THE PROBLEMS OF THE PANNONIAN OF HUNGARY

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The Pannonian basin has formed in post-Badenian times in the considerably contracted, gradually bracked and segmented western part of the Paratethys; between the Vienna, Styrian, Croatian and Transsylvanian basins. The extension, the degree of interrelation, the sediment thickness and development of these basins, as well as the fauna, the direction, date and interruption of the faunal migrations necessarily were subordinated to the emergent or submergent movements of the basinal floors and the surrounding mountain chains. These movements resulted in the *occasional* relationships between the Pannonian basin and the Euxinic basin through the Porta Ferrea and the Dacian basin *(Fig. 1)*.

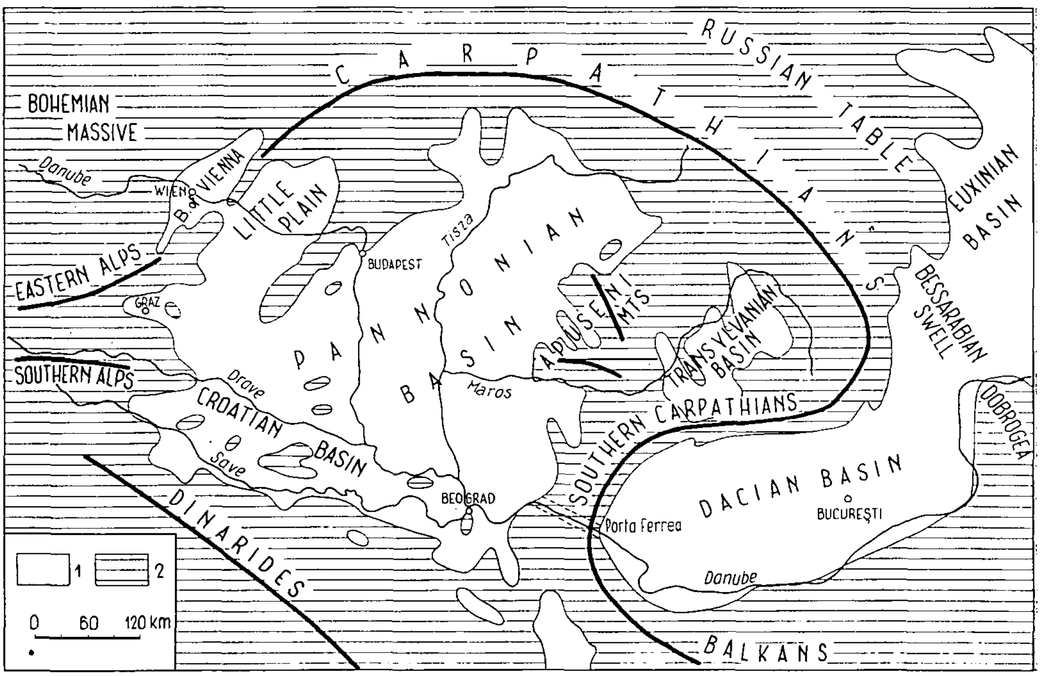

Fig. 1. Location of the Pannonian Basin among the partial basins of the Pliocene Paratethys. *1.* Sea. *2.* Land.

The sediment-mass of the Pannonian exceeds that of any other geological age in Hungary. Its greatest thicknesses are 3500 to 4500 m, and its distribution is country-wide. Surfacial exposures can be found abundatly in its lower and upper parts; the facial and faunal profusion is especially striking in the upper part.

The Pannonian sequences bear a great economic importance: i. e. these accumulate hydrocarbons and water, and contains thick, sub-superficial lignite deposits in several places. Consequently, the deepboring exploration of the Pannonian is statisfying *(Fig. 2)*.

The name Pannonian Stage is used here — in agreement with L. ROTH V. TELEGD [1879] — for the *Congeria*-bearing sequence between the Sarmatian and Pleistocene of the Carpathian basin, as a synonym of the Pliocene. However, the views of the Hungarian and foreign researchers are differently varied about the subdivisioning and parallelization of the certain subdivisions of the Pannonian *(Fig. 3)*.

The first to publish Pannonian fossils was Hörnes, M. (1853—67), from the Vienna basin. The earliest, relatively well determined Pannonian faunas from Hungary and Banat (Kup, Tihany, Radmanest) were described by FUCHS [1870*a*, *b*], but the stratigraphic evaluation was given by Böckh [1874, 1881]. In the years after the turn of the century HALAVÁTS [1911], LŐRENTHEY [1911], VITÁLIS [1911] and LÓCZY, SEN. [1916] raised the number of the known localities over a hundred, and in their faunal lists, numbering some hundred species, many new forms also appeared. These pioneers attempted firstly the parallelization of the Pannonian with the coeval rocks of the surrounding countries. The excessive increase in the number of species raised, even in that time the question of justness of their species concept. However, the first statistical mass-analyses which were suitable for more precise deliminations of the variability ranges were carried out only from the early forties [STRAUSZ 1941*a*, 1942*c*; BARTHA 1954, 1955, 1956, 1959*a*, *b*, 1962, 1963, 1966, 1971*a*].

It was appeared about the Pannonian of Hungary, in the light of the data of boreholes having been increased from the thirties, that

a) in contradiction to the previously presumed 300 m, the maximal thickness is several thousand metres;

b) the cross-section of the sedimentary basin was considerably asymmetrical, and the deepest parts of its floor were situated in the Little Plain and in the southern and south-eastern part of Hungary, i. e. in the marginal parts of the basin [SÜMEGHY 1939, SZÁDECZKY-KARDOSS 1939, SCHRÉTER 1940, DANK 1965, KŐRÖSSY 1968, STRAUSZ 1941, 1942, SZÉLES 1968, 1971*a*, URBANCSEK 1963, VÖLGYI 1965].

The intermittent coring in the hydrocarbon drillings, and the almost entire giving up of the core drilling in the water exploration encumbers markedly the detailed mass-investigations, just as that mistaken view, wich have attempted to overcome the problems arised from the continuously increasing data by the unjustified oversimplification of the geological events. On the other hand, the present writer showed through several examples that the sedimentological and faunal studies by every 10 cm leads to the following advantages:

a) Besides the statistically based separation of species having appeared abundantly in specimens, these studies enable to trace the horizontal (i. e. within beds) and the vertical (i. e. through beds) variability of the forms, that is to recognize racial disintegrations in space, and speciations in time together.

b) These studies supply realistic ground for the layer by layer comparison of the bio-associations, for the interpretation of the temporal and spatial variations in the faunal spectrum and the biofacies, together with the quantitative evaluation, on the basis of the principle: "from more the more, from few a few remains".

c) These studies make the manifold and detailed correlation of the faunas and sediments possible.

