Pannonian

by

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In the Sümeg area, except for the relatively elevated morphological units, the Lower Pannonian is common, being represented by diversified geological features resulting from the once basin-marginal position of the area involved. While studying the facies distribution of the Pannonian formations from Sümeg the features generalizable for the Transdanubian Central Range of the basin margin formations are readily traceable. The relationship between abrasional landforms and abrasional sediments is conspicuous.

The Upper Pannonian is represented by karstic fissure-fill with a rich paleovertebrate fauna—extremely important for terrestrial stratigraphy—occurring on the margin of the Gerinc quarry. Upper Pannonian sediments other than this one are unknown over much of the study area but the Várvölgy basin farther southwest, where the Upper Pannonian attains a couple of tens of metres in thickness. Boreholes located farther away exposed the Somló Formation in 20 to 30 m thickness, represented by argillaceous and sandy silts and fine sands with siltstone. These are underlain, in a thickness of 10 to 20 m, by the Kálla Gravel Formation constituted, for the most part, by well-sorted and well-rounded pebbles made up almost exclusively of quartz and 0.5 cm in diameter. Let us note here that the redeposited sands forming the overburden of the bauxite body in the bauxite opencast pit of Hajnal-hegy has been derived by several students of the study area from Upper Pannonian deposits, but we do not see any evidence that should corroborate this statement.

Lower Pannonian

Exploration history

L. Lóczy (1913) in his Balaton monograph correlated the Pliocene formations of the Sümeg area with the sand and unconsolidated "rustbrown" sandstone beds extending from the Keszthely Mountains as far as Nyirád and, respectively, with clay layers locally observable at an altitude of + 180 to 190 m a.s.l. The traces of abrasion and corrosion that we believe to be of Badenian age and that are observable on the Haraszt and the Csúcsos-hegy as well as the similarly Badenian conglomerates of the Oltár-kövek (Altar Stones) were taken to be products of wave action in Pannonian time.

Similarly to the case of the Balaton Highland and the Somogy Hill Country, he drew the upper boundary of extension of the Pannonian formations at an altitude of + 260 m a.s.l. From this altitude, he mentioned unconsolidated sands from the Szőlő-hegy and coarse conglomerates from the slope of the Csúcsos-hegy, conglomerates which he supposed to occur beneath the sands of the Szőlő-hegy, too. As for the genetic circumstances of the strata exposed in the clay pit of the brick-yard on the Kopasz-hegy and their relation to the rocks of coarser grain size from the neighbourhood, he explained them by the fact that the NW–SE trend of the mountain here turns abruptly W–E and by suggesting that the resulting spur would have caused the currents from the northwest and east that met here to be broken and bend southwards and to deposit first the coarse gravels, then the small gravels and finally the fine sands they had been carrying all the time. In the quiet, non-agitated water not affected by the currents fine-sandy muds would be deposited. On the basis of the fauna collected from the brick yard's clay pit and the Sümeg–Tapolca saddle, respectively, he dated the rocks as Lower Pannonian.

In his summarizing account of the Pannonian sediments, J. Sümeghy (1938) assigned the deposits preserved as deflation and erosion residues in the Sümeg area to among the Pannonian breccias, calcareous conglomerates, slightly cemented limonitic gravels, gravelly sands, whitish-grey sands and sandstones that are traceable in a narrow belt or minor patches along the southwest and southeast margins of the Bakony. On the basis of the fauna listed already by L. Lóczy, he considered these formations to be of Lower Pannonian age.

During his geological investigation of the Sümeg area, R. Hojnos (1943) came to conclude that the sediments of largest extension of the area belonged to the Pannonian-Pontian stage and were observable not only on the level tracts but they were encounterable at higher altitudes as well.

L. Strausz (1952), in his study on Transdanubian gravels examined the roundness of the quartz pebbles. Those on the slope of the Csúcsos-hegy were derived by him from the gravels on top of the hill that he believed to be of Miocene age. He considered of course that the gravels produced by redeposition, together with the Eocene blocks broken off by erosion from the lake-shore and then rapidly buried, were younger than Miocene. The strongly flattened pebbles in the sand pit of Haraszt, now assigned to among the products of Badenian abrasion, were similarly taken to be lacustrine formations.

K. BARNABÁS (1951), in his report on bauxite exploration in the Sümeg area and its extended neighbourhood, took the existence of differences in roundness between the pebbles, as determined by the examination of the pebbles by L. STRAUSZ, to be proved. He ascribed these differences to differential water agitation, but he did not go into particular detail as far as the age of the pebbles was concerned, because, in his opinion, the problem was irrelevant for the geology of bauxites. That the gravel deposits that were not blanketed by limestone had been mostly redeposited by the dynamic action of the Pannonian inland sea, i.e. the emplacement of their bulk had taken place that time was to him a probability, though the role of the Pleistocene events was not negligible either. For this reason, he assigned all gravels and sands and even the silica-cemented conglomerates to the Pannonian, whenever he failed to discover evidence in favour of their being older or younger.

During his lowland mapping work in the study area, A. RÓNAI (1952) postulated an earliest Pliocene transgression that would follow after a terrestrial and lacustrine accumulation period. The gravel and sand beds of the Haraszt were assigned by him to the Lower Pannonian. As for the age of the large limestone and quartz boulders overlying the former, he did not take a stand. The clay and sand beds constituting the Kopasz-domb were regarded as Upper Pannonian and the mechanism responsible for their birth suggested by L. LÓCZY was believed unlikely by him.

J. NOSZKY, in his report on the mapping of 1957, criticized L. STRAUSZ' roundness measurements and K. BARNABÁS' opinion suggesting the irrelevance for bauxite prospecting of an exact distinction between gravel formations of similar character formed in different times. From the ditch at the Tapolca–Nyírád fork, he mentioned an alternation of grey, yellow and variegated, argillaceous and looser yellow, fine-sandy beds which he assigned to the Miocene gravel and sand sequence of the Városi-erdő. The Pannonian beds occupying large areas and showing a diversified pattern in the lower-situated tracts were not specified in terms of an exact dating. The small gravel material from the gravel pits on the northern and eastern slopes of the Vár-hegy were correlated with the conglomerate and coarse-grained sandstone beds with small pebbles underlying the clay deposits on the Kopasz-hegy. He mentions in this context that the limonitic sand bed with small pebbles at the very base of the Pannonian is often very thin, to pinch out completely in some places. The fingertip-like corrasion phenomena observable on the carbonate surfaces were correlated, all without exception, with the Pannonian. The superposition of Miocene and Pannonian coarse-detrital sediments on one another is not mentioned by him.

In 1970, P. JAKUS, mapped the Csabrendek quadrangle lying north of the study area, where Lower Pannonian formations occur over a considerable area, too. As initial member of the Lower Pannonian sedimentary cycle there is here a thin gravel bed overlain, in a considerable thickness, by argillaceous marls and siltstones representing the *Congeria czjzeki* Horizon. The gravel beds traceable along the Sümeg–Csabrendek road Jakus regarded as Pannonian abrasion deposits.

In a summarizing work dedicated to the gravel formations of the Transdanubian Central Range, Á. JÁMBOR and L. KORPÁS (1971) considered the pebbles of the gravel pit by the Sümeg–Csabrendek road to be of Lower Tortonian age—a judgement based on the *Lithodomus* borings they had observed in the underlying rock. Lower Pannonian pebbles were mentioned only from the Tapolca basin as opposed to the Upper Pannonian gravels common in the Tapolca basin, the Devecser basin and on the margin of the Keszthely Mountains.

Á. JÁMBOR (1980), in his summarizing account of the Pannonian in the Central Range, assigned the Pannonian formations known from outcrops and boreholes in the Sümeg area to the Kisbér Pearl-Gravel and the Szák Claymarl Members of the Lower Pannonian Formation.

