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SOME STRATIGRAPHIC PROBLEMS OF 'MASTODON GRAVELS' IN THE HUNGARIAN GEOLOGICAL LITERATURE

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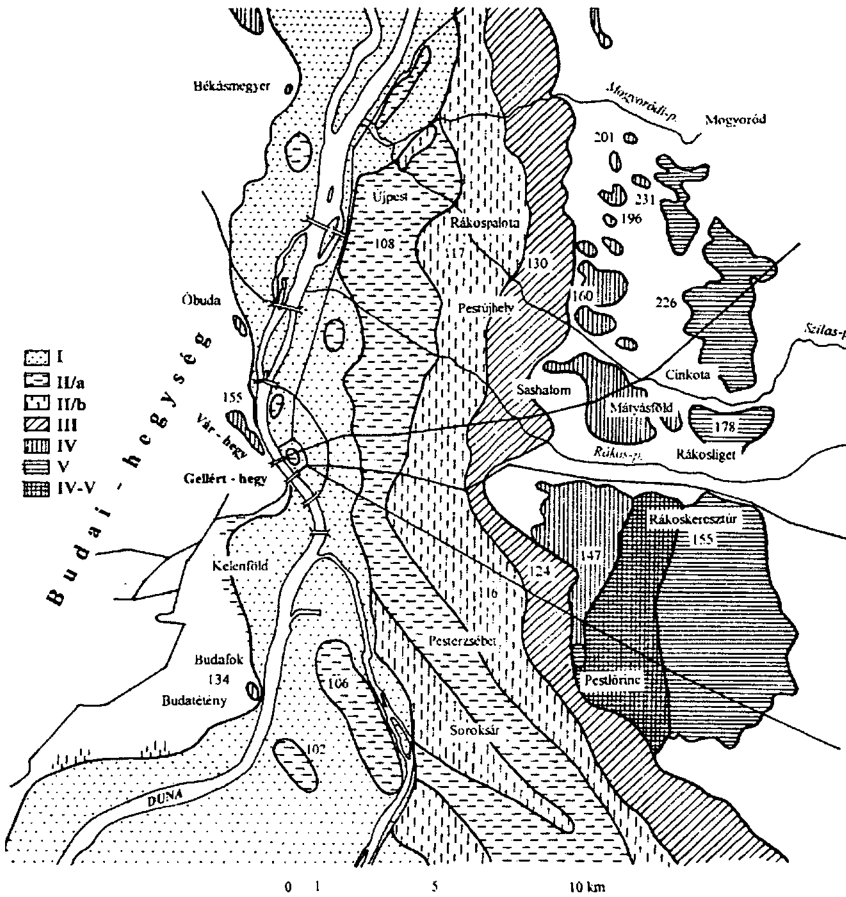
Introduction - aims

The investigation of lose clastic sediments in the vicinity of Budapest has ever been an open issue in the Hungarian geologic–geomorphologic literature. For one and a half centuries a series of researchers have examined the material composition, the formational conditions and the age of the sediment of diverse facies, that was deposited partly under our capital city, and partly in its close vicinity during the latest periods of geologic history.

In spite of the numerous publications on the gravel-bed that is in an uplifted position in the North, and that is claimed to be old, the age and way of its formation is still an unsolved question. These gravels were given several names by the different authors, nevertheless, in the classical geologic literature they are named – after *Halaváts, Gy.* (*1898*) – as "Mastodon gravels" or "Levantian gravels". In recent geologic literature they are mentioned as *Upper Pliocene gravel or Pliocene gravel.* From geomorphologic publications it is known – after *Pécsi, M.* (*1959*) – as Terrace V. Here, in the following it will be called as No.5 gravel-body.

The gravel-body under discussion is the greatest of its kind on the Pesti Plain. It appears on the surface uncovered on the left bank of the Danube in the region of Mogyoród and Kerepes, 250 m above sea level. While widening toward the South its altitude around Csömör, Kistarcsa, Nagytarcsa, and Cinkota decreases to 225 m. Through Rákoskeresztúr, Rákoscsaba, Ferihegy, and Ecser toward Vecsés its surface slopes further, until South of Vecsés, around 130 m, it is already covered by younger sediments (*Pécsi, M. 1959*). Its relative altitude – compared to the 0 point of the Danube at the Lánchíd Bridge: 96,65 m – gradually lessens along the transversal brooks from 150 m to 35 m on a 25 km distance. Its mean slope from the North to the South is 5,7 ‰. In an East-West direction it is practically horizontal. In the region of Mogyoród, Kerepestarcsa and Cinkota it represents two geomorphologic levels, toward the South it gets to the level of neighbouring older and younger formations, and its geomorphologic isolation disappears (*Map 1*).