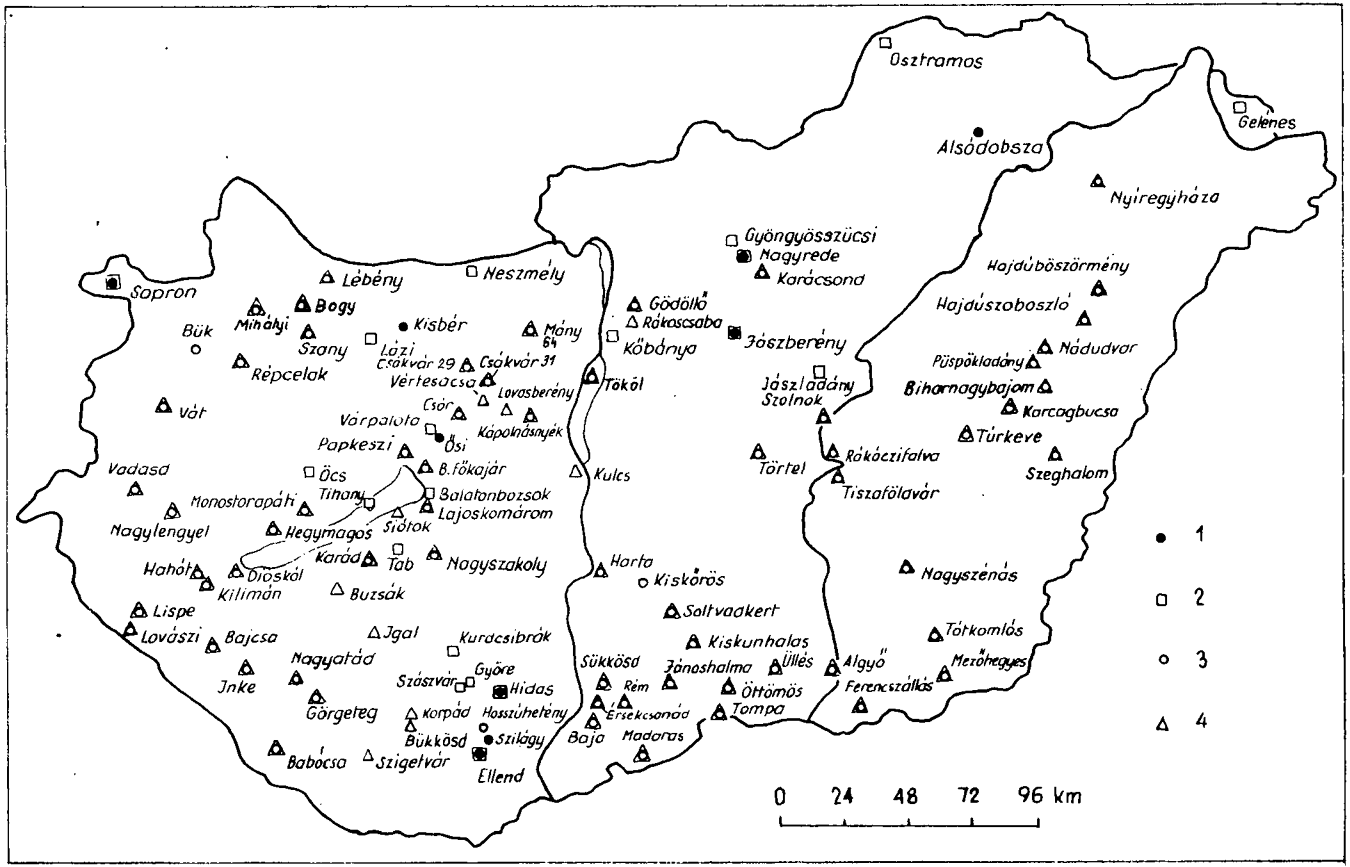

Fig. 2. The most important outcrops of the Pannonian sequence in Hungary.

1. Early Pannonian standard profiles. *3.* Late Pannonian standard profiles. *3.* Boring with Early Pannonian sequence.*4.* Boring with Late Pannonian sequence.

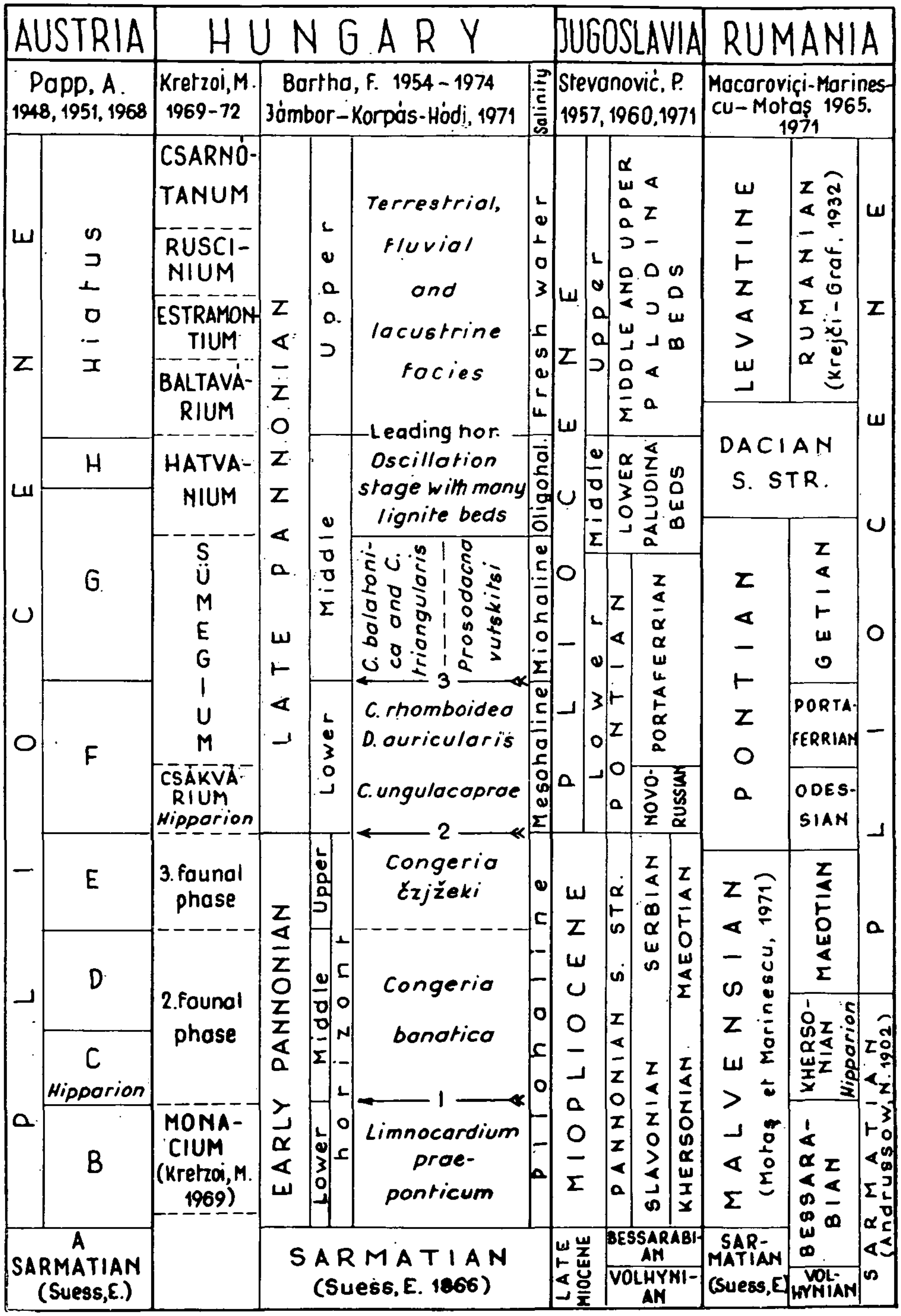
AUSTRIA
HUNGARY
JUGOSLAVIA
RUMANIA
Papp, A. 1948, 1951, 1968
Kretzoi, M. 1969-72
Bartha, F. 1954-1974 Jámbor-Korpás-Hódi, 1971
Salinity
Stevanović, P. 1957, 1960, 1971
Macarovici-Marinescu-Motaş 1965, 1971
PLIOCENE
Hiatus
H
G
F
E
D
C
Hipparion
B
A
SARMATIAN (Suess, E.)
CSARNÓTANUM
RUSCINIUM
ESTRAMONTIUM
BALTAVÁRIUM
HATVANIUM
SÜMEGIUM
CSÁKVÁRIUM
Hipparion
3. faunal phase
2. faunal phase
MONACIUM (Kretzoi, M. 1969)
LATE PANNONIAN
EARLY PANNONIAN
Upper
Middle
Lower
horizont
Terrestrial, fluvial and lacustrine facies
Leading hor.
Oscillation stage with many lignite beds
C. balatonica and C. triangularis
Prosodacna vutskitsi
3
C. rhomboidea
D. auricularis
C. ungulacaprae
2
Congeria čzjžeki
Congeria banatica
1
Limnocardium praeponticum
SARMATIAN (Suess, E. 1866)
Fresh water
Oligohal.
Miohaline
Mesohaline
Pliohaline
PLEIOCENE
MIOPLIOCENE
LATE MIOCENE
Upper
Middle
Lower
PONTIAN
PANNONIAN S. STR.
MIDDLE AND UPPER PALUDINA BEDS
LOWER PALUDINA BEDS
PORTAFERRIAN
NOVOROSSIAN
SERBIAN
SLAVONIAN
MAEOTIAN
KHERSONIAN
BESSARABIAN
VOLHYNIAN
LEVANTINE
RUMANIAN (Krejči-Graf, 1932)
DACIAN S. STR.
PONTIAN
GETIAN
PORTAFERRIAN
ODESSIAN
MALVENSIAN (Motaş et Marinescu, 1971)
MAEOTIAN
KHERSONIAN
Hipparion
BESSARABIAN
SARMATIAN (Suess, E)
VOLHYNIAN
SARMATIAN (Andrussow, N. 1902)

