Geomorphological environment of boulders and grain-size analysis of gravel sheets in the Southern Börzsöny, Hungary

József Szeberényi[1]

Abstract

Previous authors draw attention to gravel sheets in the south of Börzsöny Mountains, which are not related to Pleistocene gravels of Danube terraces. Two areas were studied: in the south-western and south-eastern parts of the mountains. These pebbles have survived in good condition. Although there are considerable horizontal distance and difference in altitudes between the two gravel sheet locations, the geomorphological and grain-size analyses have resulted in some important conclusions. The geomorphology of the two areas is very similar to each other. The correlational statistical analysis of grain size shows similarity between the samples collected from the occurrences. In the environment of both locations some boulders are found composed of quartzite. They are usually between 20 and 40 cm in diameter, but some of them are of 60 cm size. In the opinion of the author these boulders were very probably transported by floating frozen in ice floes.

Keywords: geomorphology, grain-size analysis, gravel sheets, pebbles, Börzsöny Mountains, Southern Börzsöny

Introduction

Szabó, J. (1872) was the first Hungarian researcher who dealt with cobbles up to 20 cm in diameter. He found boulders in the Mátra Mountains and considered them moraine sediment. Since then numerous studies have appeared on more or less rounded boulders. They occur mostly in the Danube Valley and in the Mátra, but were also found in the Bodrogköz and in the alluvium of the Maros River. They are mostly composed of quartz, andesite, gneiss and other metamorphites. Gravel occurrences in relation to the research of the Börzsöny volcanism and of the Visegrád Gate were mentioned in different studies published during the second third of the 20th century.

In the above mentioned studies gravels observed in the Börzsöny were not put in relation to those of Danube terraces. Former researchers wrote about

[1] Geographical Research Institute Hungarian Academy of Sciences, H-1112 Budaörsi út 45. Budapest Hungary. E-mail: szeber@mtafki.hu

boulders encompassed by these sediments as large as a „*head*" or a „*chair*". Nowadays these gravel sheets appear in patches isolated from each other by the terrain in certain parts of Southern Börzsöny *(Figure 1).* The dilemma is whether to distinguish between them in respect to their origin or to consider as remnants of fluvial deposits of one ancient river. In every deposit there are some large size gravels, generally between 25 and 40 cm in diameter, but in many cases well rounded quartz and quarzite boulders more than half meter in diameter can also be found. These gigantic boulders are meant to be a common feature between the isolated gravel deposits of the Southern Börzsöny.

The discipline of geomorphology examines these sediments with terrain analysis of their environs. The gravels investigated in this study were already mentioned in former articles as we will see in the chapter on history of research. Attempts were made to determine the origin and the place of provenance of gravels, but thorough terrain and geomorphological analysis of their environs have not been carried out yet. Hence in this study an analysis was to be performed from this point of view. The location of pebbles and boulders mentioned in former studies were visited and the database became expanded with new occurrences.

The history of research on boulders in the Börzsöny Mountains

Papp, F. (1933) described pebbles in the western part of the Southern Börzsöny (in the Sas Hill side and on the Koppány Saddle). He held that these gravels are older than the volcanism but did not refer to any boulders. Ferenczi I. (1935) was the first who wrote about the gravel sheets on the eastern side of the Börzsöny. They were brought into connection with ancient pebbles near Vác and Pestszentlőrinc, based on similar composition and „*roughness*". In his opinion the ancient Ipoly running along the eastern side of the Börzsöny, carried these pebbles from the Vepor Mountains (part of the Northwestern Carpathians in Slovakia) during the Late Pliocene and Early Pleistocene. He paid special attention to the boulders near Nógrád described as "yellowish brown" and as big as a "head" or a "chock".

Láng, S. (1952) wrote a comprehensive study about the geomorphology of the Börzsöny. He dealt in details with gravels found at the eastern margin of the mountains. During his research he found lots of new occurrences and plotted them on a summary map. He standardized the origin and accumulation of the pebbles around the mountains. He could not accept Papp's opinion on their genesis preceding volcanism. His stance was similar to that of Ferenczi I. instead: gravels are younger than the volcanism and they were transported by ancient rivers in the Late Pliocene. Láng, S. came across some reworked gravels in the south-western Börzsöny, and he amended Papp's work accordingly. The

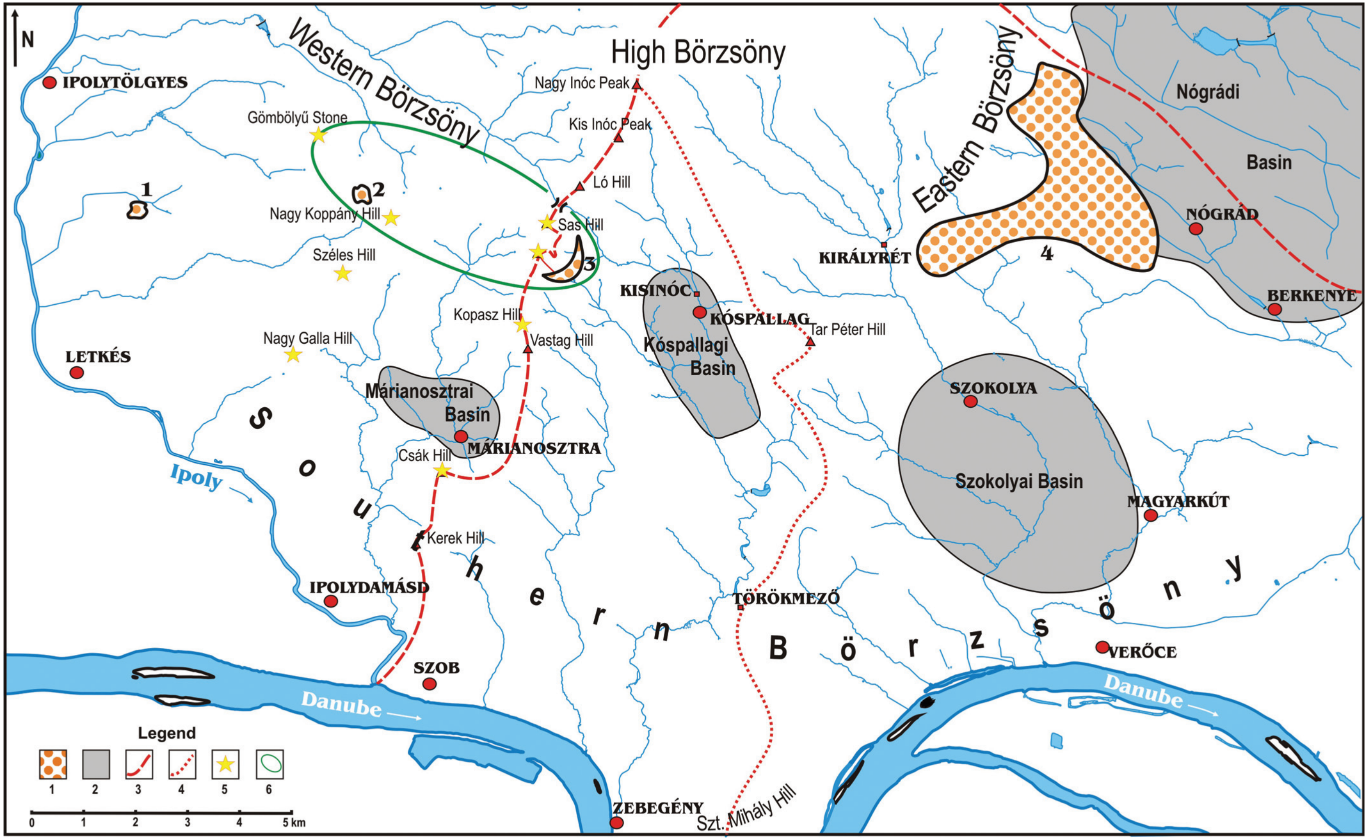

Fig. 1. Important gravel sheet occurrences in Southern Börzsöny. – 1 = Important gravel sheets; 2 = Basins; 3 = Primary drainage divide (Danube/Ipoly); 4 = Secondary drainage divide; 5 = Ancient volcanic explosion center; 6 = Headwaters of streams in south-western Börzsöny. This area is shown enlarged on *Figure 2*