During the examination of this gravel-body, that is in the highest position from all, in all cases one of the most serious questions of the territory has arisen at once, namely: when did the Ancient Danube – a key factor in the geomorphologic evolution – appear on the territory, and what was its role in landscape evolution? The genetics and the extension of the sediments, that were deposited here in different ways at different times, served as a base for several theories, and are still debated.



Map 1 Alluvial-fan terraces, and delta gravels of the Danube on the Pest Plain (*Pécsi M.* 1996)

I = Holocene flood-plain levels, II/a = Late Pleistocene lower terrace (W), II/b = early Upper Pleistocene higher terrace (R/W), III = Middle Pleistocene terrace (R), IV = older Pleistocene terrace (M), V = gravels of oldest alluvial fans and deltas of the Danube (Pliocen and Upper Miocene), IV –V = delta gravels overlain by the oldest alluvial-fan gravel, 155 = metre above sea level

To overview the abundant knowledge accumulated in connection with the geologic setting, the geomorphologic position, and the evolution of the territory is a difficult task. However, it is far not useless, since the knowledge of the predecessors' results, the gathering and rethinking of their precisely detailed – in many cases irreplaceable – observations are the prerequisites of any further analyses. (*Table 1*)

Contrary to other studies, my aim is not the chronological introduction of the works of different authors, but in order to enable an easier overview, I have separated the features of the "*Mastodon gravel*": mineralogic-petrographic, sedimentologic characteristics, age, and genetics; and I introduce them one by one through the relevant theories and their brief explanations.

Table 1 Summary of the evolution of the theories* of the "Mastodon gravel", based on literature of greater importance (* In the lack of a concrete notion there is a "?" in the table. Concerning age, the difference of former and nowadays divisions must be considered.)

Author	Age	Facies	Origin
Szabó, J. (1858)	Newest Neogene or Lowest Quaterrnary	?	?
Böckh, J. (1872)	Pliocene	?	?
Szabó, J. (1873)	Upper Pliocene or Quaternary	?	?
Salamon, F. (1878)	Beginning of Quaternary	?	Alp-Carp. and Czech-Moravian
Szabó, J. (1879)	Quaternary	?	?
Inkey, B. (1894)	Upper Pliocene	Alluvial deposit	?
Halaváts, Gy. (1895)	Levantian	gravel cone	Danube
Lóczy, L. Sr. (1896)	Levantian	alluvial deposit	?
Halaváts, Gy. (1898)	Levantian	?	?
Böckh, H. (1899)	Levantian, maybe Pontian	debris cone	Danube
Treitz, P. (1903)	Levantian	debris cone	Danube
Cholnoky, J. in Lőrenthey, I. (1904)	Levantian	?	Redeposited from older - product of torrents
Lőrenthey, I. (1906)	Levantian	?	Galga
Cholnoky, J. (1910)	Levantian	debris cone	?
Strömpl, G. (1915)	Levantian	debris cone	Redeposited from Mio. – product of the torrents of Cserhát
Lóczy, L. Sr. (1914)	end of Pontian	debris cone	From NW Carp.s not the Danube
Schafarzik, F. (1918)	Levantian	delta	Danube
Horusitzky, H. (1924)	Levantian	debris cone terrace	Danube
Schafarzik, F. and Vendl, A. (1929)	Levantian	debris cone	Danube
Pávai Vajna, F. (1937-38)	Levantian	alluvial fan terrace	
Bódi, B. (1938)	Levantian	delta	Danube
Kerekes, J. (1939)	Levantian	?	Danube
Bulla, B. (1941)	Levantian	debris cone terrace	Danube
Mottl, M. (1941)	lower part of Upper Pliocene	terrace formation	
Szentes, F. (1949)	Levantian	gravel sheet (terrace)	Danube
Sümeghy, J.(1953)	Levantian	debris cone terrace	Danube
Schréter, Z. (1958)	Upper Pliocene	alluvial fan	Danube
Pécsi, M. (1959)	beginning of Pleistocene (Günz)	alluvial fan terrace	Danube
Urbancsek, J. (1963)	beginning of Quaternary	debris cone	Danube
Moldvay I. et al. (1966)	Lowest Pleistocene	alluvial fan terrace	Danube
Erdélyi, M. (1967)	beginning of Pleistocene	debris cone	Danube
Kretzoi, M. (1981)	Upper Pliocene	?	Danube
Pécsi, M. (1981)	Upper Miocene and Pliocene	delta and alluvial fan terrace	Danube
Szabóné Drubina, M. (1981)	Upper Pliocene	delta	N-NW accumulation redeposited from Miocene
Kretzoi, M.- Pécsi, M. (1982)	from Pliocene (Ruscinium)	delta and alluvial fan terrace	Danube
Kordos, L.-Jaskó S. (1990)	Lower and Middle Pliocene	delta or alluvial fan	Danube
Pécsi, M. (1991)	Pliocene	delta and alluvial fan terrace	Danube
Pécsi, M. (1995)	Upper Miocene and Pliocene	delta and alluvial fan terrace	Danube