Situated in the northwest foreland of the Rendeki-hegy and represented throughout its occurrence by pearl-gravels and quartz sands, the Kisbér Member is the product of an abraded shore environment that submerged during the upper third of the Lower Pannonian and that was, as a result of growing water depth, eventually replaced by an environment which deposited inland-sea argillaceous marls.

Extension, mode of superposition and stratigraphic subdivisions

Except for the swells represented by the Rendeki-hegy–Hárs-hegy–Hajnal-hegy and the Vár-hegy and Köves-domb–Mogyorós-domb hill ranges and the Városi-erdő, the Lower Pannonian formations are common to the study area (Fig. 80). Irrespective of some very small outcrops, the Lower Pannonian rocks can be studied in artificial exposures only. They overlie the older rocks underneath, as a rule, subhorizontally with a marked hiatus. Attaining a few tens of metres in thickness, they are overlain by Pleistocene or Holocene formations (Fig. 84).

The Lower Pannonian of the study area includes two lithostratigraphic units. In the monograph of Á. JÁMBOR (1980) dedicated to the Pannonian of the Transdanubian Central Range, the Kisbér Pearl-Gravel and the Szák Claymarl figured as members of the Lower Pannonian Formation.

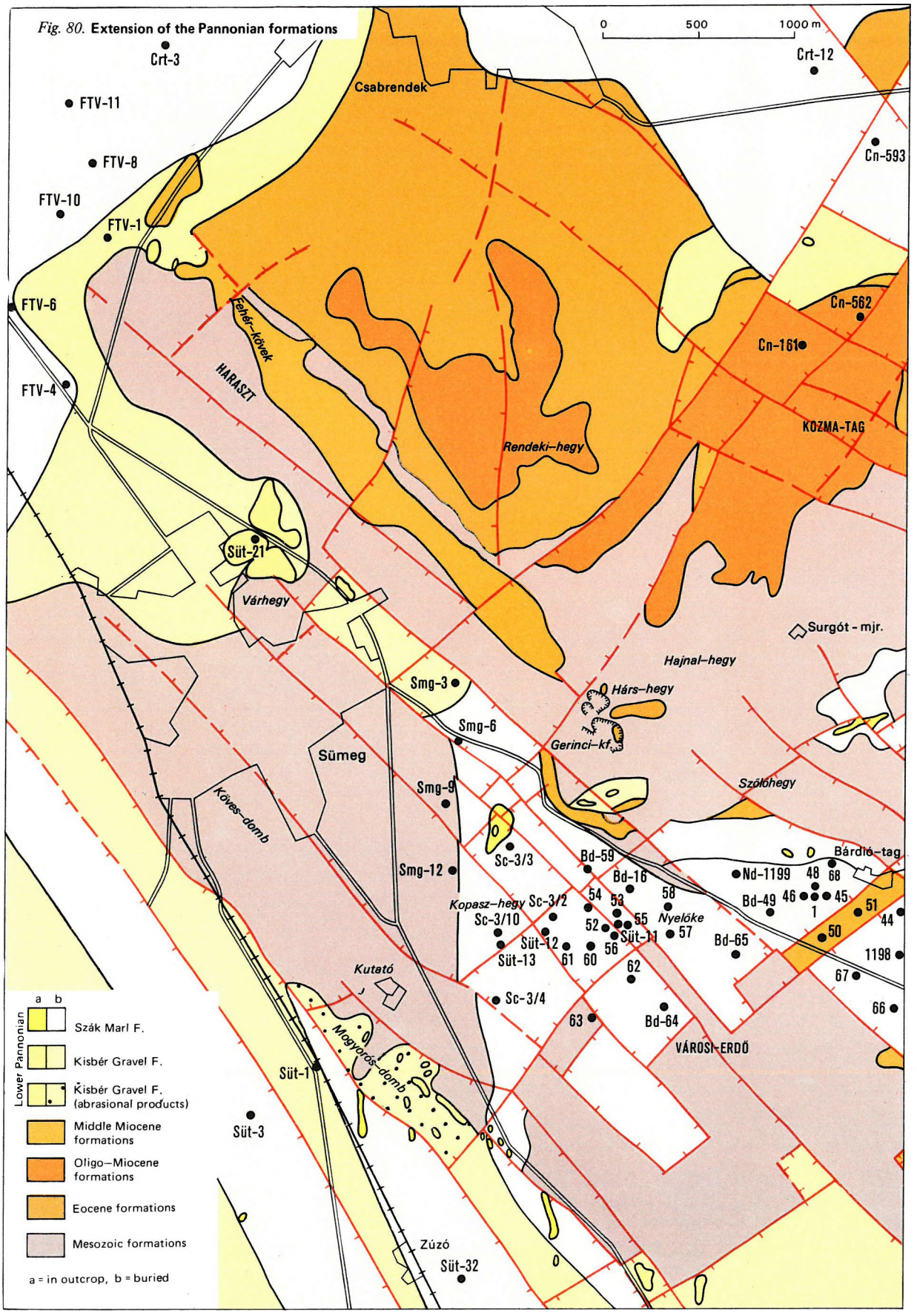
Fig. 80. Extension of the Pannonian formations
0
500
1000 m
Crt-3
Crt-12
FTV-11
Csabrendek
Cn-593
FTV-8
FTV-10
FTV-1
FTV-6
Cn-562
Cn-161
FTV-4
Fehér-kövek
HARASZT
KOZMA-TAG
Rendeki-hegy
Süt-21
Várhegy
Surgót - mjr.
Hajnal-hegy
Smg-3
Hárs-hegy
Smg-6
Gerinci-kf.
Sümeg
Szőlőhegy
Smg-9
Köves-domb
Bárdió-tag
Sc-3/3
Bd-59
Smg-12
Bd-16
Nd-1199
48
68
Kopasz-hegy
Sc-3/2
54
53
58
Bd-49
46
45
Sc-3/10
52
55
Nyelőke
57
51
44
Süt-12
Süt-11
50
Bd-65
Süt-13
61
60
56
1198
Kutató
62
67
Sc-3/4
66
63
Bd-64
VÁROSI-ERDŐ
Mogyorós-domb
Süt-1
Süt-3
Zúzó
Süt-32
Lower Pannonian
a b
Szák Marl F.
Kisbér Gravel F.
Kisbér Gravel F. (abrasional products)
Middle Miocene formations
Oligo–Miocene formations
Eocene formations
Mesozoic formations
a = in outcrop, b = buried

In the table proposed in 1982 by the *Subcommission on Pannonian Stratigraphy of the Stratigraphic Commission of Hungary* the Szák Claymarl and the Kisbér Gravel figure as formation-rank units of the Peremarton Claymarl Group. In this work the official nomenclature has been used. A Kisbér Gravel of special abraded shore facies can be observed in a few m thickness on the slope of the Mogyorós-domb overlying Mesozoic rocks. In our opinion, inasmuch as they occur elsewhere in the distribution area of the formation, these beds should be separated as an independent member of the unit. A typical facies represents the Kisbér Gravel over much of the Lower Pannonian area, the only exception to the rule being the northern subarea, the Kopasz-domb and the southern part of the Nyelőke, where it pinches out gradually. Its thickness is as low as a few m, the maximum (30–35 m) being reached in the western part of the Városi-erdő. Stratigraphically, its overburden is represented by the Szák Claymarl Formation which, in the northern subarea and in a narrow zone on the Kopasz-domb as well as in the northern part of the Nyelőke, is superimposed on the Kisbér Formation, while to the north or to the south of the pinch-out zone of the latter, it overlies Upper Cretaceous or Eocene and Mesozoic or Badenian rocks, respectively, attaining a total of a couple of tens of m in thickness.

