. However, the major part of the area is characterized, in the Holocene, by erosion processes such as soil erosion, rather than by accumulation.

SUMMARY

The Hungarian share of the Bácska Loess Area is exposed in numerous geological sections *(Figs. 1, 2)*. Out of the sections most typical of the geology of the study area, that of Madaras was studied in detail both sedimentologically and paleontologically and the results were compared with ones obtained for other sections. Using this and also earlier informations, the authors have sketched up the Latest Quaternary geohistory of the study area *(Fig. 3, 4, 5)*.

On the basis of the sedimentological features and according to the mechanism of sedimentation and changes in its kinetic energy, several minor intervals and subintervals could be distinguished even within vertical stretches appearing to be totally homogeneous to the unaided eye. The intervals and subintervals thus distinguished are in good agreement with the relevant paleontological results (*Fig. 3*, items III and IV). Wherever any, differences between the two types of interval boundaries are due to some delay with which a new biotope and the associated changes in the fauna tend to follow the establishment of a new regime in the sedimentary environment.

In the mollusc fauna of the Bácska Loess Area the thermophile species are present in greater number as compared to the case of the typical Transdanubian loesses [E. KROLOPP, 1965. 1966]. On the basis of some other peculiar features of the fauna (e.g. the presence of *Vitrina pellucida* (MÜLL.) and the high abundance of *Punctum pygmaeum* (DRAPP.)) the Bácska loess fauna differs from the loess faunas of other areas. These observations encourage even the possibility of regional correlations of subdivisions within the loess sequence.

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