gravel sheet on Koppány Saddle superimposing andesite rocks with a thickness of 2–3 meter was found very important. Characterizing the pebbles on the Sas Hill side and in the valley of Ló-hegyi Stream Láng, S. wrote: „*Grain size is varied, every size occurs in diameter between 1 and 50 cm. There are many boulders as large as the childhead or a chair.*" He agreed with Ferenczi's opinion, the gravels in south-eastern Börzsöny were transported by the ancient Ipoly, but he thought the pebbles at Pestszentlőrinc were probably transported by the Danube.

Vadász, E. (1953) studied the gravels in south-eastern Börzsöny near Nógrád, but he concentrated mostly on dreikanters. In his opinion these sediments are „*reworked tuffy gravel, terrestrial conglomerates mixed with coarse sand, which were deposited in the Sarmatian, after Tortonian (Badenian) andesite volcanism*". He believed that this pebble was transported by an ancient river in Sarmatian-Pannonian, from a Mesozoic mountain, located north of Börzsöny Mountains. The dreikanters formed from these pebbles in Würm. The author noticed some large sized boulders. He wrote about them: „*their size is between fist and half a meter in diameter*". This statement corresponds with those having been made by former authors.

Jankovich, I. and Hála, J. (1972) found an outcrop during the geological mapping located south-east of Ipolytölgyes and it shows the relations of settlement between Leitha limestone and the volcanic rocks. Authors commented: „*as it can be seen the Leitha limestone is underlain by pyroclastic rocks. There are also some andesite and quartzite boulders directly under the limestone in the agglomerate cemented by tuff. These quartzite boulders are as large as a head*". Based on the description of this outcrop it can be stated that these boulders deposited in a period between the volcanism and the Badenian transgression. We know this occurrence only from references, so we cannot decide, if there is any kinship between these boulders and those found in the mountains. In any case the approximate position of this outcrop was plotted on our map *(Figure 1, symbol 1).*

Vargáné Máthé, K. (1975–1976) dealt with pebbles found along the eastern margin of Börzsöny when she participated in the geological mapping of the mountains. She believed that the gravels were deposited during the Oligocene and Early Miocene. Accordingly these pebbles were transported from Vepor rocks, which were uplifted northward from Börzsöny Hills until the Middle Miocene. She referred to the works of Wein Gy. This standpoint is in agreement with the concepts of Ferenczi, I. 1935. and Vadász. It is surprising, that Vargáné has not mentioned boulders near Nógrád in her study.

Drainage network and basic morphology of Southern Börzsöny

Drainage network and basic morphology of Southern Börzsöny have developed since the Late Pliocene, after the Danube appeared in the Visegrád Gate.

The drainage network of the western part changed with the appearance of Ipoly River in the Pliocene *(Figure 1).* The first drainage divide is running along the border between the drainage basins of the two rivers. It starts from the mouth of Ipoly, and stretches then through Csák Hill–Sas Hill–Nagy-Inóc Peak to High Börzsöny. There it turns south-east and proceeds near Nógrád and Berkenye to the Nógrádi Basin.

The drainage pattern of the area has always been controlled by the Danube and Ipoly rivers, but it was modified significantly by the small basins of Börzsöny. The uplift of Börzsöny Mountains has been accelerating since Late Pliocene. Parallel with the general uplift there is an ongoing subsidence of small basins, but the latter is slower than the rate of downcutting of Danube. Therefore the streams running to Danube, cannot build debris cones or only accumulate those of small size. Streams are downcutting persistently thus having shaped the hilly surface of small basins. The section Csák Hill–Sas Hill of the primary drainage divide separates from each other the Márianosztrai Basin and the Kóspallagi Basin. A secondary drainage divide separates the Kóspallagi Basin and the Szokolyai Basin. It starts from Nagy-Inóc Peak and runs through Tar Péter Hill and Törökmező to Szt. Mihály Hill.

In the course of a geomorphological analysis of the areas of gravels of Southern Börzsöny, they were divided into two parts. The western occurrences of pebbles are on the boundary of High Börzsöny, Western Börzsöny and Southern Börzsöny. The gravel sheets are found on the hillsides. They have been raised up to 440–450 m above sea level by the general uplift of Börzsöny. The eastern part of the area of pebbles marks the boundary of High Börzsöny, Eastern Börzsöny, Southern Börzsöny and Nógrádi Basin. There are gravel sheets near the margin of the basin. They are located at altitudes between 290 and 310 m a.s.l. due to the uplift *(Figure 1).*

In both places some lag surfaces can be found on the valley sides. These are relics of an ancient plain that used to surround the mountains, and later it was dissected by the current drainage network. So the traces of ancient river valleys can be sought by geomorphology. In geomorphological and topographic considerations a secondary drainage divide was chosen as the border between the southwestern and southeastern locations. This boundary lies along the crest connecting Nagy-Inóc Peak–Törökmező–Szt. Mihály Hill.

Geomorphology of the environs of the gravel sheets in south-western Börzsöny

The geomorphology of south-western Börzsöny was determined mostly by channel erosion. It is interesting that the surface drainage network of this area is not controlled by through streams of High Börzsöny, but there is an independent local headwater. This is on the boundary of High Börzsöny, Western Börzsöny and Southern Börzsöny, in the vicinity of the Só Hill, Sas Hill and of a ridge starting from these hills and stretching along the crest of Nagy Gyertyános Hill–Nagy Koppány Hill–Kis Koppány Hill–Gömölyű Stone *(figures 2* and *3).*

The headwaters were developed by the unique drainage network of south-western Börzsöny. The base level of erosion forms a semicircle that follows the pattern of Danube and Ipoly rivers *(Figure 1).* The backward erosion of valleys running from the base level of erosion and converging upstream is confined to the radiuses of the semicircle. In this way a narrowing area of headwaters has been developing by the backward erosion in the course of the ongoing landform evolution. The general direction of channel erosion is shown with black arrows in the *Figure 2.* Quite logically, the backward erosion hit last these headwaters in the south-western Börzsöny, so the area was fractured least of all. In order to search some information about geomorphology of south-western Börzsöny prior to the formation of present-day drainage network, a study of these headwaters were needed. During scrutiny of headwaters there could be found two gravel sheets *(figures 2* and *3)* on andesite rocks, which are definitely fluvial deposits of an ancient river. There are some kilometers between the two occurrences, but both are on lag surfaces, at an altitude of 440–450 m a.s.l.