The mineralogic-petrographic and sedimentologic characteristics of the No.5 gravel-body.

Regarding the works on the petrography of the gravel-body, the study of *Bódi, B.* (1938) entitled *The petrographic analysis of Tertiary gravels in the vicinity of Budapest, with special respects to Levantian gravel-formations* is outstanding. By summarising previous observations of *Szabó, J.* (1858, 1879), *Böckh, J.* (1872), *Inkey, B.* (1894), *Halaváts, Gy.* (1898), *Lõrenthey, I.* (1904, 1906, 1912), *Schafarzik, F.* (1910, 1918) and that of his, he found that the major components of the gravels are: quartz and quartzite (90-99%), eruptive granite, quartz porphyry and andesite (1-4%), sedimentary limestone, sandstone, arkose, and shale (1-7%), metamorphic gneiss and schist (1-2%). Based on the directions of *Mauritz, B.*, he originated the greenish-chloritic granite, the microcline granite, and the amphibole granite after *Schafarzik, F.* (in *Lóczy, L. Sr.* (1914)) from the area of Ruttka, Passau and Winden, respectively. Aplites, pegmatites and quartz porphyry were eroded from the Western Alps and the Carpathians, while arkose and sandstones from the lower Mediterranean sequence. Consequently, according to him, gravels were transported partly from the Alps and partly from the Carpathians. He claims that the amorphous iron ore that often gives a rusty colour to the gravels' surface is formed during the infiltration of surface waters containing ferriferous solutions.

Szabó, J. (1879) was the first who drew attention to the andesite varieties that occur in the gravel-bed. Based on his own nomenclature, he named them as trachytes. From long ago, andesites were thought to be of Visegrádian type after *Schafarzik, F.* (1910, 1918); *Bódi, B.* (1938) also described them as andesites from the Dunazúg Mountains and the region of Selmecbánya.

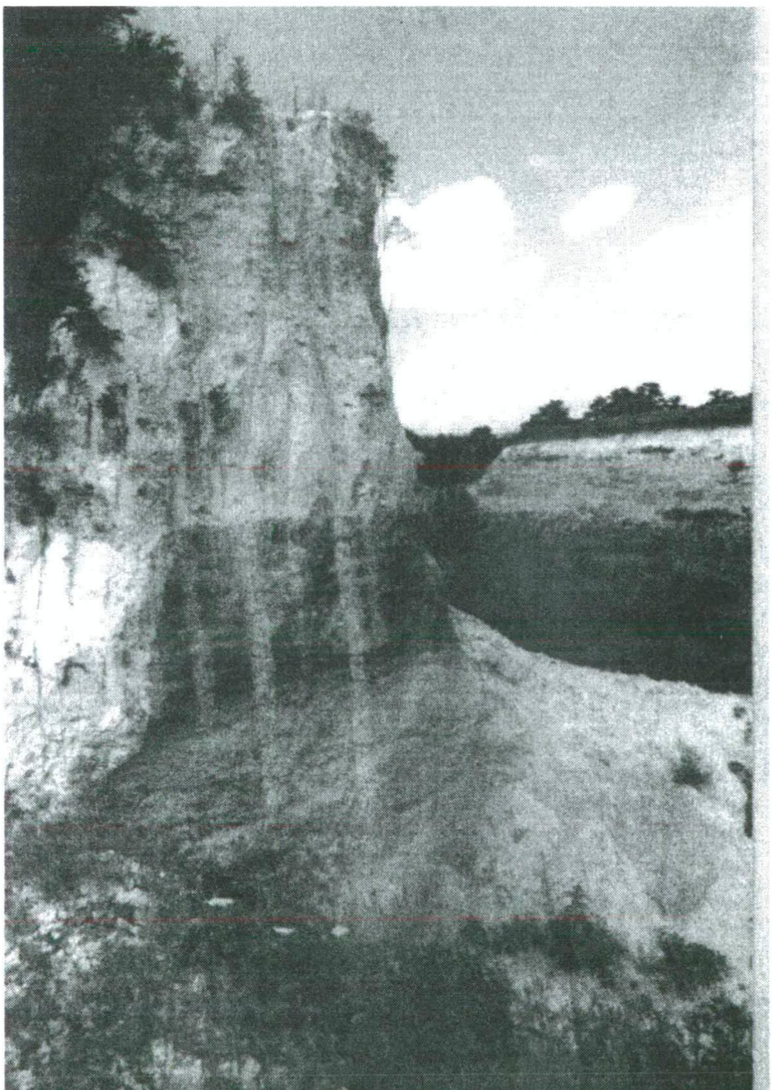
According to the observations of *Pécsi, M.* (1959), from the above mentioned gravel-bed the andesite gravels (he claims that these can be petrographycally separated from younger gravel deposits, that often contain andesite-cobbles, too) are missing, and only andesite or rhyolite *tuff* gravels have larger diameters. The proportion of rhyolite tuff increases toward the South, and contrary to andesite tuff, its altered material is significant in mines North of the Rákos Brook. He also found that gravels of carbonate rocks are very rare in the gravel-body (contrary to younger gravels, where they can be measured in %). He explains this – after *Szádeczky–Kardoss, E.* – with subsequent dissolution.

