# MOLLUSCA-PERIODS IN THE SEDIMENTS OF THE HUNGARIAN PLEISTOCENE. II. THE UPPER ARID PERIOD OF THE BORING OF FELSŐSZENTIVÁN

by

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In the first part of this work (Acta Biol. Szeged 1962. Tom. VIII. Fasc. 1—4, p. 173—192) author established that corresponding to the periodical changes of the Pleistocene the *Mollusca*-fauna showed also periodical changes and the circumstances of these periods may be reconstructed with the aid of the knowledge of the life of the *Mollusca*. Author gave also full details of the methods of investigation of the *Mollusca* residues found in the 77 m deep boring of Felsőszentiván (Hungarian Plain) made for scientific purposes in 1954. The species demonstrated were distributed into 6 ecological groups according to their mode of life and the ecological and geographical data needed for their evaluation were also published. The ecological requirements (e. g. cold-living, thermophilic etc.) were compared with the present circumstances of Hungary and the Hungarian Plain.

In this paper author begins the publication of the detailed treatment of the *Mollusca* of the boring of Felsőszentiván. Author's aim is the establishing of the *Mollusca*-periods, their comparison and to ascertain that from the periodical changes of the *Mollusca* fauna what kind of changes in the circumstances may be deduced.

## General characterization of the I. or upper arid period

The material of the boring was taken into consideration only from 1,6 m because higher up the sediments are disturbed by human influences. On the fauna an upper humid period (from 11 to 14,5 m) and a lower one (from 44,2 to 56,5 m) are strictly deliminated with a remarkable abundance of the aquatic fauna. These two humid periods divide the profil into an upper (from 1,6 to 11 m), a middle (from 14,5 to 44,2 m) and a lower (from 56,5 to 77 m) arid period. Author established in this way five periods which are designated with Roman numerals from above. This paper deals only with the uppermost one.

The I. or upper arid period is bordered at 11 m by the upper humid period in contrast to which it is characterized by the followings: The aquatic fauna lacks almost completely; it is represented in the 41 samples of the period only by 2 species and not more than 3 individuals. Thermophilic species occur only sporadically (only in 15 samples) and the number of individuals is also

low. In contrast to this in the neighbouring period the aquatic and the thermophilic fauna occur in all samples, the aquatic fauna is rich and thermophilic species are represented by a considerable number of individuals.

The lack of the aquatic fauna indicates arid climate. In the Holocene on the Hungarian Plain they were many smaller or larger marshy stagnant waters inhabited with a rich aquatic *Mollusca* fauna. This waters were eliminated mainly with human efforts. The cause for the lack of the aquatic fauna during the time of the sedimentation of the 11 m thick layer may be only a climate considerable dryer than that of today. At present the arid region of the Hungarian Plain is characterized by a thermophilic *Mollusca* fauna with a low number of species but with a high number of individuals. Therefore author explains the poverty of the thermophilic fauna of the I. period not by the aridity but by a climate colder than present. The cold character of the period is directly proved by the presence of oligothermic species. So in the upper part of the period *Columella edentula* subsp. *columella* (at present an inhabitant of high mountains), and *Pupilla sterri* (an alpine-carpatian inhabitant of rocks), in the lower part of the period, besides a series of *Pupilla sterri, Vallonia tenuilabris* (at present inhabitant of *Siberia)* were found. The cause of a so much more arid and colder climate in the period might be only the continental ice cover of the Pleistocene. Naturally, the ice cover exercised an influence on the climate not by its immediate presence but only by its proximity, because the Hungarian Plain was situated in the periglacial zone. The sediments of the profil are undoubtedly of aeolic origin because they contain a terrestrial fauna.

Summarizing the abovementioned data author states that the I. period of the profil was formed through aeolic way during the arid and cold climate of the glacial period of the Pleistocene.

Inside the period the fauna shows periodical changes too, therefore author divides the period into subperiods. The subperiods are designated with the Roman numeral of the period and (separated with a sign of division) with Arabic numerals.

The geological data were taken from the geological profil established by Prof. Dr. I. MIHÁLTZ.

## Subperiod I./1 (1,6 — 2,4 m)

From o to 1,6 m the sediments were disturbed by human influences and they contain no fauna worth mentioning. In the geological profil from o to 1,2 m a loess containing much humus, from 1,2 to 1,6 m a loess with a low humus content are denoted.

The subperiod I./1 is 80 cm thick. It consists of loess. The 4 samples contain altogether 119 snails. No aquatic organisms were found, consequently nor temporary stagnant waters did not exist on this area.

The ecological group of the amphibiotic species is represented by 2 individuals of *Succinea oblonga*. It is the most frequent species of the Hungarian Pleistocene; the low number of individuals found in the samples indicates a pessimum of the circumstances for it. The factor of decisive importance in this respect was not the cold but dryness. This appeared, however, only from

the further analysis of the fauna. *Succinea oblonga* subsists far-off the water too. Its occurrence does not indicate water but proves that soil was humid and covered with vegetation.

In the subperiod predominate the ubiquitous hygrophilic organisms. They are represented by 4 species and 100 individuals. All these species are cold-tolerant. Their quantity is proportional to their drought-resistance. In greatest number (43) was found *Pupilla muscorum*. This species of our hygrophilic ubiquitous organisms is found most frequently on more or less arid places. It is rather thermophilic and arid places are usually warm too. The same may be said about *Vallonia costata* (29 exemplares were found). The lower number of the more hygrophilic *Euconulus trochiformis* (27 exemplares) and *Trichia hispida* (1 exemplare) and the lack of the other cold-tolerant ubiquitous species in contrast to the high number of *Pupilla muscorum* may be reasoned not with the cold but only with aridity. Humidity of soil and its vegetation are conditions of existence also for ubiquitous organisms. *Euconulus trochiformis* may be considered, somewhat superficially, as an inhabitant of groves.