Fig. 3

In the course of their revisions on the profile of Fehérpart, Tihany, the present writer [BARTHA 1959*a*,*b*] and ZALÁNYI [1959*a*] proved that the complexity of the studies can considerably enlarge when taking the mollusc and ostracodes together into consideration, and when comparing the biofacies curve to the grain-size distributional curves. Taking all these, just as the conclusions of PAPP [1951] about the salinity of the Pannonian Lake, into account the parallel running of the two curves could have been unequivocally due to the result of oscillation. On the other hand, the faunal enrichment of the Upper Pannonian as compared to that of the Lower Pannonian could have been interpreted by the hypothesis suggested by STEVANOVIĆ [1951, 1955, 1959, 1960, 1971, STEVANOVIĆ and MLADENOVIĆ 1956], namely that in latest Early Pannonian times the Pannonian basin was temporarily connected to the Dacian basin, through the *Porta Ferrea* canal. This gateway made the migration of such species possible, which would be hardly generated from the Lower Pannonian forms, even with the supposition of pleiotropic mutations.

In the following the paleogeographical reconstructions of the Pannonian horizons are given upwards, referring at the same time to the differences of these horizons, too.

THE PROBLEM OF THE SARMATIAN-PANNONIAN BOUNDARY

At the boundary between the Vienna basin's Sarmatian and Pannonian HOERNESS, R. [1900] and FUCHS and KARRER [1870] postulated a break. On the other hand FUCHS [1870*a*,*b*], HALAVÁTS [1911] and LÓCZY, SEN., suggested continuous sedimentation within the Pannonian basin. On the basis of the litho- and chronofacies GAÁL [1912, 1938] rendered again a hiatus probably.

At the base of the Pannonian, continuous sedimentation, as well as uncomformity are equally possible; but the areal distribution and degree of the latter is not cleared up so far. The Sarmatian species in the "intermediate" fauna of the Virágvölgy-valley of Sopron [VITÁLIS 1951] are presumably redoposited. According to BÖCKH [1881], FERENCZI [1937] and VADÁSZ [1935], the Sarmatian ended with regıession along the coastal lines (e. g. in the Mecsek Mountains). South of the Mecsek Mountains, in the continuous sections of boreholes *Hidas—53* and *Ellend—1* some traces of shallowing (i. e. occurrence of *Orygoceras* sp., *Planorbis* sp., carbonized plant remains) were recognized at the Sarmatian-Pannonian boundary [BARTHA 1966]. However, according to KŐRÖSSY [1968], the sedimentation could have been continuous only is smaller relict lakes, because in latest Sarmatian times the major part of the Pannonian basin emerged by the Attic synorogenic movements, and became the region of the „pre-Pontian erosion". SZÉLES [1971*a*] similarly inferred continuous sedimentation enduring from the Sarmatian to the Pannonian only within the deepest basinal parts, just as the Békés depression. ZALÁNYI [1955, 1956, 1959*b*] frequently found, even in the central part of the Pannonian basin (Great Plain), sapropelic swamp deposits between the Sarmatian and the *Amplocypris-*, *Heterocypris*-bearing strata

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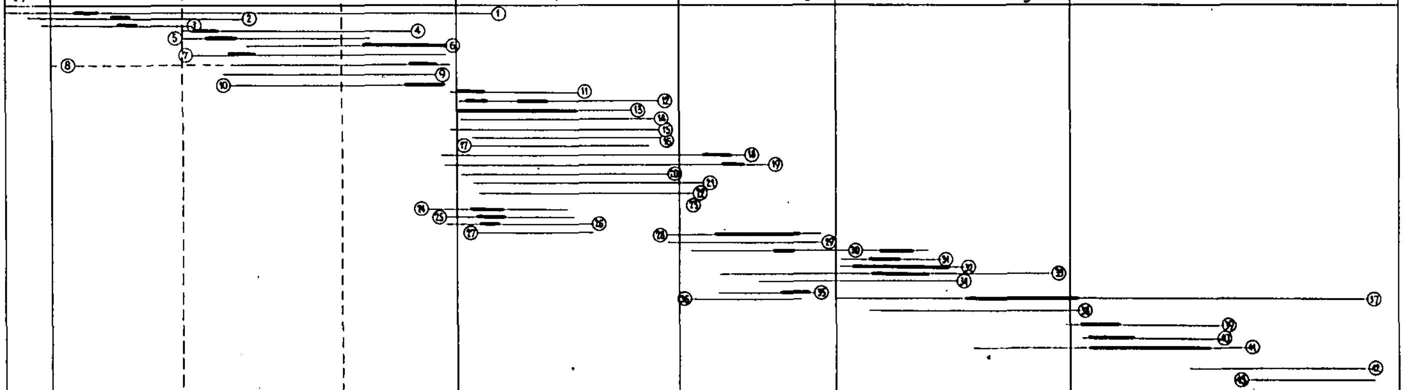
Fig. 3. Presumable correlation of the Pliocene chronotaxons established for the different partial basins.