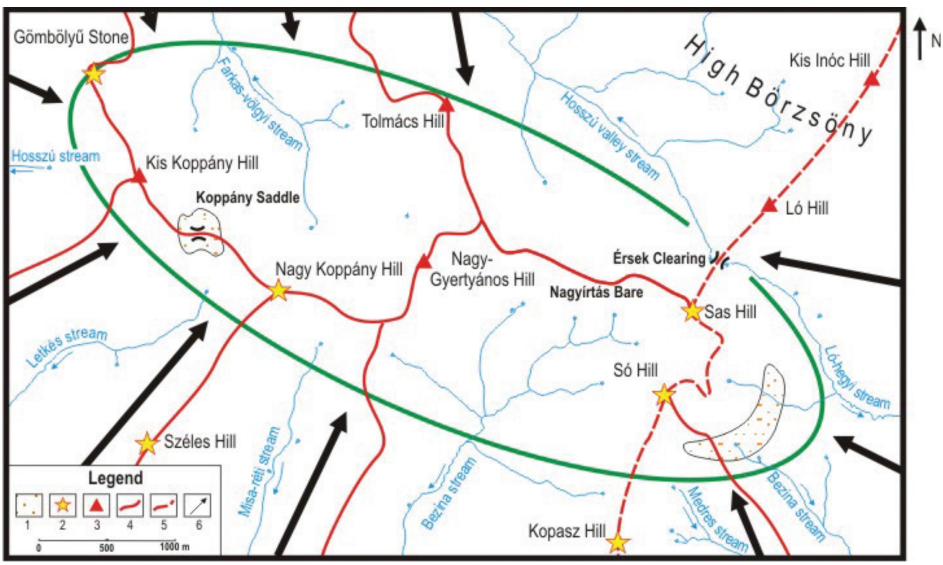

Fig. 2. The headwaters of south-western Börzsöny. – 1 = Important gravel occurrences; 2 = Ancient volcanic explosion center; 3 = Other hilltop; 4 = Secondary drainage divide; 5 = Primary drainage divide (Danube/Ipoly); 6 = General direction of backward erosion

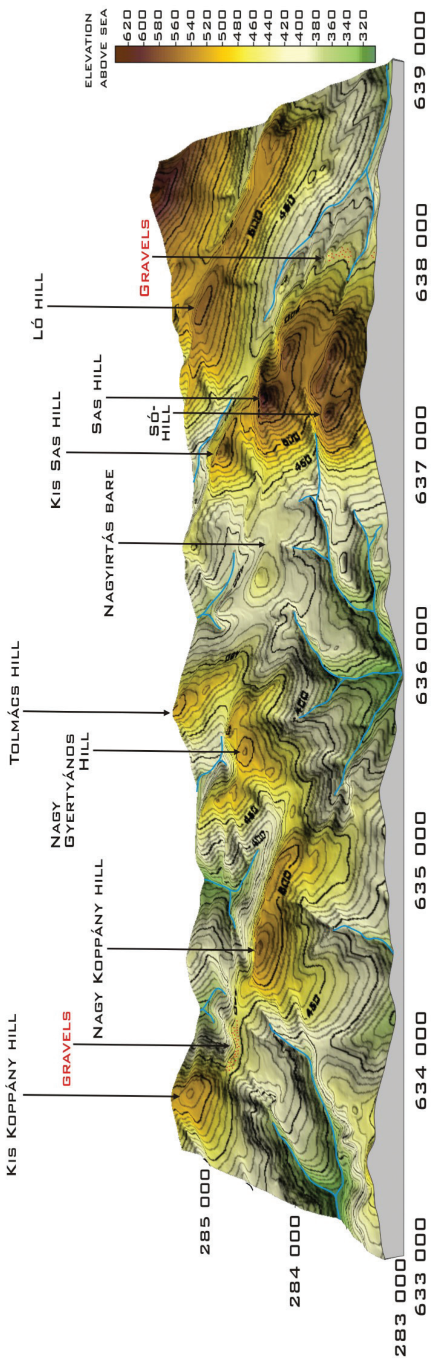

Fig. 3. Digital elevation model of the headwaters of south-western Börzsöny

The correlation of gravels is still under way, but it is conceivable that these pebbles are the remains of fluvial deposits of an ancient river. The gravels of Sas Hill and Só Hill are more important, than those of the other site on Koppány Saddle. On the Sas Hill–Só Hill and their environment the layer of pebbles is thicker than at the other site and here some boulders were found *(Photo 2).* These boulders were noticed by Láng, S. in 1952, but he did not analysed this area geomorphologically and the boulders in the surroundings of the Sas Hill has not been mentioned since then.

I would like to remedy this deficiency in the present study. The pebbles and the large sized boulders are now partially in the valley of streams in the environs, because they were moved from their original place by channel and areal erosion. The small streams could not transport far away the boulders, so it is sure that the initial place of these boulders was the lag surfaces of the Sas Hill and Só Hill, which are situated at 440–450 m a.s.l..

The Sas Hill and Só Hill are key landforms in the south-western Börzsöny. They are the ruins of two ancient volcanic explosion centers, which were one landform with four pikes by erosion. These are part of the first drainage divide between the Kóspallagi Basin and Márianosztrai Basin. There rise a lot of springs on the sides of the hills. From here some streams flow to Danube and some other ones

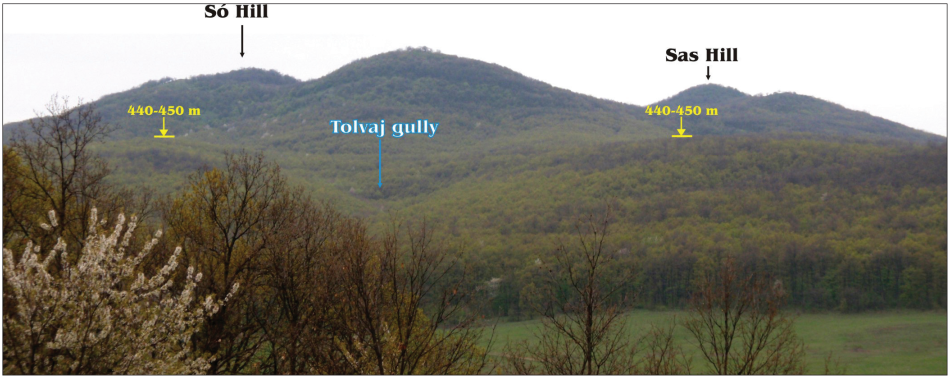

Photo 1. The Só Hill, the Sas Hill and the lag surfaces on their sides

empty to Ipoly. The Ló-hegyi Stream flows eastward, the Tolvaj Stream and Medres Stream run southeastward. These come under the drainage area of Danube. The Bezina Stream flows southwestward and the Hosszú-völgyi Stream northwestward. These streams are part of the drainage basin of Ipoly *(figures 2* and *3).* Erosional valleys of these streams have dissected the foreland of Sas Hill and Só Hill. There are some lag surfaces around the mountains at 440–450 m a.s.l. *(Photo 1).* To show them both contour lines were drawn in red on the digital elevation model *(Figure 4).*

Initially the two hills were very probably surrounded by a continuous plain surface that later became dissected by current streams. These lag surfaces are discernible nowadays. The elongated plain surface on the top of the Ló