On the other hand the geologic explanatory notes attached to the 1:10 000 Building Geologic Atlas of Budapest [Budapest Építésföldtani Térképsorozata 1:10 000] (*1981*) – compiled by *Szabóné Dubrina, M.* – reports on andesite-cobbles that join to the base of the gravel deposit, and exceed significantly the local maximum size. Referring to chemical analyses, she emphasises that these mainly amphibole and biotite andesites are not from the region of Visegrád–Nagymaros, but they rather originate from the Miocene vulcanites or redeposited vulcanites of Northeast Pest and the South Cserhát. She assumes that the carbonate rock varieties mainly of Budai Mountains origin are missing because they were not even deposited here.

In his work: *The paleohidrography of the Danube at Budapest* (1918) *Schafarzik, F.* – after *Lóczy, L. Sr.* – gives an account of *"certain silicified nummulitic rocks"* and silicified pieces of wood, that were found among the gravels described as bluish-grey, and were redeposited from the lower Mediterranean sequence. He found these gravels also in the Middle Miocene gravel-bed of Rákosszentmihály (156 m), around Fót (200 m), and on the

Óvári Mountain (327 m) in Nógrád County. The solid form of these silicified pieces of metasomatic limestone of inner Carpathian origin is not known, though, pieces were found at Etyek (*Jaskó, S.* 1939) and in the region of Csömör and Mogyoród, too (*Bartkó, L.* 1939).

The clarifying of the stratigraphic position, origin, and age of the green clay with calcareous concretions *(bentonite)*, that can be found in some places in the gravel's cover, in some places interstratified *(explanatory notice of the 1:10 000 Building Geologic Atlas of Budapest (1981))* may contribute to the solution of problems above. (*Picture 1*).



Picture 1 Bentonite in the cover of the alluvial fan gravel (abandoned gravel mine at Rákoscsaba)

Noszky, J. put this argillic formation, that is at some places 15 m thick, to the *Unio Wetzler* level of the Upper Pannonian (*Noszky J. Sr.*1925). *Pávai Vajna, F.* describes it as the washed up alternation of the calcareous, dried, final product of the fresh watered Pannonian–Pontian inland lake, that diminished under a tropical climate (*Pávai Vajna F.* 1937-38). While, according to *Szentes, F.* (1949), it is the decay of the Middle Rhyolite Tuff that were spread into the sea. The *Geologic explanatory note of the 1:10 000 Building Geologic Atlas of Budapest* (1981) supports also this view. Based on the investigations of *Nemecz, E.*, the above mentioned greenish-grey coloured, plastic, "rich clay" contains Na-montmorillonite, that developed during the fresh water decay of acidic plagioclases, that had originated from redeposited minerals which were capable of hydrolysis among limnic conditions. The most regular forms of such redeposition to a lake are: tuff spreading through the atmosphere, fluvial tuff transportatio, or sedimentation of arkose in the lake (*Nemecz, E.* 1973). We have to notice though that in the same geomorphological position as that of the bentonite, red clay appears (maximum thickness: 14-22 m) in the vicinity of Rákosliget and Ferihegy on the Western edge of the Gödöllöi Hills, too *(Geologic explanatory note of the 1:10 000 Building Geologic Atlas of Budapest,*1981*)*. However, this is not a unique case, since bentonite that is deposited on Upper Pannonian sediments and contains red clay in its cover is widely known in the foreground of the North Hungarian and the Transdanubian Mountains (e.g. open cast lignite mines of Gyöngyösvisonta) (*Pécsi, M.* 1991).