The ecological group of the inhabitants of groves is represented only by 2 species and 11 specimens. *Columella edentula*, which lives in forests, groves, on water-shores and riversides, occurs in the subperiod with the subspecies *columella*. This subspecies lives in the high mountains of Europe and in North-Scandinavia above the timber line among stones and in humid plant debris. It requires besides low temperature much humidity too. Because here it had no possibility to hide itself among stones, it must be supposed the existence of a suitable vegetation. *Pupilla sterri* (2 exemplares were found) demands more warmth and less humidity than the former species. It is an inhabitant of rocky walls in the mountains, according to the present climate of the Hungarian Plain it may be considered as a definitely cold-loving organism. It lives in forests but not in the forests themselves but in the humus accumulated on the limestones. It occurs above the timber line too.

The low number of individuals indicates unsuitable circumastances for the two species, they mere presence proves a climate rather colder than today. If the ratio of their numbers may allow to draw some conclusion, the climate might be somewhat warmer than that of the optimum of subsp. *columella* and somewhat colder than that of the optimum of *Pupilla sterri*. Temperature was more favourable for subsp. *columella*.

The thermophilic organisms are represented by 6 individuals of *Imparietula tridens*. This species shows itself regularly but in consequence of the cold only with few exemplares. It tolerates the cold relatively good, in the Alpes it occurs at 1000 m too. Its presence indicates a somewhat temperated coldness, relative dryness and an open vegetation.

On the basis of the above-mentioned data the following renconstruction may be given about the environmental conditions during the formation of this layer: The climate was arid, cold, continental, resembling to that of the high mountains or of North-Europe. Precipitation did not produce nor temporary stagnant waters. The soil was slightly but constantly humid. This humidity originated perhaps from the melting of frozen soil. Desiccation was inhibited by low temperature and vegetation. The vegetation was open, characteristic for the steppe. No proves were found for the existence of forests

but presence of shrubs from dwarf pines or from other cold-loving plants is probably.

### Subperiod I./2 (2,4—3 m)

It is only 60 cm thick. It consists of fine sand, the lower samples contains some loess too. Number of samples is 3 and only 27 snails were found in them. The fauna is very similar to that of the former subperiod, the number of individuals, however, is much more lower. *Pupilla sterri* was not found, otherwise the specific composition remained unchanged. One *Succinea oblonga* individual was found in each samples, consequently its conditions for existence were unchanged. Conditions of existence for *Pupilla muscorum* (11 exemplares) and *Vallonia costata* (5 exemplares) were much more miserable. They occur regularly, but the number of individuals is much decreased. From the ubiquitous group *Euconulus trochiformis* sufferred mostly the changes. It has the least drought-resistance; only 1 individual was found. Increase of aridity may be the cause of impoverishment in the number of individuals of the two former species too, because they are hygrophilic organisms after all. 1 individual of *Trichia hispida* occurs also here. There is a great loss in cold-living organisms too. The number of *Columella edentula* subsp. *columella* is very reduced (2!) and *Pupilla sterri* is lacking. Conditions of existence of the thermophilic *Imparietula tridens* did not change very much. Compared with the former subperiod the loss is considerable in hygrophilic and oligothermic species. All these data indicate a cold and arid climate which was arider, more continental and warmer than that of the subperiod I./1.

### Subperiod I./3 (3—4 m)

This subperiod consists of running sand, from 3,9 to 4,0 m fine sand with loess. Two of the five samples were empty and in the remaining three only 4 pieces of hygrophilic ubiquitous organisms were found. The definitely hygrophilic *Euconulus trochiformis* was found at the top, the xerotolerant *Pupilla muscorum* in the middle, and the somewhat more humidity requiring *Trichia hispida* (2 pieces) at the bottom. Increase of humidity on the transition of the two neighbouring humid subperiods is reasonable. Strangely, this is shown also by the 4 snails found. The lack of oligothermic species indicates the decrease of the cold while the disappearence of the thermophilic organisms and remaining of the ubiquitous species refer to a climate colder than today. Poverty in snails was caused by aridity and not by the inadequate temperature. The vegetation was developed probably only on solitary flecks. The considerable dryness shows the continental character of the climate too.

### Subperiod I./4 (4 — 4,6 m)

It consists of running sand. The fauna of the three samples contains mainly debris of *Succinea oblonga* and *Trichia hispida* from which the exact numbers of individuals were not determinable. The shells were crushed in all probability

by the running sand. The debris are uniformly distributed. Author estimates the number of individuals of each species for 10 in each samples; this means altogether 60 individuals. Both species require considerable humidity and on places without water they need abundant vegetation as protection against desiccation. The presence of these species indicate in contrast to the former subperiod more humidity and a richer vegetation. The thermophilic species are represented again by *Imparietula tridens* (3 exemplares) and *Helicella hungarica* (1 exemplare). The latter is at present a frequent inhabitant of the sand regions between the rivers Danube and Tisza. Presence of the thermophilic species shows a little rise of temperature, their low number and the presence of *Trichia hispida* (which may be considered in the Hungarian Plain as a cold-loving species) indicate a climate considerably colder than at present. After all the climate of this subperiod was also continental somewhat milded by oceanic influences. Considering the great increase of the number of the hygrophilic organisms and the only slight increase of the thermophilic ones impovement of the climate may be attributed rather to milding of the winters than to warming up of the summers.