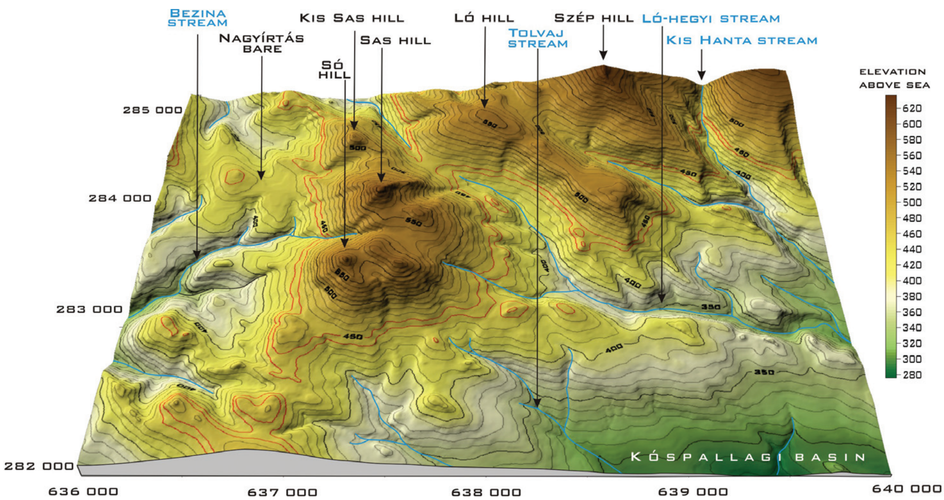

Fig. 4. Digital elevation model of the environs of Sas Hill and Só Hill

Hill is also conspicuous. Láng, S. recognized several flat summit levels in the south-western Börzsöny and Helembai Hills. In his opinion they are also lag surfaces, which were developed in the Late Miocene and Early Pliocene by etchplanation; the Ló Hill is an example. His concept has not gained adherents. In the course of our fieldwork no fluvial sediments were found. During the geomorphological mapping of Sas Hill and its environs a great amount of reworked pebbles were identified in the valleys of Ló-hegyi Stream, Tolvaj Stream and Medres Stream.

The areas of pebbles were plotted on a map *(Figure 5).* The original places of gravels are on the lag surfaces located on the eastern and southern sides of the Sas Hill and Só Hill at 440–450 m a.s.l.. The backward erosion from Kóspallagi Basin has fractured the previously contiguous plain surface and sheet erosion still keeps on destroying the superimposing gravel sheets *(Photo 2).*

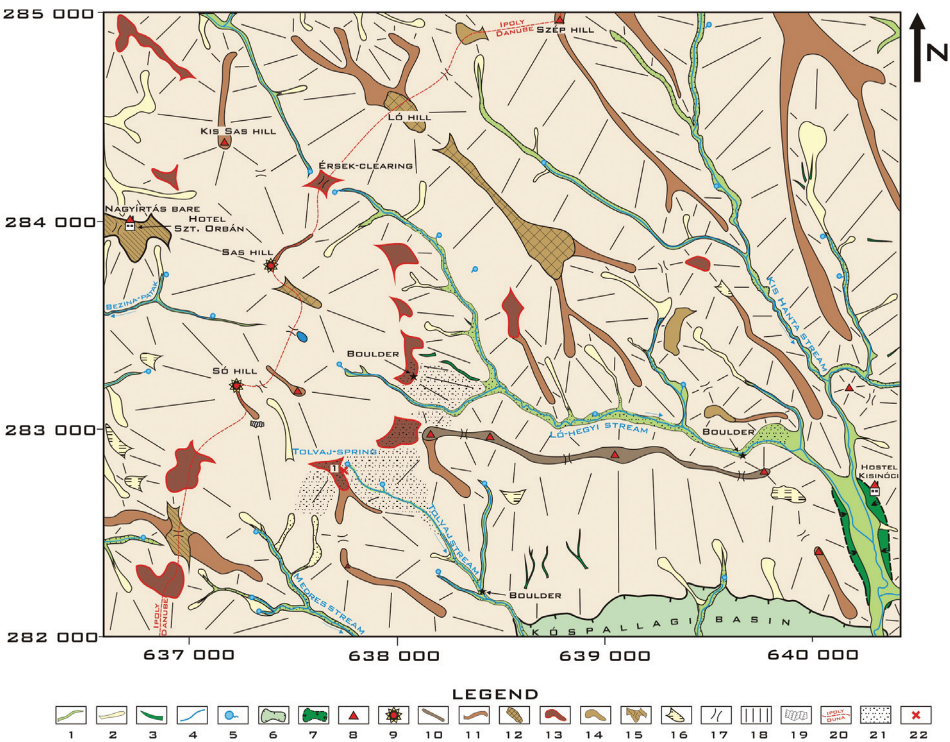

Fig. 5. Geomorphological map of environment of Sas Hill and Só Hill. – 1 = Erosional valley; 2 = Derasional valley; 3 = Rill; 4 = Stream; 5 = Spring; 6 = Basin; 7 = Local tectonic depression; 8 = Hilltop; peak; 9 = Pike (old volcanic explosion center); 10 = Crest; 11 = Interfluve; 12 = Summit level; 13 = Lag surface (440–450 m); 14 = Other lag surfaces; 15 = Wide saddle surface; 16 = Gentle slope segment; 17 = Saddle; 18 = Slope; 19 = Cliff; 20 = Primary drainage divide (Danube/Ipoly); 21 = Gravels; 22 = Outcrop

Photo 2. Boulder in the valley of Ló-hegyi Stream

Gravels of the south-western Börzsöny and their grain-size analysis

The most beautiful and intact layer of pebbles is to be found next to Tolvaj Spring on the side of the Só Hill. This place can be seen on *Photo 1*, above the Tolvaj gully, lying west of it (lag surface at an altitude of 440–450 m a.s.l.). The shape and elevation of this slightly undulating lag surface is similar to akin surfaces in the surroundings around the Sas Hill and Só Hill. The gravel layer near Tolvaj Spring is 4–5 m thick. In its upper part an outcrop was made (*Figure 5*, *Photo 3*). General colour of the profile is pale yellowish brown. The well rounded granules are mostly 0.5–1 cm in diameter. Middle-sized and well rounded granules, with grain-size of 1–5 cm in diameter also occur frequently, and there are some larger pebbles (10–15 cm in diameter.) Usually these gravels are composed of quartz and quartzite, subordinately of crystallic, metamorphite rocks and partly of local andesite. The pebbles are likely to have originated from the Alps or from the Carpathians. After sampling a grain-size analysis of the material smaller than 2 mm in diameter was made in the Geographical Research Institute of the Hungarian Academy of Sciences (GRI HAS). The results can be seen on *Figure 9*, summarized in a curve (green), which has four apices. The first apex of median curve of sample is at 11.16 μm, the second apex is at 27 μm, the third one is at 123 μm and the fourth is at 1000 μm. The average and median values can be read from *Figure 9*.