Kisbér Formation

Abrasional deposits

On the tectonically controlled southwest margin of the Mogyorós-domb and the southern part of the Köves-domb, the abrasional sediments lie on the abraded surface of different Mesozoic formations (Fig. 80). On the gently sloping hillside representing the one-time rocky coast the abrasional landforms of the rock surface and the abrasional deposits such as abrasional gravels and sandy gravels are observable.

Abrasional landforms of the rocky surface

The abrasional landforms produced by the surfs along the shoreline are still observable on some rocky surfaces even today. Lithology must have played, of course, an important role in the birth of these forms. On surfaces of thin-bedded cherty limestone or radiolarite, respectively, no traces of abrasion are found. On Triassic and mainly on Upper Cretaceous thick-bedded limestones, however, wave action produced smoothed, slightly inclined surfaces, abrasional platforms and also some arched depressions of different size, varying mostly between 5 and 15 cm. These are on the southwest slope of the Köves-domb most suited to observation (Plate LI, Fig. 1).

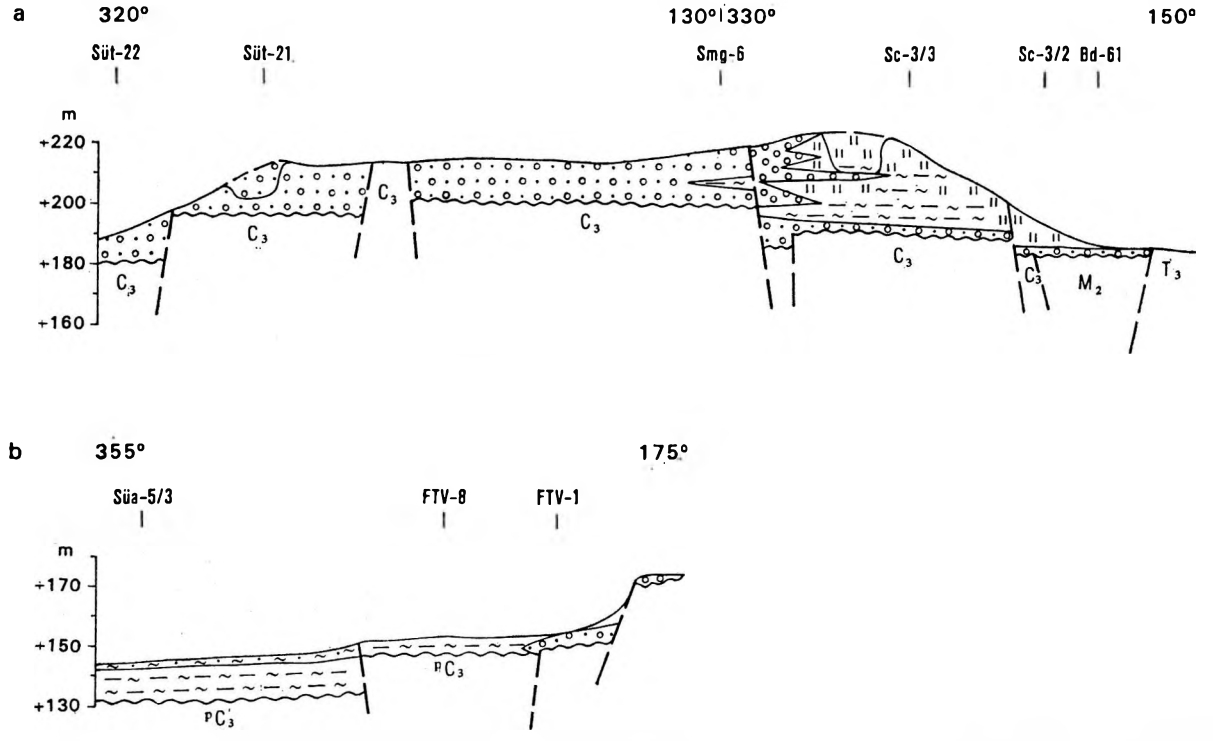

Fig. 81. Profiles presenting the individual facies areas of the Lower Pannonian. (For the explanations, see Fig. 84.)

Rounded surfaces similar to the abrasional landforms of Köves-domb, i.e. abrasional platforms, could be observed a few years ago on the surface of the Ugod Limestone beneath the Gerinc quarry, but they are now hidden by the spoil-heap of the quarry. Corrosion markings occurring, at present, at an altitude of +225 m on the Vár-hegy should also be quoted among the abrasional phenomena, markings probably associated, however, with the Upper Pannonian cycle (Plate LI, Fig. 2).

Abrasional deposits

On the slope of the Mogyorós-domb, at an altitude of 170 to 190 m a.s.l., in a zone of 200 to 300 m width, a course boulder deposit is superimposed on the Mesozoic basement or on a very thin basal sandy gravel bed (Plate LI, Fig. 3, 4). The boulders vary between 0.2 and 0.4 m in size, but they may, in rare cases, attain even 1 to 2 m in diameter. The boulders of smaller size are very well-rounded, entirely globular, even the bigger ones being very well-rounded. The giant pebbles are similarly composed of local rock varieties, i.e. in the southern part of the Mogyorós-domb consisting of Upper Triassic–Lower Liassic limestones only boulders and pebbles of Dachstein Limestone (the variety with chert globules, in the thin section of which *Triasina hantkeni* Majzon was observable, is abundant), Kardosrét Limestone and Hierlatz Limestone occur and, in addition, the boulders of a pink, ammonitic-gastropodal limestone of Pliensbachian age representing a facies unknown from the study area are encountered. In the radiolarite zone, mainly chert pebbles, in the Tithonian to Lower Cretaceous tracts, gravels of biancone facies occur. On the margin of the Köves-domb, a hill made up of Upper Cretaceous rock, in turn, Ugod Limestone boulders are predominant.

To the southwest of the boulder zone—nearer to the one-time basin—the Mesozoic substratum carries very well-rounded (3–4), usually a little flat pebbles measuring 5 to 8 cm in diameter and traceable in a strip of 100 m width. The pebbles agree in lithology with the boulders. On their surface no traces of borer or corroding organisms can be observed.

Farther southwest of the coarse gravel strip, the basement is overlain by sandy gravels showing a close resemblance to the material of the typical exposures of the Kisbér Gravel.

Other, non-abrasional, facies of the Kisbér Formation

The non-abrasional facies of the Kisbér Formation occur over almost the entire area of the Lower Pannonian. Their most typical and thickest occurrence is around the Vár-hegy, to the southwest of which its intertonguing with the Szák Formation is observable (Fig. 81, Profile a).

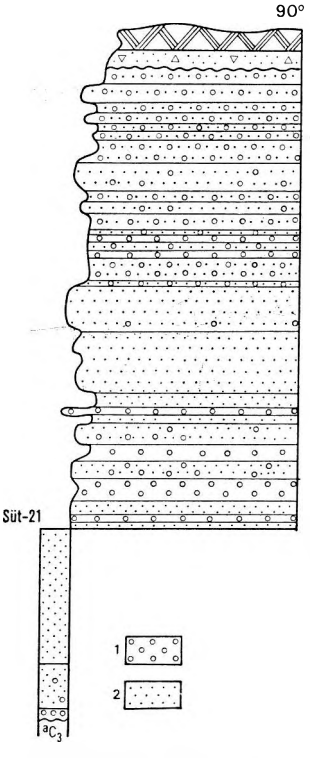

Fig. 82. Section of the Kisbér Formation in the exposure by the Vár-hegy
1. Gravel, 2. sand

The most conspicuous exposures are found in the quarries around the Vár-hegy (Fig. 80, 82). The unit under consideration is underlain, as observed in the borehole Süt-21 spudded in the yard of the quarry to the north of the Vár-hegy, by the Senonian Ajka Formation, while it rests elsewhere on the Polány Formation. Within the 3.5 m interval exposed by the drill, the Senonian beds are overlain by gravels and gravelly sands with pebbles of 0.1 to 1.0 cm size, of varying roundness (1–3), composed of quartz, quartzite and, in lesser measure, of chert. The beds that lie above these and that are represented by gravels, sandy gravels, gravelly sands and, subordinately, by sands are exposed, in a thickness of 8 m, in the quarry face (Plate LII). Higher upwards in the profile the gravels are observed to become prevalent. The pebbles have a size of 0.2 to 3 cm and an average of 0.5 cm. Varying in roundness, they are usually well-rounded, being composed almost exclusively of quartz with a little chert and Mesozoic limestone admixed to it. The sand is generally light grey, predominantly coarse- to medium-grained, subordinately fine-grained, in some places a strong limonitic cementation being observable. Gravel lenses of a couple of cm size are frequent in the sandy beds and even cross-bedding can be observed in some places.