### Subperiod I./5 (4,6 — 6,4 m)

This layer is 180 cm thick, it consists of fine sand containing loess. From the 5 samples the 3 lower ones are larger than the standard size (20 cm). *Succinea oblonga* and *Trichia hispida* dominate also in this subperiod. They are also here fragmentary; only 14 whole shells of *Succinea oblonga* and 27 whole shells of *Trichia hispida* were found. The debris may correspond about 50 individuals of each species in the two upper samples while in the three lower ones their correspond about 100 individuals. This means on the whole 800 individuals. There are many juvenile exemplares among them. They are equally distributed through the whole subperiod; the greater number of individuals found in the lower samples corresponds their larger size. In contrast to the former subperiod the number of individuals of the hygrophilic species increased about fivefold. This proves much more humidity. The vegetation might be more abundant too. At present *Trichia hispida* lives mostly in forests and groves, while *Succinea oblonga* was found by the author only in such biotopes if remote from water. Onesidedness of the fauna, the lack of the real inhabitants of forests indicate a monotonous steppe with pine-shrubs. The great number of *Trichia hispida* besides the lack of the thermophilic organisms prove that the climate was also in this subperiod considerable colder than today. The possibility of an extreme coldness is precluded by the abundant presence of *Succinea oblonga*. As a matter of fact this organism is rare in North-Europe and even in England. Disappearence of the thermophilic organisms shows a diminished summer-temperature as compared that of the former subperiod. At the same time the considerable increase of the number of the hygrophilic organisms proves a more expressed oceanic influence and milder winters. Two exemplares of the forest-inhabitant *Clausilia dubia* were found in the hole period only here. This might prove a climate colder than today, more humid circumstances and the presence of groves. *Clausilia dubia* occurs, however, in the Alpes above the timber line too. In

consequence of the very low number of individuals it is of little significance. Other species occur only in the lowest sample which has already a transitional character. *Pupilla muscorum* (4 exemplares), *Vallonia costata* (1 exemplare) and *Punctum pygmaeum* (1 exemplare) are enduring ubiquitous organisms. *Pupilla sterri* (6 exemplares) indicates a climate much more colder than today without proving an absolutely very cold climate.

### Subperiod I./6 (6,4 — 7,6 m)

It is 120 cm thick. The two upper samples consists of fine sand containing loess, the lower sample (7,4—7,6 m) consists of loess. The subperiod is delimited from the neighbouring layers by the much greater number of species and individuals. Number of species is 14 as against that of the 7 and 8 species in the subperiods I./5 and I./7 respectively. The number of exemplares counted was 3706. This value is eminent even than if in order of proportionality the number of individuals will be divided with 2 in the upper and with 3 in the middle sample.

Water-inhabitant organism was found first here: *Galba truncatula* (only 2 exemplares). It is an inhabitant of little waters, it lives also in temporary waters. It is insensitive to changes of the temperature, it is distributed from Abessinia to the high North. In the loess of the Hungarian Plain it was more frequent than at present; therefore considered it author as a moderately oligothermic organism. Its presence indicates water by all means and here probably also the most humid intervall of the whole period. The considerable increase of the number of *Succinea oblonga* (1214 exemplares!) may be the consequence of temporary stagnant waters, it proves certainly a considerable increase of humidity and a relative temperate temperature.

In this layer the group of hygrophilic ubiquitous organism is the greatest (8 species, 1569 exemplares). Dominant is *Trichia hispida* (811 exemplares). It lived here among optimal circumstances, this indicates a climate which was more severe than today but in the Pleistocene was only temperately cold and indicates also humid circumstances and shrubs. *Pupilla muscorum* (511 exemplares) found here also favourable circumstances. It has a more thermophilic character although it tolerates more cold and especially dryness than the former species. Here a temperate coldness, not very great humidity and a grass-landvegetation may be indicated by it. *Vallonia pulchella* and *Vallonia costata* occured in nearly equal numbers (78 and 75 exemplares respectively). Their high number too indicates an increase of humidity. *Vallonia costata* tolerates cold and drought more and requires more warmth, therefore it is in the loess generally rarer than *Vallonia pulchella*. Its relatively high number in another prove of a moderate cold. *Deroceras agreste* was found first here (59 exemplares), it has a considerable requirement for humidity as all snails without shell, its presence is evidently connected with the increase of humidity. *Vallonia enniensis*, a South-European species known from the loess long ago remains behind its more enduring species-associates (30 exemplares were found). Its proportion corresponds to the temperately cold and humid surroundings. *Cochlicopa lubrica* with 4 exemplares and *Punctum pygmaeum* with 1 exemplare play

an unimportant role. At present in Hungary they are more frequent in the mountains than on the Hungarian Plain.

*Pupilla sterri* belonging to the following ecological category fived under optimal circumstances. This indicates a micro-climate similar to that of the biotopes where this species lives at present: on the warmer places of the Alpes and Carpates at the foot of limestone rocks in rotten plant material. Occurrence in the mountains, hiding from the insolation at the foot of the rocks into the plant debris show oligothermic charakter, while on the other hand occurence on more or less warmer places, seeking for the easily warming limestone rocks and requiring of the warmth of rotting are thermophilic property. Avoiding of humid places indicates thermophily too. Hiding into the plant debris shows hygrophily. All these prove a climate much more colder than the present climate of the Hungarian Plain, but this may be considered in the Pleistocene still as a temperate coldness.

Here was found firstly *Perpolita hammonis* (5 exemplares) which later disappears again. It lived among unfavourable conditions. Its appearence indicates the increase of humidity and a climate colder than today.

The thermophilic organisms are represented by a single exemplare of *Imparietula tridens*. In the subperiod I./5 no thermophilic organisms were found, and they are lacking further down too. This single exemplare may indicate only a little more warmth in summer.

*Vallonia tenuilabris* (135 exemplares were found) lived in Europe only in the Pleistocene. At present it is an inhabitant of Siberia, East-Turcestan and North-China. It is lacking in the former subperiods, but here it was all right. It lives in cold, continental climate on places covered with pines. Its occurrence indicates similar circumstances. Its presence does not contrast the former evaluations but enlightens it from an other side. Like all snails, this species requires humidity too. In its native land the summer is relatively warm, temperature may rise above 20° C. Under arctic climate it does not occur. The long and hard winters it sleeps through, probably hidden in the plant debris.