The mean and maximal size of gravels, their sorting and roundness may serve as a starting point in determining the hydraulic conditions of the transporter, the distance of transportation, and the place of the gravels' origin, therefore, several researchers have dealt with these parameters. The size of gravels described by *Schafarzik, F.* (1918) are of walnut, rarely of fist, or exceptionally of head size. Mostly, they have flattened spherical, oval shape. They occur together with sharp fluvial sand, that can be found among gravels or in independent layers – long stretching lenses which in some places are *"cross bedded"*.

According to *Bódi, B.* (1938), 1a -1b, 2a (arkose, sandstone, andesite) and 3b, 4a - 4b (granite, diorite, quartz porphyry, gneiss, quartzite) levels of roundness are the dominant, while that of some quartzes are 1a -1b. Both the granular distribution and the roundness of gravels represent diagrams with two peaks.

Pécsi, M. (1959) examined precisely the morphological features of gravels, as well. He emphasises the sorting of gravels, and he claims that the characteristic diameter is 2 - 4 cm. According to him, there are just a few quartz gravels of fist size, and larger sizes can be reached only by andesite and rhyolite tuff gravels, that are often seem to be quite unrounded. He determined roundness with the CPV method, and on the basis of v, he got 6,4 - 7,1. He assumes that the thickness of the gravel-body is 15 - 30 m, and in his opinion its structure is undisturbed, horizontal. He lays emphasis on the great amount of sand, a part of which was redeposited from older sediments, on the basis of the correspondences of heavy-minerals. He successfully separated a younger, unsorted gravel deposit that covered in some places the old gravel-body. This deposit is probably younger with one generation, it is 1 - 2 m thick, it is irregularly stratified, it also contains cobbles, and it represents a lower geomorphologic level (Terrace IV.) westward from the gravel-body.

Several authors found in the upper layers calcareous deposits, vertical gravels, "*wrinkles*", and funnels that are *"filled with sand and some gravels"* (*Halavúts, Gy.* 1898) (*Picture 2*).

Picture 2 Frost wedge in the gravel mine of the Concrete Road Constructing Company at Kerepestarcsa

Inkey, B. (1894) describes these formations as the results of slow slides, induced by the diluvial elevation of the territory. *Schafarzik, F.* (1918) claims that these formations were the results of ice-pack. According to him, the irregular funnel-shaped gravel-sacks were formed during thawing when ice floes sank into the wet ground. He handled these funnels not as a part of the old body, as former authors did, but as a part of a younger gravel-bed that was separated from the gravel-body by him. *Cholnoky, J.* "*was to claim that they are wadi-like lines on the dried surface of the gravel-body, and they were formed by occasional rains*" (in *Lőrenthey* 1906). *Szádeczky-Kardoss, E.* (1936) and *Kerekes, J.* (1939) are the first who correctly explain these formations as fossil tundra formations. Later *Pécsi, M.* (1962 - printed in 1997) deals with these formations detailed, and assigns a dating role to the multi generational cryo-phenomena.

The age of the No.5 gravel-body at different authors

When determining the age of the gravel-body, the occurring fossils are of the greatest importance. Naturally, in connection with these it is problematic to: decide whether these are of autochtonous or allochtonous type; clarify the range of the groups of living beings; harmonise the different stratigraphic classifications.

There are serious debates on where to draw the borders between stratigraphic subdivisions, the existence of which is questioned in many cases. At present, the Neogene - Quaternary border is either marked with the Olduvai event (1,8 Ma) or the Matuyama / Gauss paleomagnetic change (2,4 Ma) (*Pécsi, M.* 1992). This means a significantly longer period than the former, Milankovic - Bacsák concept with its 600 000 year long *Pleistocene*, though, because of older literatures it must be taken into consideration, too. Within the Neogene, the *Pannonian - Pliocene* (in older literatures Levantian or Upper Pliocene) border is put to 5,6 Ma on the basis of Mammalia fossils (*Jaskó, S.–Kordos, L.* 1990).