A typical facies represents the unit under consideration in a part of the Haraszt, to the north of the quarries around the Vár-hegy (Plate LIII, Fig. 1) and on the northwest and northeastern slope of the Rendeki-hegy, in a strip of a width of a few hundred m, where, however, it will considerably decrease in thickness as one proceeds northwest- and northeastwards. Overlain by the Szák Claymarl Formation, it appears locally in a strongly sandy facies. To the south of the Vár-hegy quarries, in the neighbourhood of the abrasional formations of Mogyorós-domb and/or to the southwest of the fault bounding the Mogyorós-domb in the southwest the unit is present in a typical facies (Fig. 83, Diagram a), while in the southeastern neighbourhood of the quarries its intertonguing with the Szák Formation can be observed. It is known to be finer-grained

as compared to the typical facies and sandy in the Nyelőke and the Szőlő-hegy subareas and also in the southern part of the Mogyorós-domb as well as on the southwest side of the fault extending on the margin of the Köves-domb.

A few metres of sand with small pebbles at their base that overlie the bauxite on the Hajnal-hegy and in the József II Openwork stripped off in the 1940's seem to have derived by redeposition from a sandy facies of the Kisbér Gravel.

To the north of the mine pits by the Vár-hegy, on the Haraszt, the borehole Süt-22 exposed the unit in a thickness of 6 m represented mainly by gravelly sands and subordinately by sands and argillaceous sands.

On the Haraszt there are a few small patches, along the Sümeg–Csabrendek road (Fig. 83, Diagram b) there is a larger continuous zone in which gravels and sandy gravels are superimposed on the Senonian or, within a small patch, on the Badenian abrasional conglomerate (Plate LIII, Fig. 2–3). In this area the Kisbér Gravel is exposed, in a thickness of 2.5 to 3 m, by a gravel pit (Plate LIV, Fig. 1). At the base of the section there are gravelly sands exposed in a thickness of 35 cm, containing very poorly rounded, locally corroded limestone detritus. This is followed, in a thickness of 1.5 m, by sandy gravels with pebbles of light quartz and black chert material, very poorly rounded, averaging between 0.5 and 0.6 cm and attaining a maximum of 1.5 cm in grain size, less frequently with Eocene detrital material and chert pebbles of greater size. This bed is overlain by a conglomerate of limonitic matrix in which the pebbles are bigger with a maximum of 5–6 cm, being a little more rounded, too. Some poorly rounded Eocene limestone material occurs in this bed, too. Next to follow are limonite-stained gravelly sands presenting a facies similar to their counterparts beneath the conglomerate bed.

Rocks of the unit under consideration were exposed in a strip a couple of hundred m wide to the northwest of the nortwestern foot of the Rendeki-hegy by boreholes spudded by the Surveying and Geotechnique Company and by the survey borehole Crt-3 (Fig. 84). In these, only a few m of gravel and gravelly sand with sporadical *Limnocardium* detritus underlie the Szák Formation.

On the northern slope of the Rendeki-hegy 9 m of sandy gravel are exposed in the wall of a gravel pit of Csabrendek (Fig. 83, Diagram c). The pebbles have a maximum size of 5 cm at the bottom and 3 cm at the top, and an average of 0.5 cm. Their roundness degree is 2, their material is composed mainly of quartz, in lesser measure of lydite (black shale) with an admixture of some Triassic limestone and chert and sporadical metamorphite. Some bigger boulders of 20 to 30 cm size represented by a

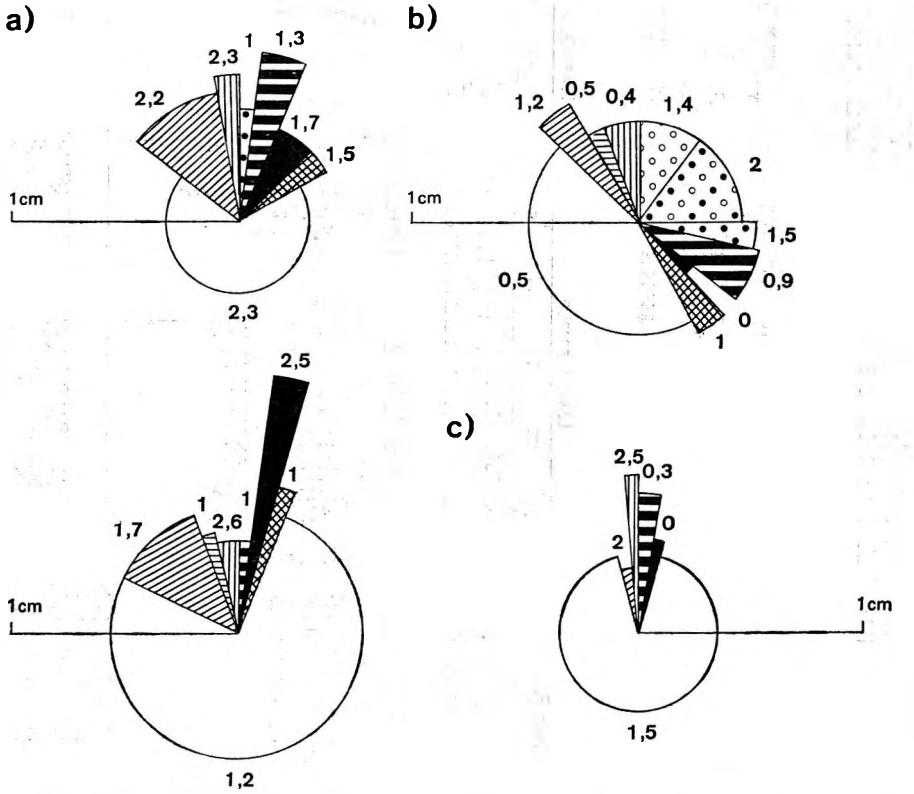

Fig. 83. Composition of the gravels of the Kisbér Formation. (For the explanations, see Fig. 85.)
a) Mogyorós-domb, *b)* along the Sümeg-Csabrendek road, *c)* the quarry at Csabrendek

metamorphic material of Csatka Formation origin also occur in the gravel. The sands are yellowish-grey to ochre-yellow, limonite-banded and medium-grained growing gradually upwards in amount.

A sequence of similar facies can be observed to the NE–E of the afore-mentioned gravel pit, at a distance of 500 to 600 m, close to the road to Nyíres-puszta, in another gravel pit. Here the gravel sequence overlies the Eocene Csabrendek Formation.

Behind the barn facilities of the one-time Csabrendek farming estate the unit under consideration appears in a strongly micaceous sand resembling to the Szák Formation.

On the eastern slope of the Rendeki-hegy, in the quarry devoted to extracting the Ugod Limestone, above the Badenian abrasional beds an alternation of sandy gravels and gravelly sand bands is observable, the pebbles varying between 1 and 2 cm, being poorly rounded.