Photo 3. The outcrop of Tolvaj spring

Geomorphology of the gravel sheets of south-eastern Börzsöny and of their environs

The contour map and the relief map show the environment of gravel sheets of south-eastern Börzsöny *(Figure 6).*

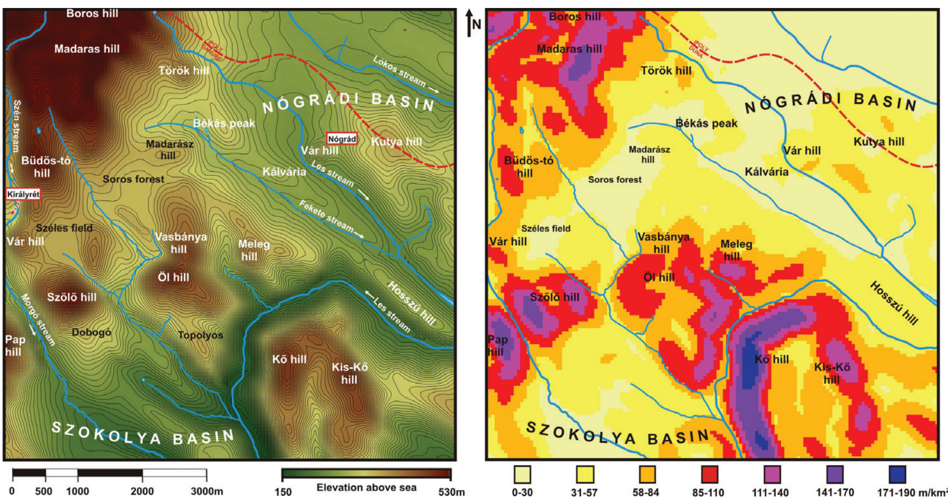

Fig. 6. The contour map and relief map of south-eastern Börzsöny

As for the drainage pattern of the area, most streams flow from north-west to south-east, but in some places the direction turns perpendicular. Tectonic predestination of this pattern seems to be quite probable. The border between the drainage basins of Danube and Ipoly runs near Nógrád settlement. North of this line lies the catchment of Ipoly River, whereas south of it is the drainage area of the Danube. The most important waters of the studied place are called Morgó Stream and Les stream, both running into the Danube. Brooks and other smaller watercourses are rising from the local springs empty into them.

There is a hilly surface between the Nógrádi Basin and the Szokolyai Basin. It is shown on the contour map. This hilly surface can be divided into two parts. The range on the north-western side of *Figure 6* is Boros Hill–Madaras Hill–Büdös-tó Hill–Vár Hill (near Királyrét); the latter is the southernmost tip of Eastern Börzsöny. The semicircle hillrange on the southern side of *Figure 6* includes the chain of Pap Hill–Szőlő Hill–Ől Hill–Kő Hill which all belong to Southern Börzsöny as the marginal elevations of Szokolyai Basin.

There are some valleys which run through this semicircle range of hills to Szokolyai Basin. As it is evident from the relief map, three gates with steep walls have developed in these places. On the same figure an area is visible enclosed by the ring of Büdös-tó Hill–Vasbánya Hill–Öl Hill–Szőlő Hill–Vár Hill (near Királyrét). This is a wide intramoutain surface with a very similar relief as the two basins, but is situated at a higher altitude *(Figure 6).* Consequently this area has to be separated from the Nógrádi Basin for geomorphological reasons. It lies between the Southern and Eastern Börzsöny and is composed tripartite of Széles Field, Soros Forest and Madarász Hill.

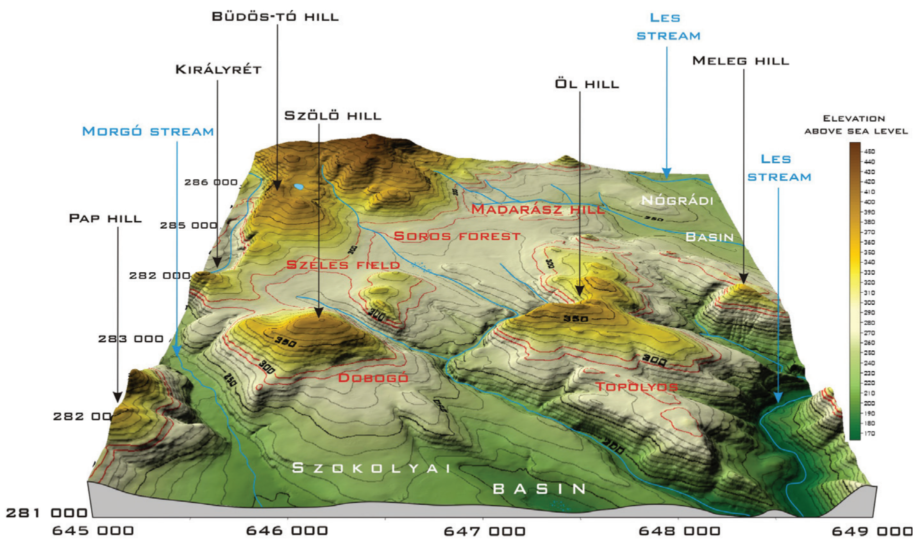

Fig. 7. Digital elevation model of the area between Nógrádi and Szokolyai basins

There are some lag surfaces on the valley sides of andesite hills. The most important ones are located at 290–300 m a.s.l. For the sake of visual perception the contours of 290 and 300 m are shown in red on the digital elevation model *(Figure 7)*. Two lag surfaces (Dobogó and Topolyos) are on the side of the Szőlő Hill and Öl Hill, above the Szokolyai basin. What is most important, the intramountain surfaces of Széles Field, Soros Forest and Madarász Hill are also at the same altitude. This area is a gently rolling surface of south-west–north-eastern extension having shaped by backward erosion, which developed from Szokolyai Basin, and it has formed three depressions in this area *(Figure 8)*. The south-western and the north-eastern depressions are derasion valleyheads, whereas the central depression is an erosional-derasional valley of a minor stream.