Schafarzik, F. (1918) believed that older gravels can be divided further. He claimed that the gravels of the Csömör, Cinkota, Kistarcsa region are as old as *Pontian*, and he separated them from the Levantian or even younger sediments that can be found westward in the Rákoskeresztúr, Pusztaszentlőrinc, Pusztagyál, Alsónémedi region. However, he did not support his idea of separation with any kind of petrographical or paleontological evidences.

According to *Lóczy, L. Sr.*(1914), the gravels of Cinkota are originating from periods "*when desert climate dominated on the present territory of Hungary*". In his opinion, as a result of the "Pannonian desertification", an arid climate characterised the Carpathian Basin and the Mediterraneans at the end of the Pannonian period and the beginning of Pleistocene (*Lóczy, L. Sr.*1918).

The name, "*Mastodon gravel*" was created by *Halaváts, Gy.* in 1898, when on the basis of its typical Mammalia fauna he named the gravel-body like this in his work: *The age of the gravels of the Budapest area* [A Budapest-vidéki kavicsok kora]. He found that on the basis of the remainings of *Mastodon avernensis CROIZ. et JOB.* and the *Mastodon borsoni HAYS* molars, he could believe – after *Fuchs T.* – that the gravels between the Pontian sediments and the blown sand are of Pontian age, but similarly to *Szabó, J.* (1858, 1879) he rather declares that there is a younger than Pontian, *consistent* formation that is of *Levantian* age.

While the idea of *Schafarzik, F.* did not meet with a great response, the later point of view of Halaváts, Gy. was accepted and emphasised by every geologist from the last century on: *Böckh, J.* (1872), *Inkey, B.* (1894), *Böckh, H.* (1899) – according to whom, the sedimentation could start at the end of the Pannonian –, *Lőrenthey, I.* (1904, 1906, 1912), *Horusitzky, H.* (1924, 1933, 1935), *Bódi, B.* (1938), *Pávai Vajna, F.* (1937-1938), *Sümeghy, J.* (1952, 1953), *Szentes, F.* (1949, 1958), *Mauritz B.* (1958), *Schréter, Z.* (1958), *Raincsákné Kosáry, Zs.* (1975), *Szabóné Drubina, M.* (1977), *Kretzoi, M.* (1981), *Jaskó, S.–Kordos, L.* (1990), and by geomorphologists: *Strömpl, J.* (1915), *Bulla, B.* (1934, 1941, 1953), *Kerekes, J.* (1939), and *Kéz, A.* (1933).

The formulation of an alternative point of view, that was popular in geomorphologic literature, is noted for *Pécsi, M.* In his monograph on the Danube (1959) based on his own observations /syngenetic covered cryoturbations/ and accepting the standpoint of paleontologists: *Mottl, M.* (1941) and *Kretzoi, M.* (1953) – who found that the *Mastodon borsoni HAYS* is younger than Levantian –, he put the main period of the gravel-body's formation to the Günz, i.e. the *beginning of Pleistocene.* This point of view was accepted by *Rónai, A.* (1959, 1963, 1972, 1985), *Erdélyi, M.* (1967), *Szûts, S.* (1972), *Scharek, P.* (1974), and this can be detected in the explanatory note of the 1:200 000 Geologic Map of Hungary [Magyarország 1:200 000 földtani térképe] (*Moldvay L. et al.* 1966). In his further works he has improved his idea, lately he supposed that there can be much older (Miocene) gravels than Günz–Pregünz, and their genetics is different, as well. He assumes that these are present not just in an uplifted position but in the normal sequence of the Great Plain, on the gravel plane of uniform height that can be found South of Budapest (*Pécsi, M.* 1991).

It must be added that based on the increasing number of Vertebrata findings, the age of the gravels is possibly Pliocene (*Jaskó, S–Kordos, L.* 1990), however, due to inwash processes, the simultaneity of fossils and gravel deposits is uncertain. The role of the abundant findings – found at Pestlőrinc and Ócsa, in boreholes at Szabadhídvég, Tata: Grébics Mt., Martfű, and Győrújfalu – of *Mollussca* species (e.g. *Potomida sturi*) in dating must be considered and examined, as well (*Jánossy, D.–Krolopp, E.* 1994). The correct classification is made difficult by the fact that the fossil can be transported far even by coarse sediments (16 - 18 km), and its seemingly autochtonous position, due to small injuries, can be misleading (*Boda, J.* 1982).