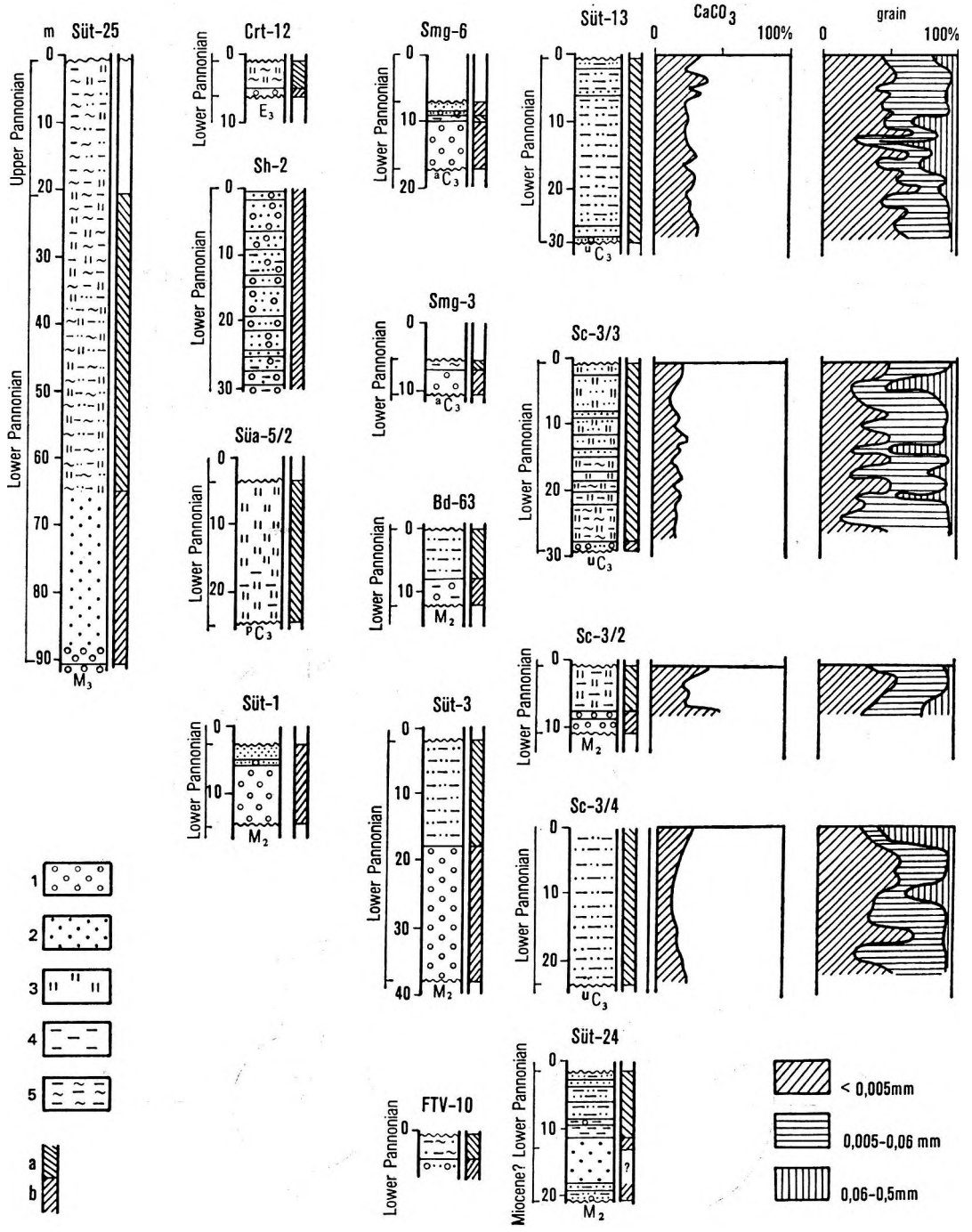

Fig. 84. Lithologic logs of the important boreholes exposing the Lower Cretaceous in the Sümeg area
1. Gravel, 2. sand, 3. siltstone, 4. clay, 5. argillaceous marl. — *a)* Szák Marl Formation, *b)* Kisbér Gravel Fm.

At a distance of 500 m to the northeast of the Kozma-tag, in blocks heaped on the boundary between forest and arable land, a conglomerate with pebbles of 0.5 to 5 cm size and a roundness of 0 to 2 can be recognized. The poor sandy matrix is heavily cemented by limonite. The gravel sheet covering the neighbourhood seems to be composed of material deriving from this conglomerate.

At a distance of 600 to 700 m to the east of the Kozma-tag, gravels composed of quartz, quartzite and, subordinately, lydite (black shale) with a grain size of 0.5 to 1.5 cm and an average of 0.7 to 0.8 cm and a roundness degree of 2 to 3 are observed to occur beneath redeposited Quaternary boulders or a gravel blanket, respectively. In boreholes located in a strip a couple of hundred m wide on the eastern slope of the Rendeki-hegy the thickness of the unit is only a few m, in boreholes farther away it is only a couple of dm, being composed of gravels, gravelly sands and sandstones. The pebble size attains a maximum of 1.5 cm, the constituting material being, for the most part quartz, subordinately lydite (black shale); detritus of *Congeria* and *Limnocardium* occur quite frequently. The unit is overlain here by the Szák Formation.

On the Mogyorós-domb lying south of the type exposures, locally between the abrasional boulders or under them, there are a few dm of poorly or, in some places, strongly cemented, often limonitic, medium to coarse-grained, heavily micaceous sand of calcareous cement. The proportion of the gravels often increase markedly so that the rock is cemented into conglomerate. The pebbles are constituted by well-rounded quartz in the majority of the cases, less frequently by Triassic limestone or Jurassic chert, respectively. In some places, the internal moulds of small gastropods or cavities left over after their dissolution abound. This sandy, gravelly bed of calcareous cement, to the southwest of the abrasional coarse gravel strip on the Mogyorós-domb, is superimposed directly on the Mesozoic. A 20-cm-thick bed exposed in an excavation trench for the exposure of the Kimmeridgian-Tithonian sequence contains, as pointed out by M. Korpás-Hódi, the following fauna: *Theodoxus leobersdorfensis dacicus* J., *Melanopsis* sp., *M. (bouei?)*, *M. (sturi?)*, *Limnocardium* sp. *(? mayeri)*, *L.* sp. *(penslii)*, *Congeria* sp.

In the boreholes (labelled Süt) (Fig. 84) to the west of the fault bounding the Mogyorós-domb in the west, the Kisbér Gravel overlying mainly Badenian formations is represented by 2 to 20 m of gravel, sandy gravel, gravelly sand at the base and sands at the top. Attaining a maximum of 5 cm and an average of 0.5 to 1.0 cm in size and generally well- to fairly-well rounded, the pebbles are made up for the most part of white and grey, subordinately red quartz; lydite (black shale) is abundant, while poorly rounded Mesozoic limestone pebbles are subordinate, metamorphic pebbles may occur in rare cases, too. The sands are fine-grained, slightly cemented by a calcareous matrix. An atypical, finer-grained facies showing a transition to the Szák Claymarl represents the unit under consideration in the southern part of the Mogyorós-domb, in the sand pit by the road (Plate LIV, Fig. 2, 3). In the exposure the contact with the underlying formation cannot be seen. At the base of the exposed section 5 m of light grey, small-grained, locally microlaminated, micaceous sand are observable. This subunit is overlain, in a thickness of 3 m or so, by an ochre-yellow, heavily limonitic sand, strongly reworked at the top. As evidenced by the trench dug above the sand pit, the overburden is represented by the Szák Claymarl, though a continuous superposition cannot be observed. A Kisbér Gravel of similar facies is exposed in the now abandoned quarry on the southwest side of the marginal fault, adjacent to the northern part of the Köves-domb, where a little gravelly coarse sands, strongly cemented in particular bands can be observed. Made up of quartz, the pebbles attain a maximum of 0.5 cm in size, being poorly rounded and containing some very poorly rounded limestone debris fairly often.