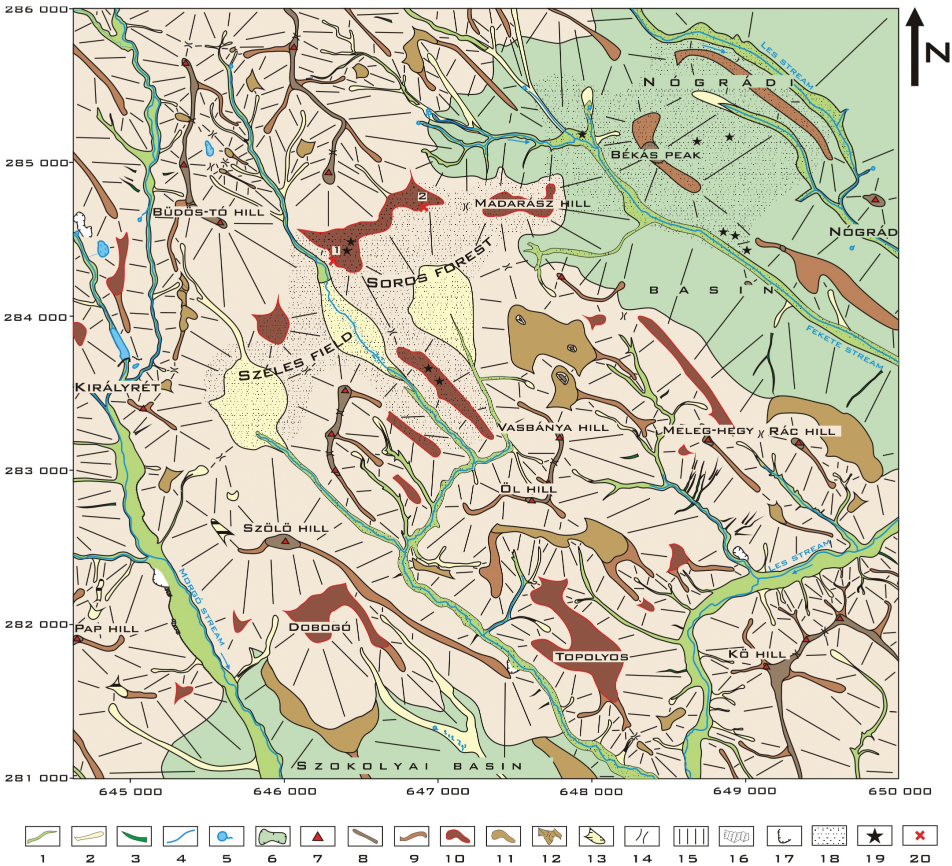

Fig. 8. Geomorphological map of the area between Nógrádi and Szokolyai basins. – Legend: 1 = Erosional valley; 2 = Derasional valley; 3 = Rill; 4 = Stream; 5 = Spring; 6 = Basin; 7 = Hilltop; peak; 8 = Crest; 9 = Interfluve; 10 = Lag surface (290–300 m); 11 = Other lag surfaces; 12 = Wide saddle surface; 13 = Gentle slope segment; 14 = Saddle; 15 = Slope; 16 = Cliff; 17 = Quarry; 18 = Gravels; 19 = Boulders; 20 = Outcrop

Before the backward erosion this area was a continous plain surface between the Eastern and Southern Börzsöny. Also very probably all the lag surfaces (Dobogó, Topolyos and the area of Széles Field–Soros Forest–Madarász Hill) used to form a large continuous plain surface around and inside the mountains built of andesite. This ancient plain was subsequently dissected by current streams.

The lag surfaces at 290–300 m altitude are especially important, because a lot of pebbles could be found on them. In these gravel deposits are also the boulders 60 cm in diameter *(Photo 4)*, which were already noticed by Ferenczi, I. (1935) and Vadász, E. (1953). These pebbles and boulders were located originally on the northern and southern sides of Széles Field and Soros Forest, and some patches of them are still found there and in summit position on the top of the plain surface of Madarász Hill *(Figure 8)*. Nowadays the original gravel sheet is affected by denudation.

Pebbles are reworked first during transport into the derasional valleys and from there to the channels of streams that take them into the Danube. The lag surfaces of gravels also extend over the Nógrádi Basin. The gravel deposits atop Békás Peak and the gentle rolling hilly surroundings are further good examples.

Photo 4. Boulder of large size near Békás Peak

The most beautiful and thickest layer of pebbles of the area lies on the lag surface in the northern part of the Soros Forest. The form and elevation of this residue is very similar to other lag surfaces between the Eastern and Southern Börzsöny. The thickness of this fractured gravel sheet is between 2 and 3 meter. It was outcropped on two occurrences. Based on the description of outcrop these sediments can be labeled as sandly pebbles *(Photo 5).*

With regard to the colour of outcrop profile of sandy pebble sheets they show an irregular alternation of brown and grey patches. The grain size of gravels is mostly fine (0.5–2 cm in diameter) and well rounded. Middle and well rounded pebbles with grain size of 2–5 cm in diameter occur frequently, but there are also some larger ones (10 and 20–25 cm in diameter). Usually these gravels are composed of quartz and quartzite, fewer of crystallic and metamorphite rocks and some of andesite locally. The most probable source areas are Alps or Carpathian Mountains. After sampling, grain-size analysis was carried out on the material smaller than pebble fraction (2 mm in diameter) in the GRI HAS. The results of laboratory analyses are shown on *Figure 9.* As a summary on the outcrop profiles two curves of median values

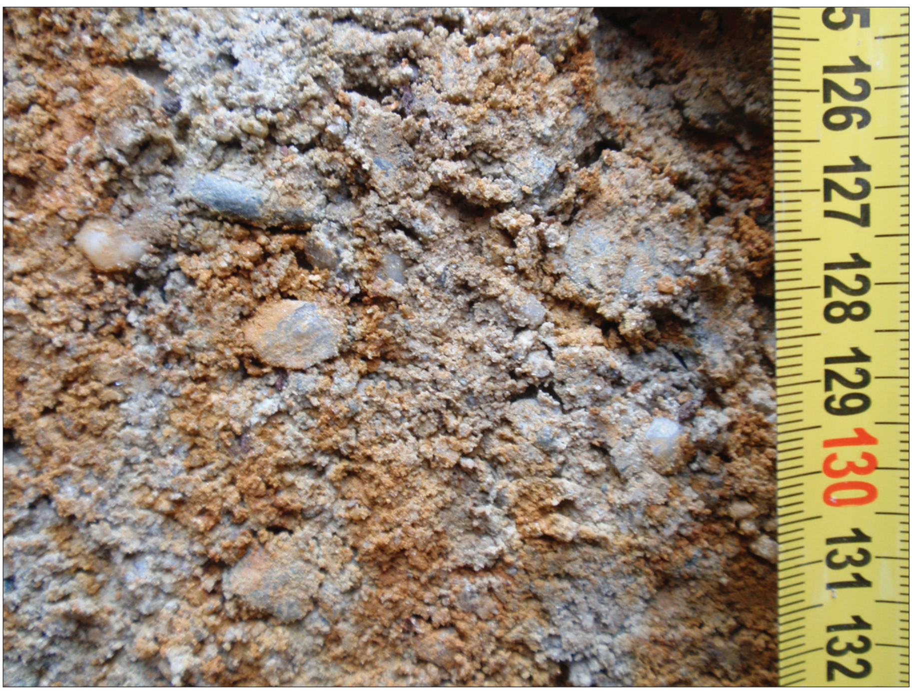

Photo 5. Outcrop profile in the Soros forest

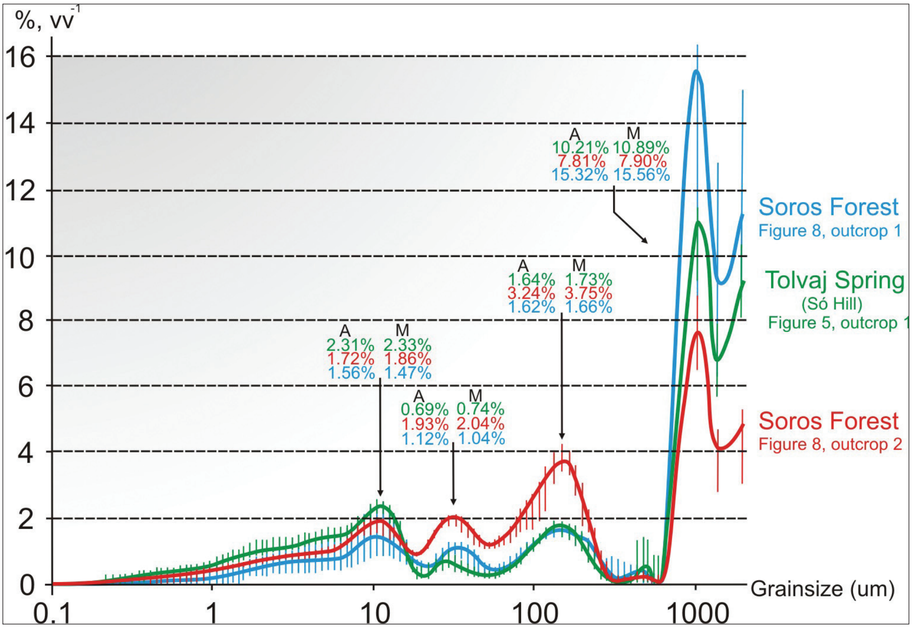

Fig. 9. Grain-size diagram (0.1–2,000 μm)

(blue and red) were drawn, which have four apices. The first apex of median curve (blue) of sample from the first outcrop is at 10.24 μm, the second apex is at 28.60 μm, the third one is at 134 μm and the fourth – at 1,000 μm. The respective apices of the median curve (red) of the other outcrop are: at 11.16 μm, 31.2 μm, 146.2 μm and 1,000 μm. The average and median values can be read from *Figure 9*.