On the basis of its reversed paleomagnetic position, the age of the formerly introduced green clay with calcareous concretions (*bentonite*) is 3,5 - 5 Ma *(Geomorphologic explanatory note of the 1:10 000 Building Geologic Atlas of Budapest,* 1981*)*. The age of the red clay occurring in some places together with the bentonite is debated: *Pécsi, M.* (*Kretzoi M. – Pécsi M.* 1982) puts the optimum of red clay formation to the Ruscinium, while *Jámbor, Á.* (1997) puts it to the beginning of Lower and Middle Pleistocene.

The genetics of the No.5 gravel-body at different authors

Different ideas have been formulated during the researches not just in connection with the gravel's age but the circumstances of their formation, as well. According to some experts, there was a *delta of a river* of great water output, while others say the formation is an *alluvial fan terrace*. None of the concepts can disregard the Danube as a transporter. According to *Böckh, J.* (1872), under the general diluvial cover the gravel fills a Pontian hollow of North-South axis, and wedges out to the East and to the West. His standpoint fits that general picture that was set most completely by *Cholnoky, J.* (1910) and which claimed that the Danube flowed almost all along the Pleistocene in its present wide valley. As a result of a Levantian fault, in the Late Pleistocene it might already follow its present course, at the western edge of the Hungarian Great Plain. On the contrary, according the concept that was first published by *Salamon, F.* (1878) on the basis of *Szabó, J.*, then was worked out detailed by *Halaváts, Gy.* (1895), *Bulla, B.* (1953, 1964), *Sümeghy, J.* (1952, 1953), the Danube flowed till the early Pleistocene (according to *Sümeghy, J.*, till the Holocene) in a transversal direction toward Kecskemét, then Szeged until its direction was changed to North-South by the Kalocsa depression system. On the basis of this concept, the direction of sediment transportation was north-westerly from the Levantian period (according to later investigations – *Pécsi, M.* 1959 – from the end of Levantian, beginning of Pleistocene)

The most important author of the early researches, *Szabó, J.* (1858, 1879) did not deal with the question of genetics. However, we can get know indirectly his standpoint on the basis of the fact, that the originally historian *Salamon, F.* (1878) several times refers to him as a source. Since, he writes about a river discharging into a lake, we can identify his point of view with the recent delta concept. The uncertainty of the geomorphologic nomenclature is proved by the fact that *Halaváts, Gy.* (1895) mentions a *"lake bottom alluvial fan of a river flowing into a lake"*.

At the turn of the century, while examining the numerous exposures of the gravel mines that satisfied the raw material demand of the expanding capital, *Schafarzik, F.* (1918), who was one of the greatest experts of the gravels of Pest, found that the main transporting and depositing factor was a Danube delta. Nevertheless, *Schafarzik, F.*, one of the most influential geologists at the beginning of the century, mentioned separately the oldest gravels of Csömör, Kistarcsa, and Cinkota which were in the highest position, and similarly to *Lóczy, L. Sr.*(1918) and *Strömpl, G.* (1915) he described them as the products of torrents of the Northern Carpathians.

On the basis of sedimentologic evidences, *Bódi, B.* (1938) explains the gravel formations as the gravely - sandy delta of the Danube. This idea was reinforced mainly by geologist circles. One of the greatest supporters of its influence was the 1:10 000 Building Geologic Atlas of Budapest (1981), that was compiled in the 1970s by several authors, and gives the most detailed summary of Budapest's close to surface geological conditions. In the explanatory notes of the atlas the authors take a stand on the delta origin of the gravel-body, but they emphasise that it is not the product of the Danube. According to them, the extended delta of Levantian age is a redeposited material of older, Miocene coarse clastic sediments and vulcanites. The question is: if not the Danube, then which river did accumulate these sediments here with a NE transport? Their standpoint is partly the approval and the general extension of the formerly mentioned, unreasoned theory of *Schafarzik, F.* (1918), to the whole territory, and partly it is related to the views of *Cholnoky, J.* (in *Lőrenthey* 1904), who claimed that the gravels cannot be of fluvial origin because they are well rounded, and they are rather the products of ephemeral streams. Nevertheless, it is doubtful how could torrents accumulate such a great amount of gravels in some places of 20 m thickness.

According to *Lóczy, L. Sr.*(1896), the horizontal stratigraphy of the gravels at Pestszentlõrinc surely refers to fluvial origin, because "*even if the river is torrent and transports cobbles, when it reaches a standing water it drops its deposit immediately and forms beds with a 25 - 30° dip rather then horizontal ones*". *Böckh, H.* (1899) might introduce the alluvial fan (at that time named as debris cone) expression for the discussed sediments of the Pest Plain after this important observation of *Lóczy, L. Sr.*.The difference in their view is that the former author believes that the alluvial fan is a product of Carpathian rivers, while the later one says it is of Danube origin (*Lóczy, L. Sr.* 1914).