One of the most intriguing exposures of the formation is the gravel pit by the Sümeg–Balatonederics road (Fig. 85, Plate LV). In the sequence exposed in a thickness of 8 to 9 m here strongly cross-bedded, coarse- to medium-grained sands alternate cyclically with similarly cross-bedded gravels of 0.3 to 1.0 m thickness composed of pebbles and boulders of varying size. The rock is in some places strongly cemented by a limonitic or calcareous matrix. The grains vary from coarse sand grain size to 20 cm, are very poorly sorted, generally well- or, fairly often, very well-rounded and even flattened in particular cases. They are made up mostly of quartz, subordinately of Jurassic cherty limestone, radiolarite, metamorphic conglomerate, sandstone and mica-schist. One of the cycles of the unit, that of 5 m thickness, beginning with a marked surface of outwash observable in the northern half of the quarry face is shown in Fig. 85. In the vicinity of the quarry, in both eastern and southern directions, the surface is covered over considerable distances by the rock types here observable. The Kisbér Gravel was exposed, in a thickness of several tens of metres, by the sand-exploratory boreholes labelled Sh (Fig. 84) without having reached the underlying formation. The exposed beds in the upper part showed geological features similar to the case of the quarry; in the lower part the clay content was abundant and a red stain appeared in some places.

To the southeast of the Vár-hegy exposures, over a distance of e few hundred metres, the unit was exposed, in a couple of m thickness and in a gravel to gravelly sand facies, by engineering geological boreholes labelled Smg. A characteristic feature of the sequences is the appearance in them of silty argillaceous marl beds of 1 to 2 m thickness belonging to the Szák Formation. In the yard of

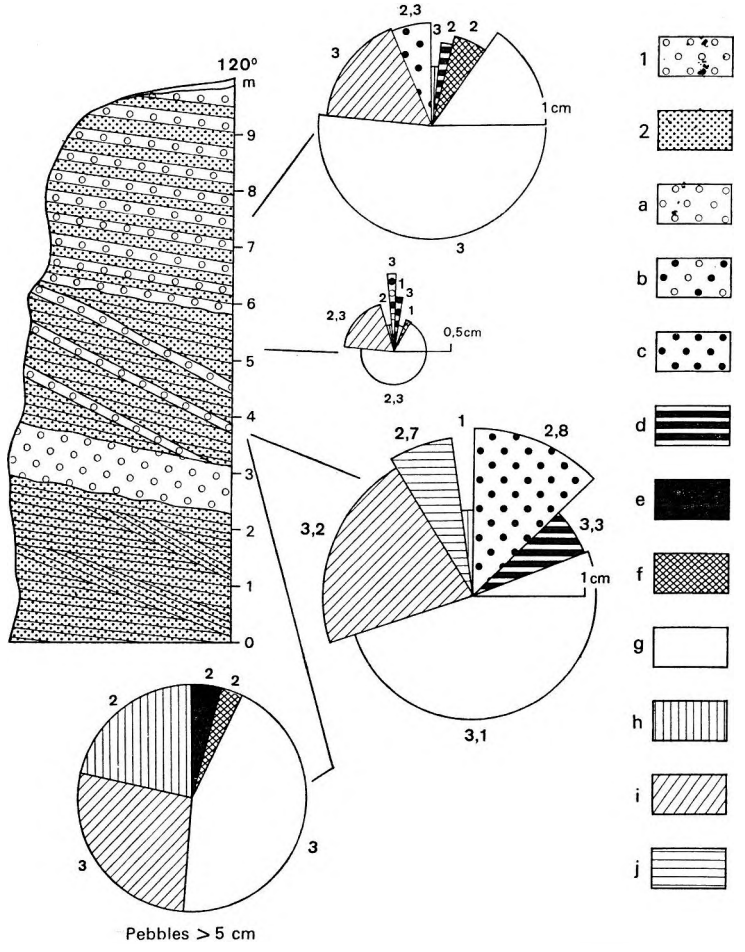

Fig. 85. Section of the Kisbér Formation in the exposure by the Sümeg-Balatonederics road

1. Gravel, 2. sand. — *Lithology of gravels: a)* Cretaceous limestone, *b)* Triassic carbonate, *c)* other limestone, *d)* grey chert, *e)* black chert, *f)* brown chert, *g)* white quartz, *h)* other noncarbonate rock, *i)* black quartzite, *j)* lydite (black shale). — The radius of the circles indicates the grain size of the pebbles: $\frac{a+c+2b}{4}$; fat numerals give pebble roundness according to the RUKHIN scale

the quarry, in the northern part of the Kopasz-domb the Kisbér Formation was explored by us by means of exploratory threnches that exposed it—below the Szák Formation—in a sandy gravel, gravelly sand and gravelly, argillaceous sand facies attaining a maximum of 1 m in thickness. The pebbles are characterized by an average of 0.2 to 0.4 and a maximum of 2 cm in grain size, a roundness degree of 2 to 3, being composed for the most part of light grey, less frequently of dark grey quartz. The pebbles show an upward decrease in amount, and a host of poorly preserved fossil debris is found at the top which M. KORPÁS-HÓDI identified as follows: *Dreissena* sp., *Limnocardium* sp., and *L.* cf. *apertum* (MÜNST.).

The Szák Formation is underlain, in a maximum thickness of 1.5 m, by limonite-cemented small-gravel conglomerate and gravelly, coarse-grained sand, as exposed in the cement-exploratory borehole Sc-3/3 put down near the quarry. The borehole Süt-13 spudded at a distance of 500 m farther south cut, already in a thickness of only 0.5 m, a sandy gravel strongly cemented by limonite in which the amount of the pebbles is 40%, their size varies between 0.5 and 2 cm, their roundness degree is 3 and their material is quartz. This is overlain, in a thickness of nearly 4 m, by yellowish-grey, heavily micaceous, microlaminated, slightly silty, medium- to fine-grained sands underlying the Szák Formation's silty clay beds.

In the light of the lithological logs of bauxite-exploratory drilling performed in the Nyelőke subarea, the Kisbér Formation, if any, is very reduced in thickness beneath the Szák Formation in the study area.

A very interesting sequence was explored in the east, near the road, but still within the Városierdő forest, by the borehole Süt-24, which penetrated it, in a thickness of about 10 m, above the Badenian beds. At the base there are is a gravelly sand layer of modest thickness containing pebbles of 0.1 to 1 cm size and a roundness degree of 2, overlain by medium-grained sands, fairly cemented by a calcareous matrix and locally containing even some gravel. A peculiar feature of the sequence is

its variegated—red, purple-red, ochre-yellow and grey—colour with prevalence of the red colour associated with the argillaceous beds, microlayers and lenses. A micromineralogical analysis of the rock was carried out by M. SALLAY. As determined by her, the rock is made up overwhelmingly of quartz of igneous origin; in addition, only a few plagioclase feldspar grains are observable in the light mineral assemblage. The heavy minerals are scant, only 0.1%, the predominant component being magnetite, for the most part limonitized; tourmaline is frequent; there is some garnet, too, and even hornblende, biotite, chlorite, disthene, crystalline pyrite, epidote, rutile and anthophyllite are sporadically observable. Strata of similar facies were observed in the bauxite-exploratory boreholes put down close to the borehole Süt-24 and in the bauxite openwork of Bárdió-tag as well. These formations may possibly belong to the Kisbér Formation, too, their peculiar structure being due to redeposition of bauxitic rocks from an immediate neighbourhood. It is, however, more likely that these rock types are older than the ones belonging to the formation. Notably, as shown by the results of mineralogical analyses, they correlate with the bentonite of Ódörögd, being overlain in the borehole Süt-24 by a thin bed with gravels including even a flat pebble and assignable probably to a subsequent sedimentary process already.