When all is said, dreikanters should also be mentioned those spread over the surface of this area. These gravels are formed by corrasion and have developed from the original gravel layer. These dreikanters do not have any desert crust or desert varnish, but its form is the evidence of their having shaped by wind *(Photo 6)*.

Photo 6. Dreikanters

The comparison of the gravel sheets of south-western and south-eastern Börzsöny

The two occurrences of pebbles are 10 air kilometres from each other. The areas of gravels are separated topographically. The boundary is the secondary drainage divide, which lies along the line Nagy-Inóc Peak–Törökmező–Szt. Mihály Hill. Also there is a considerable vertical difference, because the pebbles of south-western Börzsöny are located at 440–450 m, and those of south-eastern Börzsöny were found at 290–300 m a.s.l. Although the two sites are far from each other, the gravels of Southern Börzsöny are intriguing, because there are a lot of common features based on the geomorphological and laboratory analyses.

1. The gravel sheets of both areas are found upon lag surfaces, which developed from an earlier continuous plain surface by backward erosion of current drainage network. These lag surfaces are on the slopes of andesite mountains. Having become fractured thoroughly, they nevertheless are correlated with each other fairly well. Thus the geomorphological analysis of the environs of pebbles dicovered some lag surfaces, which are very probably remains of an earlier river valley.

2. There are some large sized boulders at both occurrences *(photos 2* and *4)* and found in their environs, on lag surfaces or confined to them. These well rounded boulders were shaped by gravelly sand stream load.

3. The grain-size analysis provides reliable evidence of the similarity between the gravel sheets. As it is also visible on *Figure 9*, the grain-size values of less than 2 μm of the samples from the three outcrops resemble each other closely. The results of the correlation analysis (R^2) are shown on *Table 1.*

Table 1. Correlation of values of grain-size analysis

Correlation of samples (R2)			
Occurrences	Tolvaj Spring	Soros Forest 1	Soros Forest 2
Tolvaj Spring	1.000000	0.969476	0.979708
Soros Forest 1	0.969476	1.000000	0.945404
Soros Forest 2	0.979708	0.945404	1.000000

The problem of transport of large sized boulders

In the chapter on history of research some sentences were devoted to the concepts evolved by the former prominent researchers concerning the gravels and large sized boulders in the Southern Börzsöny, It is quite surprising, however, that a very important problem was missing from Ferenczi's (1935), Láng's (1952) and also Vadász's (1953) studies. The question rests with the discharge a river must have as to be capable enough to move and transport these giant boulders.

In their works they did not concentrate on any way of transport of stream load, which could explain the presence of large sized boulders, in spite of the fact that former authors had made attempts to address this problem in relation to other boulders. For example Szabó, J. (1872) identified the gigantic rocks as moraine sediments in a valley near Hasznos, Mátra foothills. According to Id. Lóczy, L. (1881) the boulders at Budafok were transported by glaciers. Schafarzik, F. and Lóczy, L. (1914) thought that the boulders of large size near Cinkota, Ács and Bábolna were transported by the extremely violent spring floods of rivers. But even larger flash floods or spring floods are not able to transport the boulders over large distances. According to Horusitzky, H. (1917) the boulders of large size near Győr were transported in an alternative way. They were frozen in ice floes and the latter floated on the water surface. The boulders are as large as those found in the Southern Börzsöny. This is a brilliant idea. *Photo 7* shows the transport of a boulder in the St. Lawrence Estuary, Canada. This photo is from a study by Dionne, J-C. (1968). The work also provided evidence about that even boulders between 1 and 1.5 meter in diameter could be transported easily. In other words for this way of transporting no giant rivers are needed. Rivers of medium discharge like Danube in the Carpathian Basin can transport large boulders from a distant land. Kriván, P. (1973) put forward this theory, when he investigated boulders of large size near Vác and Sződliget.

This case raises the question of roundness of boulders, because in this case there are not any processes (similar to the transport by glaciers), which could polish these boulders. So we can see angular blocks on *Photo 8* also taken from Dionne's (1968) study. According to Bogárdi, J. (1955) only the large eddies could keep moving these boulders. These whirls developed

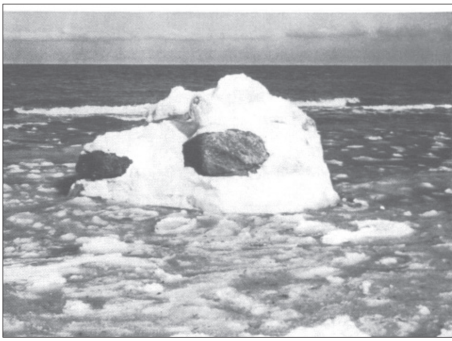

Photo 7. A large boulder transported by ice-floe in the St. Lawrence Estuary. (Dionne, J-C. 1968)

Photo 8. A large boulder in the tidal flat of the St. Lawrence River (Dionne, J-C. 1968)

during the large spring floods and polished them by sandy-gravelly channel load. Jámbor, Á. (1965, 2010) agrees with this theory, because it explains the presence of well- rounded boulders in the north-western foothills of Gerecse Mountains.

The large sized boulders of Southern Börzsöny are also well rounded *(photos 2* and *4).* In this case there might be two alternatives. According to the first one the actors were eddies having emerged in large rivers that moved and transported the boulders. It is possible, but other important facts should also be taken into account. The Börzsöny Mountains are composed of andesite, but these boulders are built of quartzite and metamorphites. So the gravels and boulders arrived after transport from hundred or several hundred kilometer distance, supposingly from the mountains of Carpathians or Alps. It is also evident that the boulders were larger and less rounded when they fell into the river than after accumulation, reworked by attrition. There are some boulders, which are 60 cm in diameter in the Southern Börzsöny. What a size could have these boulders before transporting, and what an energy was needed to move and transport them over more than hundred kilometers! The large eddies and flash floods could move them, but only over a short distance. Was it possible that any river with such a great energy had risen from the Carpathian Mountains?