Based mainly on the authors named in the table, with regard to the publications of EBERSIN, A. G. ET AL. [1966, KOJUMDGIEWA, E. [1971], MACAROVIÇI, N. ET AL. [1966], MARINESCU, F. [1973], MOTAŞ, I.—MARINESCU, F. [1971], PANĂ, J. [1971] and POPOV, N. [1971], too. However, it must be noted that both the names and extentes of the individual unities applied by the Rumanian geologists are nowadays subjected to a nearly perpetual change. For example, after MOTAŞ, I. ET AL. [1973], the Pontian can be divided into Portaferrian and Bosphorian, the Dacian, however, into Getian and Parscovian. It is clear that the sense of all these terms fairly differs from the one in the *Fig. 3*.

The arrows with numbers indicate the time of the temporary communications between the Pannonian and Dacian basin through the Iron Gate *(Porta Ferrea)*. In our opinion this communication took place three times during the Pliocene.

SARMATIAN	EARLY PANNONIAN			LATE PANNONIAN			
	Lower	Middle	Upper	Lower	Middle: Balatonica stage	Middle: Oscillation stage	Upper



	NEAR THE SHORE:				IN MIOHALINE LAKES:	BY LAND AND IN FRESH WATER:	BY LAND:
Melanopsis impressa	Pisidium sp. Congeria sp. Theodoxus sp. Orygoceras sp Melanopsis impressa	Melanopsis fossilis		Melanopsis caryota Dreissena auricularis Congeria rhomboidea Congeria schmidti Limnocardium penslii Phyllocardium complanatum C. ungula caprae	Theodoxus vetraniči Melanopsis fuchsi M. bouéi sturi Limnocard. apertum Viviparus sadleri C. balatonica C. triangularis	Tacheocampylaea doderleini Planorbis confusus Helicigona pontica Radix peregra	Tacheocampylaea doderleini
	INSIDE BASIN:					IN OLIGOHALINE WATER:	IN SHALLOW LAKES AND STREAMS:
	Limnocardium praeponticum Limnocardium plicatiformis	Congeria banatica Paradacna leinzi Paradacna abichi	Congeria czjžeki Paradacna abichi	Limnocardium mayeri		Limnocardium decorum Theodoxus vetraniči Melanopsis fuchsi Congeria neumayri Unio atavus	Viviparus dežmanianus Margaritifera flabellatiformis
	Limy marl Basis conglom.	Clayey and sandy marl	Sand and sandy aleurite	Aleurite Clay and sand	Sand, aleurite	Lignite bearing paludal beds Sand, aleurite	Variegated clay, sand, silt

Fig. 4

of the Lower Pannonian *Congeria balatonica* Horizon. On the other hand, the "white calcareous marl" of the basinal parts of the Great Plain and Southern Transdanubia, which is alternately renged into the Sarmatian of into the Lower Pannonian by different authors, presumably shows continuous deposition between the two stages. JÁMBOR and KORPÁS-HÓDI [1971], on the basis of complex studies of the samples from 123 coring drillings, postulated a break of sedimentation only in the case, when the Lower Pannonian rests on Badenian or older rocks, with the complete absence of the Sarmatian. According to them:

a) Continuous transition can be concluded in the case of offshore sedimentation, i. e. when both the Sarmatian and Lower Pannonian are represented at the boundary by argillaceous marls, which can be separated merely by their different mollusc faunas. On the other hand, the continuity is signified also by the mutational steps of the faunas in the boundary strata.

b) Continuous sedimentation can be concluded when Lower Pannonian strata suggesting deepening (e. g. pearl-gravel, argillaceous marl) rest comformably on the shallow-water Sarmatian coarse limestone. The conclusion can be similar when the stronger agitation of the transgressive water-mass, by means of the removal of the sediments, gives the impression of erosional unconformity. In these cases (on this part of Transdanubia) the degree of the subaqueous erosion can be measured by the help of the dacite-tuff index-layers interbedded to lower part of the Lower Pannonian.

c) Continuous deposition can be, at last, concluded, when the Sarmatian-Lower Pannonian boundary runs within sequences consisting in dense alternation of layers of varied — e. g. draining-lagoonal, brackish, swampy and marine — facies, or within series of terrestrial deposits. To draw the boundary can be maked easier by the disappearance of the *Foraminifera* and the genus *Cardium*, as well as by the appearance of the larger *Ostracoda* and the genus *Limnocardium* in the first case, and by observing the start of a new cycle in the second one.

Despite of the water-freshening which continued from the Badenian onwards, and the observed traces of the Late Sarmatian regression, the Sarmatian (and Lower Pannonian) overlaps the earlier Badenian (and, respectively, Sarmatian) rocks in several Hungarian localities. This phenomenon is mainly the result of that the previous, relatively steady submergence slowed down from the Late Badenian, and the neighbouring floor-blocks moved often in the opposite direction. This fact — together with the process of the filling-in — resulted in the temporary stopping of the water-covering in some places, and in the continuance of that in other ones.

The *boundary problem* of the Sarmatian and Pannonian is independent naturally of the fact that the Sarmatian of Hungary can be correlated to only two *(Volhynian+ +Lower Bessarabian)* of the three stages established by ANDRUSOW [1902] for the Russian Sarmatian [SCHRÉTER 1912, 1941, VITÁLIS 1951, BODA 1959, 1971, JÁMBOR 1971*a*]. Consequently, in the case of continuous deposition, the lower part of the Lower Pannonian corresponds in time to the Kherzonian of the Euxinic basin. This latter, however, can be ranged into the Pliocene all the more, because its fauna differs from that of the lower two ages of the Russian Sarmatian at least as much as from the fauna of the paleogeographically separated Early Pannonian.

Fig. 4. Abundances chronological spans and assemblages of the most important molluscan species in the Pliocene of Hungary.