Szák Claymarl Formation

A typical Szák Formation represented by siltstone and claymarl is known in the north of the study area, where it is generally superimposed directly on the Mesozoic. Another important occurrence is the Nyelőke and the Kopasz-hegy and the southern part of the Mogyorós-domb. Intertongued between beds of the Kisbér Formation it is known to us, in a low thickness, from the area between the Kopasz-domb and the Vár-hegy.

In the southern part of the Mogyorós-domb, in an excavation trench located above the sand pit exposing the beds belonging to the Kisbér Formation, the basal deposit is a grey, argillaceous siltstone stained yellow by limonite which is exposed in a thickness of 0.5 m without its contact with the beds of the sand pit having been discovered. It is overlain by a 3.0 to 3.5 m alternation of sandy argillaceous marls and argillaceous sands with a little prevalence gained upwards by the small-grained, micaceous sands. In the lower, heavily argillaceous interval *Congeria* detritus ground to tiny particles abound.

In the excavation trench located in the quarry at the northern tip of the Kopasz-domb (Fig. 86) there is a continuous transition of rocks of the Kisbér Formation into a greenish-grey, sandy siltstone locally containing even some pebbles from which Á. JÁMBOR identified, upon observation in situ, some poorly preserved fossil detritus as follows: *Orygoceras* sp., *Congeria czjzeki* M. HÖRN., *Limnocardium abichi* and *L. mayeri*.

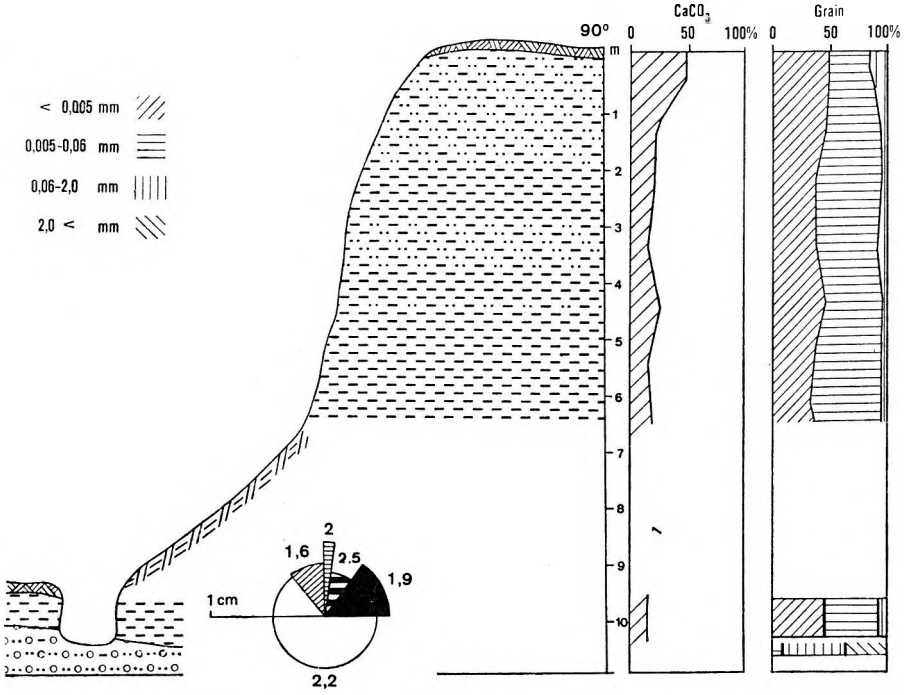

Fig. 86. Section of the Szák Marl Formation in the exposure at the northern end of the Kopasz-domb. (For the diagram illustrating the composition of the gravels, see Fig. 85.)

Next to follow, above a covered interval of 1.5 m thickness, are 8 to 9 m of strongly micaceous, argillaceous siltstone and siltstone-bearing claymarl varying between 15 and 25% in carbonate content. The rock is grey with 2- to 5-cm-thick yellow bands stained at 10 to 15 cm intervals by limonite, It contains sporadical detritus of poorly preserved molluscs.

In the boreholes put down between the Kopasz-domb and the Vár-hegy greyish-yellow to yellowish-brown silty argillaceous marl beds of a few m thickness are interbedded with the gravel, and gravelly sand beds of the Kisbér Formation. In the boreholes located on the Kopasz-domb (Fig. 84) the member overlies a very thin Kisbér Formation or is directly superimposed on the Ugod Limestone, in a thickness of 15 to 25 m. Grey at the base, it is stained yellow by limonite at the top, being constituted by siltstone-bearing, argillaceous marl and argillaceous-marly siltstone. Constituting an average of 10%, the sand content locally increases generally at the expense of the carbonate content On the bedding planes the traces of sand-filled worm-tracks are quite frequent. *Mollusc* debris are rare, only 1 or 2 fragments of *Congeria (? czjzeki)* and *Limnocardium* having come into the fore.

In the borehole Süt-12 put down in the Nyelőke subarea a Szák Formation preserved in only a few m thickness overlies the Ugod Limestone above a limonitic manganese dioxide crust of a thickness of only a few cm, being constituted by siltstone-bearing argillaceous marl, and argillaceous-marly siltstone. In micro-laminae, lenses and bands, fine-grained sands occur in some places. In the bauxite-exploratory boreholes spudded in the Nyelőke subarea the unit shows similar geological features, being approximately 10 m thick in general and superimposed, as pointed out by the relevant descriptions, almost always directly on older—mostly Badenian—formations.

In the eastern part of the study area, the Szák Formation is represented by the lithological log of the borehole Süt-24 in which the unit is 11 m thick and composed of argillaceous-marly siltstones of predominantly grey or, when stained by limonite, light brown colour, with a grain size a little bit coarser as compared to the rocks known from the western part of the area, being locally strikingly sandy and sometimes containing even quartz pebbles of 1 to 2 cm size. The argillaceous beds at the base are variegated—a frequent alternation of ochre-yellow, grey and purple bands of reduced thickness and fluidal structures are observable. At the top, in some places, a lot of poorly preserved, unrounded but weathered shell debris and a few fish teeth are contained in some intervals and such bioclastite lenses can be observed around which a thin interbedded carbonaceous clay layer occurs. As determined by M. Korpás-Hódi, the megafauna consists of the following forms: *Dreissena* sp., *Limnocardium* sp., *Melanopsis* cf. *fuchsi* Handm., *M.* cf. *pygmaea turrita* Handm., *M.* sp., *Pseudoamnicola* cf. *caradiensis* Jek., *Hydrobia* sp., *Micromelania* sp., *Planorbidae* sp. juv. The rock samples examined did not contain any microfossil.

A typical Szák Formation appears in the northern part of the study area. It was the boreholes for the exploration of raw materials for cement put down by the *Geodesic and Geomechanical Company* to the northwest of the Rendeki-hegy and the survey borehole Crt-3 that exposed it above the Kisbér Formation and the Senonian respectively, in a thickness of a few m near the hill with a northward increase up to a maximum (within the study area) of 24 m (Fig. 81 b). At the base, it is composed of grey to greenish-grey argillaceous marls and argillaceous siltstones stained with limonite mottles, containing specimens of *Congeria* and *Limnocardium*. At the top, sandy siltstone occurs in a thickness of a few m. In the sequences above the Kisbér Formation the sand content is characteristic throughout the sequence.