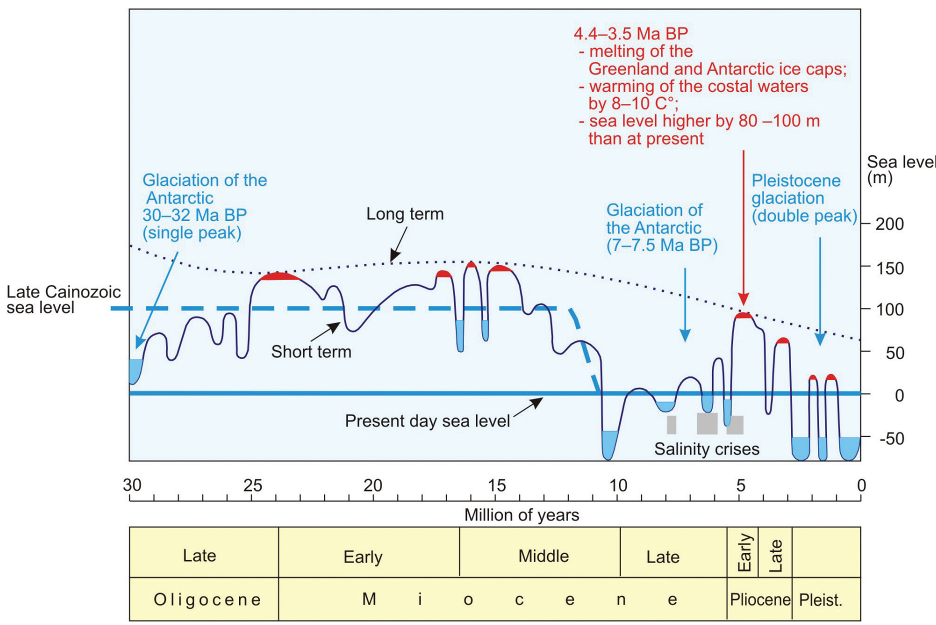

Fig. 10. The possibility of cyclic recurrence of ice ages during the Neogene (Schweitzer, F. 2004).

The other possibility is the transporting way in icefloes frozed. It provides explanation for the problem related to the capacity of the rivers, because in this case no extreme discharge is needed. At the same time the issue of roundness is raised. There is a possible solution for this problem. The angular rocks floated from the distant mountains in icefloe frozed. During the transport the icefloe was melting under a warmer climate as the river ascended from the mountains and was flowing from north to south. When the continuously melting icefloe achieved a critical size and it could not keep the blocks on the water surface, they came down into the stream bed where the rounded forms developed that is met at present. The sandy-gravelly channel load formed rounded boulders, which were transported rolling upon the bed and flowing near the bed. The bedrock-channelled rivers are developing in a similar way, the immovable things are also rounded by the channel load.

If we accept this theory we do not have to search for traces of any gigantic river, but we have to assume cold and warm periods or at least climate conditions similar to the present-day ones in Southern Canada. *Figure 10.* shows the possibility of cyclic recurrence of ice ages during the Neogene.

Summary

In the present study some gravel sheets were tackled, that are not related to the pebbles of Danube terraces. Two occurrences were selected: in the southwestern part of Börzsöny and another one in the south-eastern part of the mountains. The pebbles are relics conserved in good condition. First the studies of former authors were analyzed, then the gaps closed using the results of new investigations. For instance, these areas were characterized and new gravel occurrences found by geomorphological mapping in the environs of the gravel sheets.

The original sheets which occur on some lag surfaces were also put on the map. The sites are either at the same elevation above the sea level on the andesite hillsides, or in the surroundings, in reworked state. The above mentioned surfaces are relics of an earlier continuous river valley around the hills, fractured by recent and current drainage network, whose development began in Late Pliocene; at this time the Danube arrived in the Visegrad Gate. The western part of this drainage network altered in Pleistocene, when the Ipoly joined Danube here.

After the reconstruction of the original occurrences of pebbles by geomorphological methods, some outcrops were made. Samples were taken from these outcrops from several places and horizons. After sampling a granulometric analysis of the fraction less than 2 mm in diameter was performed in the GRI HAS. Although the spatial horizontal distance and vertical difference

between the two gravel sheets are considerable, the results of geomorphological and grain-size analyses have led to three important conclusions.

1. The geomorphological characteristics of the two areas are very similar.

2. The statistical analysis of grain size shows 94–98% correlation between samples from the two occurrences.

3. In the environs of both occurrences some boulders were found composed of quartzite.

The size of boulders is usually between 20 and 40 cm in diameter, but some of them are 60 cm. According to the authors's opinion, the route of transport of these boulders was very likely floating frozen in ice floes. After melting those boulders came down the bed of river and there had become rounded by the whirling sandy-gravelly channel load near the bed. Alternating cold and warm climate periods are assumed to have been at that time or at least a climatic environment typical of Southern Canada nowadays.

REFERENCES

Bogárdi, J. 1955. *A hordalékmozgás elmélete.* (The theory of moving of channel load). Budapest, Akadémiai Kiadó, 547.

Dionne, J-C. 1968. Morphologie et sedimentologie glacielles litoral sud du Saint-Laurent. *Zeitschrift Für Geomorphologie, Suplementband.* 7. 56–84.

Ferenczi, I. 1935. *Adatok a Börzsöny-hegység geológiájához.* (Contribution to the geology of Börzsöny Mountains) MÁFI Évi Jelentése (1925–28). Budapest, MÁFI, 131–142.

Horusitzky H. 1917. *A győri ipari- és hajózó csatorna geológiai szelvénye*. (The industrial and shipping channel near Győr) M. kir. Földtani Intézet Évi jelentése 1916-ról. Budapest, M. kir. Földtani Intézet, 619–626.

Jámbor, Á. 1965. *Üledékes összletek kavicsvizsgálatainak földtani értékelése* (Geological evaluation of gravel sediments analysis). Mérnöki Továbbképző Intézet előadás sorozat, 4420. Budapest, Mérnöki Továbbképző Intézet, 35.

Jámbor, Á. 2010. Hömpölyök – óriáskavicsok – Előfordulása a hazai pleisztocén folyóvízi képződményekben. (Boulders in the fluvial deposits of Hungary). *Földrajzi Közlemények* 134. (2): 159–171.

Jankovich, I. and Hála, J. 1972. *Magyarázó a Börzsöny-hegység fedetlen földtani térképéhez*. (Explanation to the geological map of Börzsöny Hills) 1: 25 000, Márianosztra. Budapest, MÁFI Adattár.

Láng, S. 1952. A Börzsöny geomorfológiája (The Geomorphology of Börzsöny Hills). *Földrajzi Értesítő* 1. 315–336, 443–465.

Id. Lóczy, L. 1881. A promontori Dunameder-kotrás geológiai eredményei. (The geological results of dredging of Danube bed near Promontor). *Földtani Közlöny* 11. 255–257.

Kriván, P. 1973. A periglaciális Duna-üledékek közelhegységi törmelékanyagának eredete a Duna-kanyartól a Pesti-síkságig. (The genesis of hilly debris of periglacial Danube sediments). *Földtani Közlöny* 103. 136–144

Papp, F. 1933. Márianosztra és Nagyirtás puszta környékének kőzet és földtani felépítéséről. (The geology of environments of Márianosztra and Nagyirtás Bare). *Földtani Közlöny* 63. 62–95.

Schafarzik, F. and Lóczy, L. 1914. A Dunai kavicsokról. (About the pebbles of Danube). *Földtani Közlöny* 44. 88.
Schweitzer, F. 2004. On the possibility of cyclic recurrence of ice ages during the Neogene. *Hungarian Geographical Bulletin*, 53. 5–11.
Szabó, J. 1872. Egy moréna képződmény a Mátrában (A moraine sediment in the Mátra Mountains). *Földtani Közlöny* 2. 233–241.
Vadász, E. 1953. A Nógrádi éleskavics-terület. (The area of dreikanter near Nógrád). *Földtani Közlöny* 83. 57–59.
Vargáné Máthé, K. 1975–1976. Jelentés a Börzsöny-hegység oligocén-miocén kavicsos üledékeiről (Report about the Oligocene-Miocene gravel sediments of Börzsöny Hills). Budapest, MÁFI Adattár.