1. *Melanopsis impressa* KRAUSS. 2. *Orygoceras dentaliforme* BRUSINA. 3. *Limnocardium praeponticum* KRAMB. 4. *Congeria banatica* R. HOERN. 5. *Paradacna lenzi* (R. HOERN.) 6. *Congeria cžjžki* M. HÖRN. 7. *Paradacna abichi* R. HOERN.). 8. *Melanopsis fossilis* MART. ET GMEL. 9. *Congeria partschi* CŽJŽ. 10. *C. subglobosa* R. HOERNES. 11. *C. ungulacaprae* MÜNST. 12. *C. rhomboidea* M. HÖRN. 13. *Dreissena auricularis* FUCHS. 14. *Limnocardium penslii* FUCHS. 15. *L. majeri* M. HÖRN. 16. *Phyllocardium complanatum* (FUCHS). 17. *L. rothi* HAL. 18. *L. apertum* MÜNST. 19. *Micromelania laevis* FUCHS. 20. *Dreissensiomya intermedia* FUCHS. 21. *Melanopsis pygmaea* PARTSCH. 22. *Gyraulus tenuis* (FUCHS). 23. *G. inornatus* (FUCHS). 24. *Limnocardium schmidti* M. HÖRN. 25. *Congeria zagrabiensis* BRUS. 26. *Kaladacna steindachneri* (BRUS.). 27. *Valvata variabilis* FUCHS. 28. *Congeria triangularis* PARTSCH. 29. *C. balatonica* PARTSCH. 30. *Limnocardium decorum* FUCHS. 31. *Congeria neumayri* ANDR. 32. *Viviparus sadleri* PARTSCH. 33. *Melanopsis fuchsi* (HANDM.). 34. *Theodoxus vetraniči* (BRUS.). 35. *Unio atavus* PARTSCH. 36. *Planorbis confusus* SOÓS. 37. *Tachaeocampylaea doderleini* BRUS. 38. *Helicigona pontica* HAL. 39. *Viviparus stricturatus* NEUM. 40. *V. mažuraniči* BRUS. 41. *Margaritifera flabellatiformis* (GRIG.—BREZ.). 42. *Dreisenna polymorpha* PALLAS. 43. *Viviparus dežmanianus* BRUS.

Some geochemical differences between the Sarmatian and Pannonian sediments also appear, namely the $CaCO_3$-content averages 70—75 weight percentage in the former, and 50—60 in the latter [VÖLGYI 1965]. As a local difference, it is emphashized by KLEB [1968, 1971, 1973] that the Lower Pannonian in the western Mecsek Mountains, as compared to the Sarmatian, is characterized by the quantitative decrease of the quarzite and the quantitative increase of the mica and feldspar.

LOWER PANNONIAN

The Lower Pannonian is characterized — besides the dominance of monotonous argillaceous and calcareous marls, siltes and siltstones — by that the sandstone lenses and beds loose their importance. Accordingly, its mollusc and ostracode fauna is also rather monotonous.

The earliest terrestrial vertebrate fauna of the Lower Pannonian occurs within the Monacium which corresponds to the "B" Zone of PAPP [1948—1959*b*]. This fauna that can be seemed a direct descendant of the „Upper Tortonian" ones is known sporadically (from Sopron and Diósd), and is characterized with the lack of *Hipparion* and the presence of *Anchitherium* [KRETZOI 1961, 1969].

The representatives of the second and third faunal waves of the Lower Pannonian vertebrates are unknown in Hungary so far, but these are recorded in Austria, i. e. on the western margin of the Pannonian basin. The second, hitherto unnamed phase, which can be correlated to the *Congeria partschi-* and *C. hörnesi*-bearing "*C*" and "*D*" Zones of PAPP, is characterized — besides of the restriction of the Miocene elements and the invasion of the *Hipparions* — with the survival of certain ancient types (e. g. *Anchitherium, Listriodon* and *Amphicyon;* Gaiselberg: ZAPFE [1948]; Lassnitzhöhe: MOTTL [1955], THENIUS [1959]). The third faunal phase, corresponding to the "*E*" Zone with *Congeria subglobosa*, is suggested by the findings of *Hipparion* around Brunn and Vösendorf, in which the *Anchitherium* and *Listriodon* is yet absent [KRETZOI 1969, p. 182].

The "*B*"—"*E*" beds of the Vösendorf locality has been suggested previously by the present writer, too, as the *neo-stratotype* for the Lower Pannonian [BARTHA 1971*a*, pp. 30—31, 1971*b*]. The only 20 m thick "*A*" Zone here contains still several Sarmatian elements, and the „*F*" Zone belongs to the base of the Upper Pannonian.

The water depth of the Lower Pannonian lake could not have been more than 500 m. This value was obtained by VÖLGYI [1965] using the method of SZEBÉNYI [1955], i. e. taking into account the elevation of surface, the thickness of strata, and the degree and excess of submergence. According to the present writer, it is overcalculated. On the basis of recent analogies, the water was pliohaline.

For *the basin-facies of the Lower Pannonian*, the following lithological subdivisions have been established [KŐRÖSSY 1968]. Because of the intermittent coring this subdivisioning going from above downwards has only a local value:

4. Aleuritic argillaceous marls.
3. Argillaceous marls with intercalating sandstone beds.
2. Lighter- or darker-grey calcareous marls.
1. Coastal basal-conglomerate, which, owing to its geographical position and the temporal displacement of the transgression, does not form either a continuous, or a coeval horizon. But where it occurs, this is the oldest Pannonian rock-type.

On the other hand, a litho- and biostratigraphically well established subdivisioning was elaborated for the tripartite *Lower Pannonian of the southern foreland of the Transdanubian Central Mountains* [JÁMBOR and KORPÁS—HÓDI 1971].

The separation of the grey argillaceous marls of the Lower Horizon from the Sarmatian is enabled lithologically by the basal biotitic dacite-tuff layers, and paleontologically by the small-sized, but highly mutable fossils corresponding to the „Praepontian fauna" of GORJANOVIĆ—KRAMBERGER [1890]. Among the latter ones there is a form, too, which belongs to the group of the Dacian species *Congeria neumayri* ANDR. Because of the possibility of occasional homoeomorphy, this form is referred here provisionally alone as *Congeria* sp. The several small bivalves ranging into the species *Limnocardium praeponticum* KRAMB., *L. plicatiformis* KRAMB. and *L. cekuši* KRAMB. suggest undoubtedly the lowermost horizon of the Pannonian. — The fauna impoverishes in the near-shore facies; besides *Limnocardium* sp. (from the group of the *L. praeponticum*) only some specimens of *Planorbis, Micromelania* and *Hydrobia* occur.

Within the basal part of the basin facies (in some places, e. g. in borehole Csákvár-10), *diatomite beds* also appear, indicating the temporary separation of the sedimentary site [HAJÓS 1971, JÁMBOR 1971*b*].

The Middle Horizon is characterized in the basin facies with *Congeria banatica* R. HOERN., *Paradacna lenzi* R. HOERN. and *Parvidacna laevicostata* WENZ, and in the near-shore facies with *Parvidacna laevicostata* WENZ, with the appearance of *Melanopsis fossilis* MART. ET GMEL. and with the dominance of other species of *Melanopsis (Fig. 4)*.

The Upper Horizon is demonstrated both in the near-shore and basin facies with the dominance of the *Congeria czjzeki* M. HÖRN. As associated rarer elements, *Paradacna lenzi* (R. HOERN.), *P. maorti* (BARABÁS ET STRAUSZ), *Kaladacna steindachneri* (BRUS.), and even some characteristic Upper Pannonian forms (e. g. *L. rothi* HAL., *L. rogenhoferi* BRUS. and *Congeria zagrabiensis* BRUS.) also occur.