In the geographical literature the alluvial fan terrace theory has been accepted generally. Beside *Kéz, A.* (1933), *Bulla, B.* (1934, 1941, 1953, 1964), *Láng, S.* (1967), some geologists approved it, too – *Horusitzky, H.* (1924, 1933, 1935), *Pávai Vajna, F.* (1937-38), *Szentes, F.* (1949, 1958), *Sümeghy, J.* (1952, 1953) – and put its formation to the Levantian. Because of formerly mentioned reasons, *Pécsi, M.* continued to claim the formation younger, and by emphasising the undisturbed, horizontal stratigraphy of the gravels, he stated that the alluvial fan terrace character of the gravel-body is proved again. *Schréter, Z.* (1958), *Rónai, A.* (1959, 1963, 1972, 1985), *Urbancsek, J.* (1963), *Erdélyi, M.* (1967), *Szûts, S.* (1972), *Scharek, P.* (1974) and *Moldvay l. et al.* (1966) reinforced this idea in their later publications.

In the exposures of the latest gravel mines of the Budapest region (Kistarcsa, Mogyoród) specially cross-bedded, sandy - gravely sediments can be observed in the subjacent formations of the alluvial fan-like gravel-beds. (Picture 3.) According to *Pécsi, M.*, these are old delta formations that are covered in some places by age marker clay with calcareous concretions (bentonite).

Conclusion

In the following I would like to summarise the most important still unsolved questions:

1. The genetics of the sandy - gravely sediments (*Picture 3*) in the subjacent formations of the alluvial fan gravels is uncertain. Recently, *Pécsi, M.* thinks it is possible that the gravel deposits, that are in a higher position and represent a delta structure, at edge of the Gerecse Mts. (Lábatlan - Öreg Mt., Dunaszentmiklós - Új Mt. - Öreg Mt., Köpite Mt. (*Scheuer, Gy.–Schweitzer, F.* 1988)), the gravels located at higher parts of the Pest Plain at Fót, Mogyoród, Kistarcsa, Rákosliget, Pestlőrinc, etc. (*Picture 3.*), and a part of the gravels in the vicinity of Ócsa are of common age and genetics. He assumes that between 5,0 - 2,4 Ma the Danube deposited sandy - gravely delta formations first on the Kisalföld – on which then it built an alluvial fan together with its Carpathian tributaries. Then after leaving the Visegrádi Gorge in the Budapest region, it built up a delta which was later demolished or in some places partly covered by the alluvial fan formation. The mapping, the determination of the stratigraphical position, and age of these formations require detailed further examinations not just at the present places of their occurrence but in the sediments of the Great Plain, where due to the younger covering formations, their extension is unknown.

2. The examination of the age and formational conditions of the green clay with calcareous concretions (bentonite), that can be found in the cover of the "*Mastodon gravel*", has not got appropriate emphasis in previous researches, though, by all means it is a key point in getting acquainted with the landscape development of the territory.

3. It is a matter of debate how and where do continue older sediments in the sequence of the Great Plain, i.e., how can be the data of boreholes crossing the gravel deposits South of Budapest related to the material of foothill exposures. It is imaginable that the gravel formations have more compound genetics and were formed at different times not just at the Pesti Plain's uplifted, higher strata but in their continuations, too, in the sequence of the Great Plain. At the same morphological level as that of young Pleistocene deposits or under them, there can be much older gravel-beds, as it was brought up time to time by authors from early times till nowadays: *Halaváts, Gy.* (1898), *Schafarzik, F.* (1918), *Pávai Vajna, F.* (1937-38), *Szentes, F.* (1949, 1958), *Sümeghy, J.* (1952, 1953), *Rónai, A.* (1959), *Moldvay L. et al.* (1966), *Jánossy, D.–Vörös, I.* (1979), *Jaskó, S.–Kordos, L.* (1990), *Vörös, I.* (1991), *Pécsi, M.* (1995).

As we have seen, the extremely far reaching issue still brings up some unsolved problems. To answer these questions it is essential to know precisely the theories dealing with the geologic–geomorphologic setting of the territory. This summarising work, without intending to be complete, tried to give help to this.

Picture 3 Cross-bedded gravel deposit in the gravel mine of the Concrete Road Constructing Company at Kerepestarcsa

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