In the whole period this subperiod was the most suitable for the *Mollusca* fauna. This suitability may be attributed to the effect of warmth and humidity. This warmth and humidity, however, must be interpreted only relatively. Temperature was rather cold for the prospering of oligotherm organisms, which are completely disappeared from the Hungarian Plain after climate became warmer in the Pleistocene. The climate of the subperiod was arid and cold after all, as produced in the periglacial zone by the chilling effect of the ice-cover. The relatively suitable circumstances were produced by a warm climate-effect, which compensated the chilling effect of the continental ice-cover and made it also thinner. On the basis of the present distribution of the snails the population of this subperiod may not be considered as a forest-fauna nor as a steppe population. The most appropiate designation may be a northern or mountain fauna. Some of its species may range in the mountains over the timber line, the population itself, however, may not be reconstructed in the high North nor in thehigh mountains. The population does not fit into decidous forests, because they are lacking the species charaktersitic for the forests. Such a population does not occur in closed pinewoods, which contain only very few

snails. It may be placed the best in the zone of pines on more open places with suitable micro-climate. Author considers the vegetation of the subperiod as a steppe with pine-shrubs.

### Subperiod I./7 (7,6—8,8 m)

It is a 120 cm thick loess. This subperiod is sharply delimited from the neighbouring subperiods by its poor snailfauna. The six samples contains 247 snails in all, this is only the fifteenth of the subperiod I./6 which has a similar thickness. The water-inhabitants are represented by one piece of *Anisus planorbis*. This is a eurytherm species.

Dominant species is *Succinea oblonga*, its 146 exemplares found is much more than the 101 exemplares of the other species. It occurs in a continous series, but the number of individuals is consistently lower than in the samples of the neighbouring periods. Its domination indicates at the same time the domination of the ampibic category while in the subperiod I./6 the hygrophilic ubiquitous species predominate. The diminished number of individuals is caused by the increase of cold and aridity. This species is rare northwards the 60 degree of latitude and has a considerable hygrophilic character.

The hygrophilic ubiquitous species are represented by 4 species and 83 exemplares. From this category in first line *Pupilla muscorum* came into prominence (50 exemplares). This species tolerates cold and dryness mostly. The number of individuals, however, is considerable diminished as compared with the former subperiod. *Trichia hispida* which has a narrower ecological limits and which was more frequent in the former subperiod, here fall behind *Pupilla muscorum* with its 27 exemplares. *Vallonia enniensis* (3 exemplares) and *Deroceras agreste* (3 exemplares) seem only vegetate. *Cochlicopa lubrica*, *Vallonia pulchella*, *Vallonia costata* and *Punctum pygmaeum* are lacking. The possibilities of life for this 4 species might be present, if only hardly. Their lack in the relatively little samples may be attributed to the general diminution of the number of individuals. Disappearence of *Vallonia enniensis* would be more reasonable than that of the other two *Vallonia* species which have a more expressed oligotherm character.

The following category is represented only by *Pupilla sterri* (11 exemplares). Its occurrence is continous, but the number of individuals is very low as compared to the subperiod I./6. The circumstances of life for it were getting worse. The thermophilic species are lacking. The oligotherm *Vallonia tenuilabris* occurs only discontinously with 6 individuals. The cause of this general impoverishment of the fauna might be only a much more colder and arider climate than that of the subperiod I./6. Diminishing of the ubiquitous and disappearence of the thermophilic organisms needs no further explanation. Diminution of the number of the cold-loving *Pupilla sterri* and *Vallonia tenuilabris* is also understandable considering the manner of life described above in subperiod I./6. Temperature was much more lower than the optimum of these organisms. The vegetation might be more open with few or none shrubs. The preponderant dominance of *Succinea oblonga* is surprising because this is the most hygrophilic species (except the single water-snail). The vital conditions also for this species were far under the optimum. The humidity required

might be originate not from rainfall but from melting of the frozen soil. In the continental climate of the subperiod predominates firstly the cold, the effect of winters. But on this degree of latitude all continental climate has a considerable warm summer. The effect of this warmth was almost balanced by the continental ice cover, although it made possible the existence of the poor periglacial fauna. This subperiod may be divided a relatively milder upper part (from 7,6 to 8,2 m) with more (187) individuals and into a colder part (8,2—8,8 m) with fewer individuals (60). This two parts were not separated as subperiods, because only the number of individuals was changed, the charakter of the population remained unchanged.

### Subperiod I./8 (8,8—11 m)

This layer is 220 cm thick. It consists of loess, at the lowest parts (10,8 — 11 m) mixed with humic mud. One of the samples (9,2 — 9,4 m) was lost, presumably still on the field. In the other lo samples 6137 individuals were counted. No waterorganisms were found.

*Succinea oblonga* is dominant in this layer too (2595 exemplares). The considerable increase of the number of individuals indicates the improvement of the circumstances of life. Humidity considerable increased and the colt diminished significantly too, as compared with the former subperiod.

The hygrophilic ubiquitous organisms are represented by 11 species and 2926 individuals. These organisms have already the leadership in this subperiod, the amphibic category comes only after them. From these organisms the most cold-tolerant and drought-resistant *Pupilla muscorum* is the first (1553 exemplares), and the more hygrophilic *Trichia hispida* is the second (957 exemplares). Increase of the number of *Deroceras agreste* (117 exemplares) indicates increase of humidity too. *Vallonia costata* and *Vallonia pulchella*, which are lacking in the former subperiod, here present themselves again (90 and 79 exemplares respectively). *Vallonia costata* with a little more thermophilic character is more frequent at the bottom, while *Vallonia pulchella* with its somewhat lower optimal temperature at the top. The rather thermophilic *Vallonia enniensis* which occured in the former subperiod only sporadically here lived through the whole subperiod, though only few exemplares (25) were found. The temperature remaind much lower as its optimum. On the upper part of the subperiod it is rarer. Consequently the upper part of the subperiod was indicated as colder by all three *Vallonia* species. The fairly hygrophilic, in the high mountains already rare *Cochlicopa lubrica* (66 exemplares), the temperately oligotherm *Vertigo pygmaea* (24 exemplares) and the groves inhabitant *Vitrea crystallina* (13 exemplares) are lacking in the upper part of the layer. This part may be considered therefore dryer and colder than the lower one. The role of *Euconulus trochiformis* (1 exemplare) and *Punctum pygmaeum* is unsignificant.