The origin of the Lower Pannonian fauna was interpreted by JÁMBOR and KORPÁS-HÓDI [1971] with the transmutation and continuous evolution of the Sarmatian fauna under the new conditions of the Pannonian. On the other hand — according to the view of the present writer — a direct speciation can be expected only at the Sarmatian/Pannonian boundary. One part of the molluscs of the "*L. praeponticum* Horizon" is namely unchanged Sarmatian survivor, indeed (e. g. *Melanopsis impressa* KRAUSS), but the other part is made up of new species, which would have generated by mutation from Sarmatian ancestors. The small-sized, variable representatives of *Limnocardium* in this horizon were originated from the Sarmatian *Cardium obsoletum* and *C. plicatum* already by GORJANOVIĆ—KRAMBERGER [1980] and LŐRENTHEY [1890], too. — But the derivation of the *Congeria banatica* from one of the Miocene species of *Congeria* in Hungary (e. g. from the *C. böckhi*), as well as the derivation of the "Adacna"-type bivalves (*P. lenzi, P. abichi* — dominating within the *C. banatica* Horizon) from the *Limnocardiums* of the "*L. praeponticum* Horizon" is improbable, even by the supposition of pleiotropic mutations. That much less because the species *L. praeponticum, L. plicatiformis* and *L. cekuši* outlive the earliest appearance of the "*Adacna*"-type bivalves, representing in this way a parallel, but shorter, "*dead-end*"-type evolutionary lineage. The contradiction included among the above presented facts can be explained — according to the present writer — by the following reconstruction. After the pre-Pannonian separation, already in the late *L. praeponticum*-time a connection brought about between the Pannonian and Dacian basins, and in this way the Dacian-Euxine-type species *Limnocardium* and *Congeria* would have invaded into the Pannonian basin, and under its favourable conditions, would have been flourished. This connection, which can be expected in the area of the recent Iron Gates is regarded as limited both in space and time. So, either because of this or in consequence of other, hitherto precisely uncharacterized minor environmental differences, the faunas of the two basins did not interchange completely.

Comprehensive stratigraphical and developmental studies about the Lower Pannonian sequence of the Great Plain and Southern Transdanubia are given by STRAUSZ [1941*b*, 1942*a,b*, 1971 and SZÉLES 1968, 1971*a,b*]. But the results of these works are rather different from those of JÁMBOR and KORPÁS-HÓDI [1971]. This can be due — apart from facies differences — to the fact, that the results of the latters are established upon continuously cored drilling samples making mass-investigations and detailed dominance studies possible, while the former authors could rely only on imperfect data of intermittent corings. As far as these latter data show, the *L. praeponticum*-fauna is unrecorded from the Great Plain. The counterparts of the basin-facies of the Lower Pannonian investigated by JÁMBOR and KORPÁS-HÓDI are constructed here by the beds with *C. banaticha* and *P. lenzi*, while those of the near-shore facies by the strata with *C. partschi* and *C. ornithopsis*, respectively.

Conclusively, the correlation between the recently existing three subdivisioning is a task of the future.

Some species of *Silicoplacentina* (Testacea, Thecamoeba) were regarded till now as characteristic forms of the higher Lower Pannonian [KŐVÁRY 1956]. However, according to SZÉLES [1971a], the *S. hungarica* KŐVÁRY appears between 1305 and 1310 m of the borehole *Szank—6*, in the *Dreissena auricularis*-bearing, so-called „transitional beds". This suggests an Upper Pannonian survival of the *Silicoplacentina*, a genus with Lower Pannonian abundance.

UPPER PANNONIAN

The Upper Pannonian sequences — as compared to prevailingly pelitic ones of the Lower Pannonian — are more diversified, and are developed cyclically in the SE foreland of the Transdanubian Central Mountains and in other places, too. These cycles start with coarse sand (occasionally with gravel), then, after repeated alternations of sand, aleurite, clay and clay-marl, end with pelitic rock-types. The four subsequent cycles of the Upper Pannonian of Central-Transdanubia is characterized with the graditional decrease in the average grain-size and the change in the composition of the fossil assemblages too [JÁMBOR and KORPÁS-HÓDI 1971]. Lignite beds and *Arenicola*-burrows are most common in the middle, oscillatory part of the sequence. On the marginal parts the closing members embrace freshwater limestones, terrestrial fossils and occasionally products of basaltic volcanism. For this reason, the characterization of the Upper Pannonian follows separately, by the tree differentiated parts.

Lower part *(C. rhomboidea—D. auricularis—C. ungulacaprae* Horizon*)*

The Lower and Upper Pannonian faunas — at least in the beginning — are markedly different in the quality and quantity of the species and the average size of the forms. The faunal change is rather sharp and immediate. In the borehole *Csákvár-(Lovasberény)-31* the *Congeria cžjžeki* M. HÖRN., dominating between 218,6 and 227,0 m, is replaced between 182,2 and 186,2 m by the *Dreissena auricularis* FUCHS and its attendants. In some places the lower part of the Upper Pannonian is poor in fauna, or unfossiliferous. In other cases such species are registered between the *C. cžjžeki*- and *D. auricularis*-faunas the pioneers of which have been appeared already in the Lower Pannonian, but dominate in the Upper Pannonian (e.g. *L. majeri* M. HÖRN., *L. riegeli* M. HÖRN., *Congeria zagrabiensis* BRUS.). The record of TÓTH [1971. p. 353] on the foreland of the Vértes Mts. showing the mass-occurence of *Dreissena* in 4 km distance off the coeval shore emphasizes the quite-water basin facies of these bivalves. On the other hand, the near-shore facies of the lower Upper Pannonian is indicated by the species *Congeria rhomboidea* M. HÖRN., *C. ungulacaprae* MÜNST. or *L. schmidti* M. HÖRN.

The appearance of the *Congeria rhomboidea*, *Dreissena* and *Dreissensiomya* undoubtedly suggests the new (second) opening of the *Porta Ferrea* [STEVANOVIČ

1951—1971, BARTHA 1971*a*]. But the accompanied transgression was associated with water-shallowing. Despite of the greatest extension the lake expected that time, the maximal depth of the water could have been less than 300 m. The total Late Pannonian submergence of the lake-floor, measured by the sediment thicknesses, was above 1500 m in some part-basins of the Great Plain. These movements resulted in tectonic upthrusting in certain marginal parts of the basin. In the Mecsek Mountains the temporal protraction of these Rhodanic upthurstings also can be traced. Namely these movements affected even the *Congeria rhomboidea*-bearing strata, too, containing a fauna which arrived at the Mecsek area after a certain time, through the *Porta Ferrea*, which had been opened by the first effect of the same ones.

The present writer ranges the 200 to 300 m thick, so-called "*transitional beds*", overlying the typical Lower Pannonian and cut by the *intermittently cored* boreholes of the southern Great Plain, also into the *C. rhomboidea—D. auricaularis* Horizon. The fauna yielded in these beds is constituted — besides some subordinated Lower Pannonian forms, e. g. *Congeria partschi* M. HÖRN., *C. cžjžeki* M. HÖRN. — dominantly by the aberrant varieties of the *Paradacna abichi* R. HOERN. and *P. lenzi* R. HOERN., item by *Kaladacna steindachneri* (BRUS.), *Dreissena auricularis* FUCHS, and other forms all of which has rather an Upper Pannonian character [SZÉLES 1971*a*, pp. 285—322]. The appearance of the new species and mutations is accompanied with considerable changes in the lithofacies [KŐRÖSSY 1971, p. 217], therefore the ranging of this sequence to the Lower Pannonian (loc. cit., p. 322) seems to be unjustified.