The only surface exposure is the sand pit at the northern foot of the Rendeki-hegy and its vicinity, where a few metres of greenish-grey argillaceous marl interbedded with sand bands of 10 to 15 cm stained by limonite are exposed and an upward increase in the sand content can be observed.

Survey- and bauxite-exploratory drilling on the northeast slope of the hill exposed, superimposed to Eocene rocks, 5 to 10 m of greenish-grey, less frequently limonite-stained argillaceous-marly siltstones that contained, in rare cases, some fine-grained sand, too. In addition, a few debris of *Limnocardium* and *Congeria* were encountered, too. In some boreholes the beds of the Kisbér Formation appear beneath the Szák Claymarl. In the borehole Crt-12, the sequence is heavily sandy, tiny quartz pebbles and Y-shaped worm-track fills being rather common in it.

The material of the boreholes labelled Crt was analyzed for megafossils by M. Korpás-Hódi who (according to data presented in the explanatory to the Csabrendek mapsheet of 1:20,000 scale) determined *Congeria czjzeki* M. Hörn. from Crt-6 and *Congeria* cf. *partschi* and *C.* cf. *czjzeki* from Crt-9.

Bio- and chronostratigraphy

The biostratigraphic scale of the Pannonian in Hungary was earlier based exclusively on the mollusc fauna. In recent years the biostratigraphy based on ostracods and organic microplanktonic fauna has progressed quite considerably.

While monographing the Pannonian in the Transdanubian Central Range, Á. JÁMBOR and M. KORPÁS-HÓDI, in 1976, distinguished seven biostratigraphic horizons. Of these only the *Paradacna abichi–Congeria czjzeki–Congeria zagrabiensis* Horizon can be identified unambiguously in part of the formations in the study area. The beds of the Szák Formation exposed in the extraction face of the quarry of Kopasz-domb and in boreholes put down in the northern subarea are characterized by the species *Limnocardium mayeri* appearing together with *Congeria czjzeki* and *Paradacna (Limnocardium) abichi* as well as by the genus *Orygoceras*. The genera *Dreissena*, *Hydrobia*, *Micromelania* and *Planorbis* occurring in beds belonging to the Szák Formation in the borehole Süt-24, however, are typical, as a rule, of the biostratigraphic horizon or horizons overlying the Czjzeki Horizon (JÁMBOR–KORPÁS-HÓDI 1971). The species of the concurring genus *Melanopsis*, in turn, are encountered both above and below the Czjzeki Horizon.

The *Melanopsis* species appearing in rocks of the Kisbér Formation on the Mogyorós-domb *(M. bouei, M. sturi)* are typical below the Czjzeki Horizon; the *Theodoxus* species that is associated with them, in turn, is conspicuous above this horizon. In the Kisbér Formation beds in the quarry of Kopasz-domb, it is the genus *Dreissena* and the species *Limnocardium apertum* generally characteristic above the Czjzeki Horizon that appear, but they are overlain by the Czjzeki Beds of the Szák Formation. The contradiction between bio- and lithostratigraphic zonation manifested itself in other parts of the Central Range as well (JÁMBOR–KORPÁS-HÓDI 1971).

Probably on account of the sensitivity of the mollusc fauna to facies, the biostratigraphic assignation cannot be solved unequivocally, since the faunal assemblage is not—in the first place—a chronostratigraphic marker but rather a facies indicator.

Palynological studies were performed for the boreholes coded Crt only. On the basis of the results E. HUTTER assigned the beds with *Congeria czjzeki* to palynological Zone B usually correlated with the *C. ungulacaprae* Horizon.

Unfortunately, the exposures from the study area have not been studied either for Ostracoda or for organic planktonic microfossils. The contradictory biostratigraphic data cannot be properly evaluated, unless lithostratigraphy is relied on.

The Szák Foramation can be correlated with the *C. czjzeki* Horizon. The Kisbér Formation underlies it or is intertongued with it in all exposures. Consequently, its rock was formed, for the most part, prior to the formation of the *C. czjzeki* Horizon or simultaneously with the upper reaches of its lower part. The *C. czjzeki* Horizon belongs unambiguously to the upper beds of the lower part of the Pannonian sequence. Its chronostratigraphic assignation is problematic, as the chronostratigraphic scale developed for the Central Paratethys has stipulated only the order of succession of the Pannonian, Pontian, Dacian and Romanian stages between the Sarmatian and the Pleistocene, but it has left their timing still unsolved and since no absolute dating record of the formations involved is so far available.

Paleoenvironment

Prior to the deposition of Pannonian sediments a heavy denudation had taken place which removed the bulk of the Miocene as well. With the subsidence that started at the beginning of the Pannonian, the aquatic sedimentary basin that had continuously been existing to the southwest of the study area started to expand progressively northeastwards. It was in late Early Pannonian time that the 4-km-wide bay which lay in what is now the Mogyorós-domb–Köves-domb–Vár-hegy–Harasztt-Rendeki-hegy–Csúcsos-hegy zone and which penetrated 5 to 6 km deep into the landmass was reached by the transgression. That was the time when the abrasional shores and the abrasional sediments started to evolve. In the coarse-detrital sedimentary material there appear the well-rounded debris of various Mesozoic and/or Eocene rocks making up the neighbourhood. The high degree of roundness of the quartz pebbles too bears witness to their having been redeposited from older detrital sediments, i.e. their abrasional origin. The monotonous composition of the sand-size detritus, their clay mineral content deriving from the weathering of feldspars and the crushed state of the grains are also indicative of redeposition. The strongly crushed brackish-water fossils in the sediment, their being washed into a mixture, is suggestive of heavy wave action. The most typical traces of abrasional activity are preserved on the southeast edge of the one-time bay, in the tectonically-controlled Mogyorós-domb subarea, where the Mesozoic formations set into an upright position were heavily abraded on the surf-stricken rocky shore.

That time on the southeast side of the bay abrasion may have been replaced, over a slightly emerged surface tracts, by sedimentation, and medium-grained detrital sediments started to accumulate in the local sedimentary basins. Some of the bauxite sediment of the immediate vicinity was also washed into these basins which resulted in a variegated banded-mottled pattern of the sediment. As a result of a continued subsidence, with the progress of transgression, the marginal parts of the bay would progressively submerge, and become recipients of fine-grained sediments. In the southeast part of the area, in what is now the Kopasz-domb and the Nyelőke, first an abrasional platform was

formed and then it was inundated too giving rise to the setting-in of sedimentation there. Initially, the rocky shore of Mogyorós-domb still had its effect felt, functioning as a breaker that blocked the surfs and secured virtually quiet-water sedimentation conditions for the hinterland.

Continued progressive subsidence led to a submergence of even the northern tracts that had hitherto been emerging. The Mogyorós-domb, because of the increased water depth, now stopped playing the role of a breaker and a little bit coarser-grained sediment was being deposited even in what is now the Kopasz-domb. Under the circumstances of an open-water, non-agitated, near-shore sedimentation regime that now existed throughout the study area, slightly sandy siltstone and argillaceous marl were being formed. The fauna suggests a brackish-water environment of mio- to mesohaline salinity degree (5 to 15‰). The water depth seems to have been, as a rule, more than 25 m, but it did probably not exceed the 50 m figure. The shallowest water is likely to have occurred in the southern subarea, as suggested by the allochtonous fossil content and the carbonaceous clay intercalations observable in the borehole Süt-24. The deepest part of the basin within the study area then lay to the north of the Rendeki-hegy, where fine-grained sediments were deposited in a comparatively greater thickness. Manifesting itself in the upper part of the preserved sequences, a trend of increase in sand content is either suggestive of the onset of already a new emergence or it indicates merely an oscillation which we are unable to trace or decipher owing to the modest thickness of the sediment preserved.

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