The category of the inhabitants of groves is represented by 3 species and 487 individuals. All three species prove a climate much more colder than today. On the Hungarian Plain no one of them is living at present. The preponderant dominancy of *Pupilla sterri* (413 exemplares) indicates dry, cold surroundings and a steppe-vegetation. The conditions for existence of *Pupilla sterri*

became considerable better because the number of individuals increased. Its habitat requirements were characterized in connection with subperiod I./6. In comparison with its optimum, subperiod I./7 seems dry and cold while the lower part of the subperiod I./8 warm and humid. *Perpolita hammonis* (67 exemplares) from 9,4 m downwards occurs continually. It may indicate the increase of humidity and the frequency of groves, but it occurs also on dry and cold slopes with an open vegetation. *Trichia striolata* occured in the subperiod only in three samples (9,4 — 10 m) which contain otherwise the most residues. Its number of individuals is only 7. It likes humid and foresty surroundings. Northwards it ranges not far, in South-Sweden it is already rare. In comparison with its optimum the surroundings were arid, cold and covered with a poor vegetation.

Thermophilic organisms were found in all samples below 9,6 m (*Helicella hungarica* 29 and *Imparietula tridens* 18). Their little number indicates some warmth, their quantity which is much more lower than today, points to a much more lower temperature. The vegetation might be open, steppe-like but the lack of shrubs is not proved. The upper part of the subperiod may be considered as colder on the base of the lack of the two species too. In the uppermost sample of the layer a debri of *Helix pomatia* was found which is otherwise rare in the Pleistocene. This occurrence is understandable because it occurs in the Alpes at 1800 m too. It likes shrubs and avoids direct sunshine as well as the inner parts of the forests.

The bulk of the oligotherm *Vallonia tenuilabris* (64 from the 81 exemplares) were found in the two uppermost samples of the subperiod. Elsewhere it occurs in discontinous series in low number. It indicates dry, cold, continental climate. The upper, colder part of the layer was suitable for the species, the lower parts were somewhat warmer.

After all the fauna of the subperiod is a charakteristic loess-fauna. It consists of small-sized, cold- and droughtresistant species which can also pull through unfavourable conditions. It proves a dry, cold, continental climate corresponding to the periglacial zone. The fauna is more similar to the fauna of the subperiod I./6 than to that of subperiod I./7. It indicates a climate dryer and colder than that of subperiod I./6 and humider and milder than that of subperiod I./7. The lower half of the subperiod was mildered and became a little more humid by oceanic influence. This influence was in the middle of the period the most effective. In this zone the total numbers of individuals of the samples are considerable larger, than in the other samples of the subperiod.

The vegetation was more richer than in the subperiod I./7 but poorer than in the subperiod I./6. Author supposes a cold steppe with open vegetation and with pine-shrubs.

## The upper arid peroid and the chronology of the Pleistocene

Establisment of the *Mollusca*-periods and subperiods in an attempt for the chronological division of the Hungarian Pleistocene. Authors inevitable task is the placing of these periods into the chronology of the Pleistocene used at present. Two kinds of chronology must be taken into consideration. One of them is based on the stratigrahpic structure of the sediments, the other on the

climate-curve of MILANKOVICH and BACSÁK calculated with the aid of astronomical considerations. These two kinds will be treated in the two sub-chapters of this part of the paper.

**1. The stratigraphical chronology.** MIHÁLTZ sited the boring of Felsőszentiván in 1954 on a section on which in 1950 already forty, 30 m deep borings were performed. The length of the section was 140 km, the borings were on this length equally distributed. On this section this *Mollusca*-period comprise on the three upper loess layers and the separating running sand layers. The humus-containing muddy loess, beginning at 10,8 m, which borders the third loess layer, belongs already to the II. or upper humid *Mollusca*-period. According to MIHÁLTZ the three loesses are the sediments of the three glacial periods of the Würm while the two sand layers were deposited in the two interstadial periods. The humus containing muddy loess (below the third loess) arised in the Riss-Würm interglacial period. This chronology was considered by the author first faultless on the basis of the surroundings-reconstruction with the aid of the *Mollusca* residues. At that time, however, only the fauna-composition of the stratigraphical units were evaluated and conpared.

The subperiods of the *Mollusca* period were presented in the original sequence of the investigation from above downwards. The Pleistocene chronology of the sediments will be reviewed in the sequence of the deposition, from below.

The third loess of the profil which was considered as originated in the Würm 1 ranges in the boring of Felsőszentiván from 10,8 to 7,4 m. It contains the *Mollusca* subperiods I./8 and I./7. The limit of the *Mollusca* subperiod diverge from the geological limits with 20 cm below and above equally. At 11 m the disappearence of the aquatic fauna indicates the disappearence of stagnant waters, while the reduction of the terrestrial fauna point to the disappearence of the humid micro-climate of water shores and the rich strand-vegetation. The waters were removed by the arid, windy, glacial loess-forming climate. The geological limit higher up with 20 cm indicates the elimination of the humus-forming effect of the interglacial vegetation. Deviation of the two kinds of limit might be explained by the possibility of humus-formation from the vegetation already perished through the climatic change. The abovementioned data given on the basis of the fauna on the subperiod I./8 entirely correspond to the glacial, loess-forming climate, while the data about the subperiod I./7 correspond the cold and arid essence of the same climate. At 7,6 m on the lower border of the subperiod I./6 the remarkable increase of the fauna indicates the beginning of a warm climate effect. The favourable effect on the fauna was performed not only by the warmth but also by the humidity which originated from melting of ice. The continental ice-cover, however, was only after a long period thinned down to such an extent, that through it could penetrate the westerly winds. As long as the westerly winds begins to carry the sand from the bed of the Danube, by that time the eastern winds deposited yet 20 cm thick loess layer. Therefore is the geological limit 20 cm above the *Mollusca*-limit.