In the lower part of the Upper Pannonian the rims of the part-basins around the mountains are marked by zones of the pure quartz-sand formations [SZATMÁRI 1971]. lThese were created post-orogenetically and by repeated redeposition, under specia warm and humid climatic conditions, namely by maximal hydration an maximal outleaching of the decomposed residuum of the crumbly minerals. The derivation of one part of these lower Upper Pannonian sands around the Mecsek Mountains by disintegration and redeposition of older sediments was clearly demonstrated by comparative mineralogical studies of RAVASZ—BARANYAI [in BARTHA 1971*a*, pp. 142—144].

The neostratotype of the lower part of the Upper Pannonian was designated within the profile of the Jászberényi Street brick-yard (Kőbánya, Budapest) [BARTHA 1971*a*, p. 31, and pp. 107—108, 1971*b*; HÓDI 1966]. This is one of the rare localities where both the *C. ungulacaprae* and *C. rhomboidea* occurs in the same section, and the latter only with some metres above the former.

The vertebrate fauna of this interval was described by KRETZOI [1951, 1954, 1969, p. 182], from the Esterházy-(recently Báracháza)-cave of Csákvár (Vértes Mts.). In this biostratotype of the "Csákvárium" there is no more *Anchitherium*, even if the bulk of the species is of Miocene. However, *Hipparion* and *Microstonyx* and several other forms of the *Hipparion*-faunas are also present.

The lower part of the Hungarian Upper Pannonian can be correlated with the "*F*" Horizon of the Vienna basin.

Middle part

The middle part of the Hungarian Upper Pannonian corresponds to the "*C. balatonica-bearing sequence*" s. l. of HALAVÁTS, in which were previously included both the deeper beds yielding *Congeria balatonica* PARTSCH in great number and the overlying, practically "*C. balatonica*-free" lignite measure. The segregation of these two horizons of the sequence was firstly proposed by the present writer [BARTHA

1959*a*, *b*], having recognized their faunal, litho- and biofacial, environmental and paleogeographical differences in regional dimensions. According to him, the lower, "*C. balatonica-bearing Horizon*" of the sequence in question can be characterized, in spite of the very small water-depth, by continuous water-surface, while the upper, "*Oscillatory Horizon*" by disintegration into part-lake sand by repeated swamp-formations. These latters are accompanied with the replacement of *C. balatonica* by *C. neumayri* ANDR. The average size of the specimens, as compared to the maximum observed within the *C. rhomboidea—ungulacaprae* Horizon, decreases upwards, through the *C. balatonica*- and Oscillatory Horizons. Also the distinction between the coastal and basin-facies tends to be hardly separable upwards.

The neostratotype of this part can be designated within the Fehérpart profile of Tihany [BARTHA 1971*a*, p. 31, 1971*b*].

a) The *C. balatonica Horizon* is characterized by the dominance of the *C. balatonica* Partsch, *C. triangularis* PARTSCH and locally (e.g. in Tab) the *Prosodacna vutskitsi* (BRUS.) The drawing of its lower boundary is encumbered in the Tihany standard profile by unoutcropping of the lowermost beds, which are develop from the *C. rhomboidea—ungulacaprea* Horizon. Its upper boundary can be drawn with the first paludal intercalation. The new biostratigraphic characters of this horizon, which resulted in the doubling of the species number and the sudden appearance of the genus *Viviparus* coming from the Dacian basin was interpreted by the present writer [BARTHA 1971*a*] with the newer (i.e. *the third/reopening* of the *Porta Ferrea*).

The terrestrial vertebrate fauna corresponding to the topmost *C. rhomboidea* Horizon and to the *C. balatonica* Horizon is that called by KRETZOI [1965, 1969] as Sümegium. This fauna, in addition to the close resemblance to the SE-European *Hipparion*-fauna, yields several new Mediterranean elements (e.g. "*Pentaglis*", *Progonomys*, *Rotundomys*), as well as the younger species of some older genera.

b) The Oscillatory Horizon is one of the most characteristic and most extended sequence of the Upper Pannonian. It is known and studied — besides the exposures of the Fehérpart of Tihany, the Magaspart of Balatonkenese, the open casts for lignite in the Bükk and Mátra forelands — from several boreholes of Transdanubia and the Great Plain. This, maximally 200 m thick sequence is characterized by light-grey sand and aleurite beds intercalating with dark-brown swamp-muds, lignitic strips and seams. The number of the latters can be in some places as high as 50. It may be that thinner lignite bands occur in the earlier or later members of the Pannonian, too. But the main period of the lignite deposition in Hungary certainly falls into the *C. balatonica—C. triangularis—P. vutskitsi* Horizon, with alternation of more arid and more humid forests in the Mátra foreland [NAGY 1958]. Besides the recent forest trees, the occuring species *Daphnogene cinnamomea* (ROSSM.) KNOBL., *Engelhardtia moeriptera* (BRONG.) ETT. [PÁLFALVY 1952] and *Taxodium* sp. [BÓNA and RUMLI—SZENTAI 1966] suggest a more gentle and humid climate, as compared to that of today. A coeval lignitic deposition was general also on other areas of the Paratethys [JASKÓ 1972*a*, *b*, 1973].

Since this Oscillatory Horizon is characterized by repeated biofacies-variations, it is reasonable to draw its lower boundary at the first paludal, and its upper boundary at the first oligohaline intercalation, respectively. The newer return of the oligohaline fauna can be interpreted exclusively by combination of the process of the lagoonal filling in with crustal movements, which submerged the floors of the adjacent part-basins with temporal phase-delay. In this way the oligohaline water-mass migrated into the basin-parts had sunk previously to greatest depth, while the retardedly submerged, filled-in, or emerged basin-parts became the sites of lignite-forming swamps. This is why the oligohaline beds of the part-basins bordered by faults of N—S or NE—SW direction cannot be correlated precisely. Owing to the at least half-phase difference, a lignitic coal seam corresponds to an oligohaline bed on the opposite side of a fault.

These tilting movements of the basinal floor seems to be proved also by the geoseizmically recognized distribution of the „boundary facies" of the Lower and Upper Pannonian [SZABÓ—KILÉNYI and SZÉNÁS 1971].

The Oscillatory Horizon can be correlated to the top of the "G" and to the "H" Horizon of the Vienna basin. As of the vertebrate fauna, this horizon corresponds to the Hatvanium of KRETZOI [1969], which has a wooded-grasslandfauna with North-Chinese, Siberian and North-Pontian affinity, and is characterized with the appearance of the genus *Cervocerus*.

The topmost, maximally 5 m thick oligohaline bed, which was suggested by the present writer [BARTHA 1971*a*, p. 150] as a well recognizable "guide bed", is characterized usually by the dominance of the species *Theodoxus vetranići* (BRUS.), *T. crenulatus* (KLEIN), *Viviparus sadleri* PARTSCH and *Melanopsis fuchsi* (HANDM.), and the occurence of the species *Congeria neumayri* ANDR., *Limnocardium soósi* BARTHA and *L. vicinum* (FUCHS). On the other hand, at Balatonszentgyörgy also the *Melanopsis bouéi* (PARTSCH) and at Tab the *Prososthenia sepulcralis* (PARTSCH) and *Prosodacna vutskitsi* (BRUS.) occurs in this guide bed, and the faunal elements of the overlying fresh-water beds differ also from the usual ones. However, this can be merely due to the natural slight differences in the process of freshening.