The running sand between the third and second loesses ranges from 7,4 to 4 m. According to its stratigraphical situation it originates in the Würm 1 — Würm 2 interstadial period. Except the 20 cm difference at the bottom already explained, the period coincides with the *Mollusca*-subperiods I./6, I./5, and I,/4. The climates reconstructed from the fauna make probable the follo-

wing process. The continental ice-cover grew thinner during the warm summers of the subperiod I./6 fast while during the cooler summers of the subperiod I./5 slower. In the meantime the westerly winds carried fine sand in which the eastern winds mixed loess. At the end of the subperiod I./5 the continental ice-cover became so thin, that the westerly winds could carry unmixed running sand from the bed of the Danube during the subperiod I./4. The somewhat warmer summers of the subperiod I./4 made the ice-cover further thinner.

The second loess of the profil which may be considered on the basis of its situation as originated in the Würm 2, occurs in some places only discontinually. In the boring of Felsőszentiván it is represented only with a 20 cm thick layer (4 — 3,8 m). On other places, as the borings of 1950 show, it may attain considerable thickness. No fauna was found in it in the boring of Felsőszentiván. Author range it in the subperiod I./3, which is extremly poor in snails and of which it is the lowest sample. From the borings of 1950 in this loess 32 species and several thousands exemplares were investigated. These indicate a cold, and dry loess-forming climate which was milder than that of the third loess.

The running sand layer between 3,8 and 3 m coincides with the *Mollusca*-subperiod I./3, according to its situation it is from the Würm 2 — Würm 3 interstadial period. Its extreme poverty in snails explained with dryness corresponds to the quicksand. Its climate, in the Pleistocene neither cold nor warm, corresponds with the interstadial period during which the chilling effect of the continental ice-cover manifested.

The loess-containing fine sand and running sand between 3 and 2,4 m is identical with the subperiod I./2. According to our chronology it is the transitory sediment of the Würm 2 — Würm 3 interstadial period and the loess-forming glacial period of the Würm 3. In this period the westerly winds carried fewer sand and more fine sand in which the eastern winds mixed loess. This indicates that the continental ice-cover became thicker, it hindered the westerly winds but it was not thick enough to make permanent the loess-carrying eastern winds. For the thickening of the continental ice-cover a moist climate is necessary with much snowfall in winter and with cold summers during which the snow accumulated in winter does not thaw. On the basis of the fauna this subperiod had a more humid climate than the former (I./3) one, and it was colder than the following loess-forming period (subperiod I./1); the summers were cool. The stratigraphical evaluation of the layer is in every respect supported by the fauna. The precipitation of the dry, cold, continental climate was, however, unable to produce a complete ice-cover, it could only thicken the existing one.

The first loess between 2,4 and 1,6 m with its *Mollusca* subperiod I./1 is identical with the loess-forming period of the Würm 3 in the stratigraphical chronology. To the dry and cold climate, which is supposed on the basis of the sediment, entirely corresponds the fauna.

The changes of the sedimentation processes and the changes of the fauna are strongly connected. The deviations occuring in some places are easily to explain. Two kinds of indicators were used, both indicate in his own way. From the two indicators the fauna is the more sensitive, it is suitable for further division of the sedimentations-periods. Analysis of the fauna of the sediments enlarges the knowledge connected with the stratigraphical chronology too, the chronology itself is also acceptable merely on the basis of the fauna.

**2. The astronomical chronology.** The climate-curve of MILANKOVICH and BACSÁK and its interpretation give a precise succession of the climate-changes in the Pleistocene. This succession may not be followed from the beginning of the Würm 1 of the stratigraphical chronology, nor with the aid of the *Mollusca* fauna which is very susceptible to the changes of the climate. According to the astronomical calculations from the beginning of the Würm 1, there were two periods *(krion)* with continental icecover. Author's *Mollusca*-period I. shows, however, only one glacial period. The heterogen character of the interstadial periods of the climate-curve, in contrast to the more homogen character of the stratigraphical interstadial periods, draw special attention. If author would be sure of the correspondence of the identical names used in the stratigraphical and astronomical chronology (e. g. that the third loess which is determined as the sediment of the Würm 1 is indeed the sediment of the Würm 1 period of the astronomical climate-curve), he would follow the stratigraphical chronology and in it would be denoted the defects of the sediment-formation in contrast to the climate-curve. But at present it seems more suitable to co-ordinate the *Mollusca*-periods immediately with the astronomical calculation as it was performed in the case of the stratigraphical chronology.

The youngest glacial period of the climate-curve ranges from the beginning on the Würm 2 to the end of Würm 3. The continental ice-cover of the Würm 2 did not melted during the interstadial period, only became a little thinner. The glaciation of the Würm 3 thickened it again. The influence of the continental ice manifested during the whole time and produced a climate with a dry, cold and continental basic character. This fit precisely in author's *Mollusca*-period as was already said above. Author's *Mollusca*-period would begin not with the Würm 1 but with the Würm 2 and would last to the end of the Würm 3. The glacial period begins from below with the Würm 2. It was 11 200 years long. According to the calculations, the glacial period had an oceanic climate with cool summers and average winters. During the cool summers the abundant snow of the winters did not melted entirely and became a continually thickening continental ice-cover. This is the oceanic part of the glacial period. In the continental part of the glacial period the ice-cover did not let through the westerly winds, the climate became dry, cold and continental, the eastern winds predominate which transport the loess too. Author's I./8 *Mollusca*-subperiod may be identified with the Würm 2 glacial, loess-forming period. The oceanic influence demonstrated on the lower part tinge only little the continental character. On the upper part the increase of the dry and coldness was demonstrated.

On the climate-curve follows a 9 500 years long subarctic period, while in the fauna the subperiod I./7. The subarctic climate is characterized by cold winters, average summers and by continentality. The melting of the frozen soil in the summer produce tundra. In the case of this subperiod the summers were chilled by the continental ice-cover, and were not favourable for the fauna. Directly unfavourable were for the fauna the increase of the cold in winter and the increase of aridity. Poverty of the fauna is thereafter more understandable. Analysis of the fauna shows the preponderance of the most hygrophilic species: *Succinea oblonga*. The formation of the tundra makes this occurrence intelligible. Because of the aridity, a real tundra could not form, but the process presents itself in a less characteristic form.

The following climate change was the 3 100 years long antiglacial period. In the fauna corresponds to it the subperiod I./6. The summers were warm, the winters were average, the character of the climate was continental. If a continental ice-cover already existed, it was strongly destroyed through the warm summers. The fauna of authr's period is here the most rich, which contrasts with the poverty of the subperiod I./7. The considerable warmth and melting of the continental ice was indicated by the enrichment of the fauna, while the partial surviving of the ice is proved by the great number of the oligotherm organisms. The third loess comes to an end also here, at the end of the lowermost boringsample. This is an other prove of the decrease of the continental ice. Continuation of the sediments upwards with a loess-containing fine sand indicates the restriction of the western winds and at the same time the partial existence of the ice-cover.

On the climate-curve follows now a 11 500 years long period of subtropical character. The climate was of oceanic character with mild winters and average summers. It melted effectively the continental ice, but not as fast as the previous antiglacial period. This section of the climate-curve may be identified with the *Mollusca* subperiods I./5. and I./4. The oceanic influence is proved by the preponderance of the hygrophilic *Succinea oblonga and Trichia hispida.* The role of the other species is unsignificant. On the basis of this characteristic fauna the two subperiods might be fused. In the subperiod I./4 the oceanic influence was weaker and the warmth was somewhat higher. Author reconstructed on the basis of the fauna a climate much colder than today, this may be produced in this type of climate only through the chilling effect of the continental ice.

Thereafter followed an only 500 years long glacial period. The lowermost sample of the subperiod I./3 (4—3,8 m) corresponds to it. No snails were found in the sample. The sudden disappearence of the fauna may indicate a change in the climate. The boring sample consists of loess-containing fine sand, above and below it, there is equally running sand. This very short glacial period corresponds very well this little stratigraphical change. It was mentioned, however, that in the borings of the year 1950 the second loess was situated on this part of the profil. Such a quantity of loess could not produced by the little glacial period, therefore the following period or at least a part of them must be considered as loess-forming.

The short glacial period was followed by a long (12 800 years) subarctic period. Except the lowermost sample it may be identified with the *Mollusca*-subperiod I./3. Poverty of the fauna is here also remarkable as in the older subarctic period. The temperately warm summers melted the continental ice which itself chilled the summers. The basic character of the climate was also here cold and arid, as influenced by the continental ice. The animals lived on quicksand. Humidity originated from the melting of the soil in the summer. No wonder that very few snails were found in this subperiod.

The glacial period terminates with the Würm 3 glacial period. It was 9 500 years long. Author identified it with the *Mollusca*-subperiod I./2 and I./1. The fauna of the two subperiods is similar, but they differ from the fauna of the subperiod I./3. On the basis of its fauna, subperiod I./2 had a milder climate. Its sediments (loess-containing fine sand) are transitory between the running sand and the loess. The fauna indicate a more humid climate than that of the subperiod I./3. On the basis of these, author considers the subperiod as the

oceanic part of the Würm 3 glacial period. Subperiod I./1, which was on the basis of its fauna colder and which consists of loess, may be considered as the continental part of the Würm 3 glacial period.

After all the climatic changes of the astronomical curve were easily applicable for the changes of the *Mollusca*-fauna, it nearly suits itself on them. On the field of author's *Mollusca* period the astronomical chronology is applicable on the periods of the sediments too. In this case the lower limit of the glacial period is indicated by the humus-containing zone which otherwise generally occured in the borings of 1950. Higher from this the lack of the humus-containing zone indicates the presence of the continental ice-cover. The loesses show a thick continental ice and the preponderance of the eastern winds, while the running sands a thinner ice-cover and the dominance of westerly winds. Sedimentation of the loess-containing fine sand and the fine sand occured in a time when the ice was thinner than during loessformation and thicker than in the time of the deposition of the running sand.

(To be continued)