Upper part

The upper part of the Upper Pannonian sequence — the max. thickness of that is as high as 500—600 metres — is constituted either by freshwater (lacustrine, fluvial), or terrestrial sediments (freshwater limestone, coarse fluvial sand and aleurite, variegated clay, etc.). Its fauna consists of *Viviparus, Pisidium, Unio*, etc. Its neostratotype is the Kálvária-hill profile of Várpalota, where the "guide bed" of the Oscillatory Horizon is overlain by *Planorbarius*- and *Tachaeocampylaea*-bearing feshwater limestone wich has a 1,5 m thick intercalation of fluvial sand with "*Unio wetzleri*" (K_2 bed). However, it was recently shown by KROLOPP [in BARTHA 1972], that the species *Unio wetzleri* (DUNKER), which was originally described from the Miocene molass, is not any more represented in the Hungarian Upper Pannonian, and the Pannonian forms confounded with it belong to the East-European species *Margaritifera flabellatiformis* (GRIG.—BEREZ.).

Until recently the molluscs were have been regarded as undiagnostic for the subdivisioning the upper part of the Upper Pannonian. This can be mainly due to the fact, that the stratigraphic ranges (hemerae) of the terrestrial and fresh-water molluscs are rather long, indeed. Among the vertebrates, a fast evolution rate was found only in the family of *Arvicolidae* [KRETZOI 1969]. The established faunal waves are as follows: Baltavárium [KRETZOI 1959*a*], Estramontium [JÁNOSSY 1972], Ruscinium [KRETZOI 1962], Csarnótanum [KRETZOI 1959*b*, 1962, KRETZOI and KROLOPP 1972]. The first who — by considering both the qualitative distinction and the quantitative repartition of species — succeeded in extend the analysis applied on the small vertebrates also to the molluscs, was KROLOPP. The correlation established by him upon molluscs is in good accordance with the small vertebrate stratigraphy [KRETZOI and KROLOPP 1972] E.g. the characteristic elements of the Mindszent Complex, an equivalent of the Csarnótanum on the Great Plain, are — besides the "archaic" arvicolids and *Apodemus dominans* KRETZOI — the *Dreissena polymorpha* PALLAS, an ornamented *Unio* sp., the *Vivaparus dežmanianus* BRUS., *Melanopsis* sp. and the *Tachaeocampylaea doderleini* (BRUS.).

In the outlined indiaction of the directions of ancient rivers concerned the filling-in of the Pannonian Lake are important the micromineralogical studies of MOLNÁR [1965, 1966, 1971]. On the other hand, the recognition of the contemporaneous arid-worm climate was made by LŐRINCZ [1972], on the basis of the investigation of the poor pollen material from the borehole Jászladány—1. (According to this latter author, the dominant genera *Alnus* (29%), *Gingko* (13%) and *Tilia* (12%) were still considerably associated with *Taxodium, Quercus* and *Castanea*).

PROBLEMS AND PROPOSALS

Together with the increase of the boreholes by economic causes, the informations about the sequences enlarge abruptly. However, these informations cannot be compared to the direct lithological and paleontological data supplied through unintermittent corings. Despite of this fact, it is reasonable that several authors attempted to give a lithological subdivisioning, in which the faunal elements yielded by the intermittent corings can be insert [URBANCSEK 1963, KŐRÖSSY 1968, DANK 1965]. However, the effectiveness of a correlation based upon well logging can be satisfactory in the case when the log diagrams of the intermittently cored boreholes are compared with those of the bio- and lithostratigraphically well studied, continuously cored drillings.

A large-scale subdivisioning and correlation can be made also on the basis of *the connate water salinity* of the Pannonian [KORIM 1966]. Namely the Lower Pannonian connate waters contain NaCl, those in the Lower Upper Pannonian contain $NaHCO_3$, and those in the upperpart of the Upper Pannonian $CaMg(HCO_3)_2$, respectively. On the other hand, the salinity of the connate waters is affected — besides the original environmental circumstances — by several external factor, consequently it cannot be regarded as a perfectly reliable ground for subdivisioning.

The Pannonian basin and its appendages extend to 6 different countries, accordingly the view-points of the subdivisioning of their sequences are also diverse. The correlation of the different subdivisions, which can be the ground for a uniform subdivisions, which can be the ground for a uniform interpretation of the sedimentological, environmental and faunal migrational processes, needs international cooperation of uniform standpoints, roughly according to the followings:

1. It would be important to aim at the increase of the number of the reference boreholes coring the entire section of the basin. Besides of the modern study on the materials of these boreholes, it is desirable the most detailed recollection and evaluation of the classic localities.

2. It would be useful to standardize the collection technics of the Hungarian and surrounding basinal parts, on the basis of the modern mass-investigation method. In the case of publication, it would be advisable to give information about the method of the collection and the evaluation of the studied material (e.g. it comes from intermittent or unintermittent coring; the dominance and abundance evaluation is based upon statistical method or merely estimation, etc.), why only numerical data are suitable for comparing.

3. It is most desirable to carry out the up-to-date revision of the species known from the literature as soon as possible. At least the variability limits of teh "basic species"—appearing as well preserved and in a high number of specimens—should be cleared by means of the mass-investigation to get out the nearly immense confusion of specific names at last. The following steps are proposed:

a) within a single bed, to clear the distribution of the species;
b) within a vertical profile of a single locality, to recognize the temporal ranges (hemerae) of the species;
c) in different localities, to separate the geographic craces;
d) in international summary, to take all the view-points into consideration.

The necessity of these works is well demonstrated by the great differences between the present faunal lists of the *C. rhomoidea* and *C. balatonica* Horizons of the Dacian of Rumania and the Upper Pannonian of Hungary. Namely, despite of the fact, that the increase in the species number of the Hungarian horizons can be interpreted only by the connection with the Dacian basin, the number of the common species is low. It is reasonably expected, that an international species-revision, based upon mass-investigations with respect to the whole variability range of the species would be resulted in a surprisingly high number of common species among Hungary and Rumania and Yugoslavia. This is confirmed by the specimens of the *Viviparus leiostraca* BRUS. from Öcs. Namely this species — common also in the Levantian beds of Yugoslavia — should have been ranged — on the basis of mass-investigations [BARTHA 1971*a*, pp. 53—69] — to the variability range of the *Viviparus sadleri* PARTSCH. The forms from Győrszabadhegy and Kisvaszar, which previously were determined as *Viviparus neumayri* BRUS. (common a species of the Rumanian Dacian) can be ranged similarly into the *Viviparus sadleri* PARTSCH. Accordingly, there may be numerous species appearing on the faunal lists of the different countries to-day still under several names which could be unified on the basis of their variability range into a single or few taxons.

On the other hand, it sould be accentuated expressively that the mass-investigation methods cannot be restricted only to the final (i. e. appraising) phase of the studies. Thes methods should be applied also in sampling and collecting. Namely that is the only way to decide wether really homogenous sections are comprehended by our subsequent simplifying reductions.

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