I. or the upper arid period of the boring of Felsőszentiván

loess | running sand | loess-containing fine sand | humus containing loess

* = estimated walues

| Astronomical chronologie | | Würm 3 | | | | | | | | Würm 2 — Würm 3 | | | | | | | | | | | | | | | | | | | | | | | | Würm 2 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | continental | | | | | oceanic | | | subarctic | | | | Glaci-al | subtropical | | | | | | | | | antigeacial | | | subarctic | | | | | | | | | | | | | | | | |
| stratigraphical chronologie | | Würm 3 | | | | | Würm 2 — Würm 3 | | | | | | | Würm 2 | Würm 1 — Würm 2 | | | | | | | | | | | | Würm 1 | | | | | | | | | | | | | | | | | | |
| Mollusca subperiods | | I/1 | | | | | I/2 | | | I/3 | | | | | I/4 | | | I/5 | | | | | I/6 | | | I/7 | | | | | | | I/8 | | | | | | | | | |
| stratigraphical profil | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| species | depth. m. | 0,0—1,6 | 1,6—1,8 | 1,8—2,0 | 2,0—2,2 | 2,2—2,4 | 2,4—2,6 | 2,6—2,8 | 2,8—3,0 | 3,0—3,2 | 3,2—3,4 | 3,4—3,6 | 3,6—3,8 | 3,8—4,0 | 4,0—4,2 | 4,2—4,4 | 4,4—4,6 | 4,6—4,8 | 4,8—5,0 | 5,0—5,5 | 5,5—6,0 | 6,0—6,4 | 6,4—6,8 | 6,8—7,4 | 7,4—7,6 | 7,6—7,8 | 7,8—8,0 | 8,0—8,2 | 8,2—8,4 | 8,4—8,6 | 8,6—8,8 | 8,8—9,0 | 9,0—9,2 | 9,2—9,4 | 9,4—9,6 | 9,6—9,8 | 9,8—10,0 | 10,0—10,2 | 10,2—10,4 | 10,4—10,6 | 10,6—10,8 | 10,8—11,0 |
| *Galba truncatula* O. F. Müll. | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | |
| *Anisus planorbis* L. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | |
| Aquatic species altogether | | | | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | 1 | | | | | | | | | | | | |
| *Succinea oblonga* Drap. | | | 1 | 1 | | | 1 | 1 | 1 | | | | | | 10* | 10* | 10* | 50* | 50* | 100* 1 | 100* 2 | 100* 11 | 457 | 248 | 509 | 43 | 34 | 30 | 12 | 14 | 13 | 325 | 211 | | 366 | 411 | 376 | 268 | 195 | 152 | 122 | 169 |
| Amphibiotic species altogether | | | 1 | 1 | | | 1 | 1 | 1 | | | | | | 10* | 10* | 10* | 50* | 50* | 100* 1 | 100* 2 | 100* 11 | 457 | 248 | 509 | 43 | 34 | 30 | 12 | 14 | 13 | 325 | 211 | | 366 | 411 | 376 | 268 | 195 | 152 | 122 | 169 |
| *Cochlicopa lubrica* O. F. Müll. | | | | | | | | | | | | | | | | | | | | | | 2 | 2 | | | | | | | | | | | 1 | | 35 | 5 | 2 | | 3 | 20 |
| *Vertigo pygmaea* Drap. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 2 | 7 | 2 | | 5 | 7 |
| *Pupilla muscorum* L. | | | 4 | 16 | 23 | | 8 | 1 | 2 | | | 1 | | | | | | | | | 4 | 260 | 138 | 113 | 13 | 9 | 22 | 2 | 3 | 1 | 86 | 81 | | 194 | 186 | 430 | 145 | 98 | 87 | 88 | 158 |
| *Vallonia pulchella* O. F. Müll. | | | | | | | | | | | | | | | | | | | | | | 31 | 47 | | | | | | | | 9 | 16 | | 8 | 5 | 11 | 10 | 6 | 5 | 7 | 2 |
| *Vallonia enniensis* Gredler | | | | | | | | | | | | | | | | | | | | | | 10 | 15 | 5 | 2 | | | 1 | | | 2 | 1 | | | 5 | 4 | 6 | 4 | 1 | 2 | |
| *Vallonia costata* O. F. Müller | | | | 7 | 22 | | 2 | 1 | 2 | | | | | | | | | | | | 1 | 64 | 11 | | | | | | | | 1 | | | 4 | 11 | 42 | 12 | 5 | 1 | 3 | 11 |
| *Punctum pygmaeum* Drap. | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | | 1 | | | | |
| *Vitrea crystallina* O. F. Müll. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | 2 | | | 1 | 5 |
| *Euconulus trochiformis* Mont. | | | 11 | 3 | 10 | 3 | 1 | | | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | |
| *Deroceras agreste* L. | | | | | | | | | | | | | | | | | | | | | | 47 | 12 | | | | | 1 | 1 | | 1 | 14 | 27 | | 3 | 2 | 12 | 24 | 14 | 8 | 7 | 6 |
| *Trichia hispida* L. | | | 1 | | | | | 1 | | | | | 2 | | 10* | 10* | 10* | 50* | 50* | 100* | 100* | 100* 27 | 517 | 229 | 65 | 12 | 5 | 4 | 5 | | 1 | 41 | 18 | | 178 | 120 | 145 | 99 | 98 | 85 | 28 | 145 |
| Hygrophil ubiquist species altogether | | | 16 | 26 | 55 | 3 | 11 | 3 | 4 | 1 | | 1 | 2 | | 10* | 10* | 10* | 50* | 50* | 100* | 100* | 100* 33 | 932 | 454 | 183 | 27 | 14 | 27 | 9 | 3 | 3 | 153 | 143 | | 388 | 330 | 687 | 310 | 230 | 187 | 144 | 354 |
| *Columella edentula* Drap. | | | 7 | 2 | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Pupilla sterri* v. Voith | | | 1 | | 1 | | | | | | | | | | | | | | | | 6 | 502 | 248 | 30 | 3 | 3 | 1 | 2 | | 2 | 87 | 111 | | 8 | | 108 | 4 | 31 | 35 | 29 | |
| *Clausilia dubia* Drap. | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | | | | | | | | | | | | | | | | | | | |
| *Perpolita hammonis* Störm | | | | | | | | | | | | | | | | | | | | | | 3 | 2 | | | | | | | | | | | 2 | 9 | 15 | 6 | 8 | 2 | 8 | 17 |
| *Trichia striolata* C. Pfeiff. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | 5 | | | | | |
| Inhabitant of the groves altogether | | | 8 | 2 | 1 | | 1 | 1 | | | | | | | | | | | 1 | | 7 | 505 | 250 | 30 | 3 | 3 | 1 | 2 | | 2 | 87 | 111 | | 11 | 10 | 128 | 10 | 39 | 37 | 37 | 17 |
| *Imparietula tridens* O. F. Müll. | | | | 1 | 3 | 2 | | 4 | | | | | | | 2 | 1 | | | | | | 1 | | | | | | | | | | | | | 1 | 7 | 4 | 5 | | | 1 |
| *Helicella hungarica* Soós et H. Wagner | | | | | | | | | | | | | | | 1 | | | | | | | | | | | | | | | | | | | | 5 | 14 | 4 | 5 | 1 | | |
| *Helix pomatia* L. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | | | | | | | | |
| thermophilic species altogether | | | | 1 | 3 | 2 | | 4 | | | | | | | 3 | 1 | | | | | | 1 | | | | | | | | | 1 | | | | 1 | 12 | 18 | 9 | 5 | 1 | 1 |
| *Vallonia tenuilabris* Al. Braun. | | | | | | | | | | | | | | | | | | | | | | 85 | 49 | 1 | 1 | | 4 | | 1 | | 29 | 35 | | 4 | 9 | 1 | | 2 | 1 | | |
| Mollusca exemplares altogether | | | 25 | 30 | 59 | 5 | 13 | 9 | 5 | 1 | | 1 | 2 | | 20* 3 | 20* 1 | 20* | 100* | 100* 1 | 200* 1 | 200* 2 | 200* 51 | 1981 | 1001 | 724 | 74 | 51 | 62 | 23 | 18 | 19 | 595 | 500 | | 769 | 761 | 1204 | 606 | 475 | 382 | 304 | 541 |