RELIEF TYPES AND GEOMORPHOLOGICAL SURFACES ON THE INTERFLUVE OF THE SAJÓ AND BÓDVA RIVERS

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The area enclosed by the Sajó, Bódva and Jósva rivers and the national border, which is of about 500 km², is constituted of hills and low mountatins of high relief. Within that there are the microregions of the Borsod (Putnok) Hills of Tertiary sediments and the bordering Szendrő and Rudabánya and Aggtelek Mountains of Paleozoic and Mesozoic rocks.

The interfluve of the Sajó and Bódva, selected as test area, is not an independent landscape unit. The microregions shown in *Fig. 1.* mostly belong to the mesoregions of the Aggtelek Mountains and the Cserehát Hills *(Pécsi, M.–Somogyi, S.* 1967, 1980). In spite of the variegated nature of the landscape it did not prove useful for the evaluation of the potentials of the physical environment to narrow down investigations to the homogeneous unit of the Borsod Hills, since it is in close genetic relation with its neighbourhood on the one hand and enabled the checking of the method in different areal units on the other.

Main stages in geomorphic evolution

The Mesozoic and Cainozoic evolution of the interfluve between the Sajó and Bódva was characterized by alternating geosynclines and erosion surfaces manifest in geological and geomorphological inversions. In a *structural-morphological* sense, the Borsod Hills is a *hilly region in basin position* between mountains which also includes the remnants of the Szendrő block mountains. The present relief as a basin, primarily with its Neogen sediments, results from an earlier accumulation period and as a hilly region originates from Pliocene—Pleistocene erosional-derasional processes. A characteristic feature of the hilly region in basin position is the bordering ring of planated low mountains which has ever influenced the geomorphic evolution of the basin.

Two major relief types in the region are the *inter-mountain hills* of Neogen terrestrial, marine and volcanic sediments and the *low mountains* of primarily Mesozoic (Rudabánya and Aggtelek Mountains) and Paleozoic (Szendrő Mountains) calcareous rocks showing signs of heavy folding and faulting.

The evolution of these geomorphic types has diverged since the Upper Eocene–Oligocene.

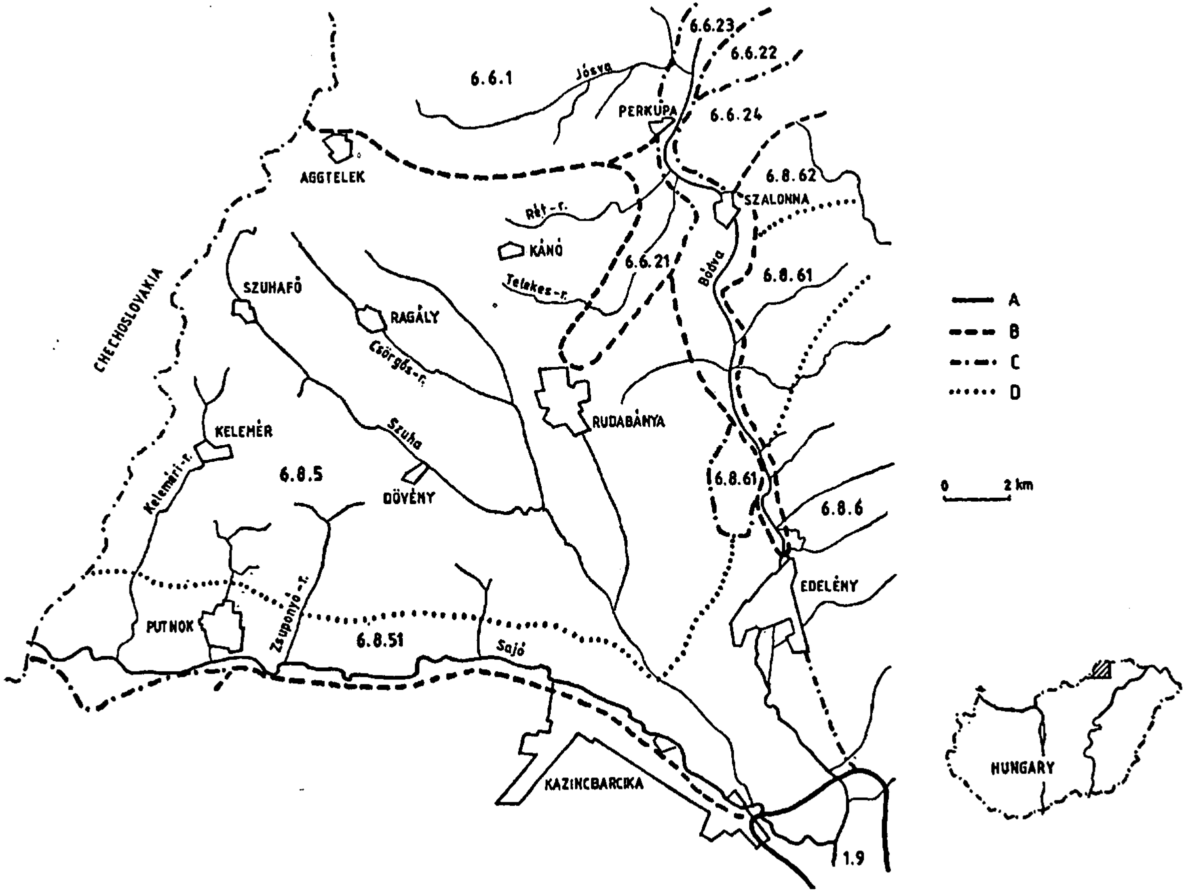

Fig. 1. Geographical location of the area under investigation and its physical geographical landscape divisions (after Pécsi, M.—Somogyi, S. 1980).
A = boundary of macroregion; B = boundary of mesoregion; C = boundary of microregion group; D = boundary of microregion; 1.9. = North Great Plain flat alluvial fans; 6.6.1. = Aggtelek Karst; 6.6.2 = Rudabánya—Szalonna Mountains; 6.6.21 = Rudabánya Mountains; 6.6.23 = Bódva valley; 6.8.5. = Borsod Hills; 6.8.51 = Sajó valley basin; 6.8.6 = Cserehát; 6.8.61 = Szendrő blocks; 6.8.62 = Rakaca valley basin.

The Sajó—Bódva interfluve lies to the northwest of the Zagreb—Kulcs—Zemplén lineament.

The area is a marginal part of the uniform plate segment (*Horváth, F.* 1978 – Tatra plate) which includes a portion of the Carpathians and was probably formed on the 'southern platform' (but not necessarily on the African).

For deep structure the area can be divided along the Darnó lineament (joining to the main lineament but younger than that) and its continuation, the Perkupa-Alsótelkes imbricate zone into a northwestern part of 'Carpathian' character (Gemerids) and a southeastern one of 'South—Alpine' nature (Szendrő—Uppony Mountains—*Balogh, K.* 1975).[1] At the same time, the Rudabánya Mountains with the transverse overthrust line along the Szőlősardó velley can be regarded a relatively independent member of the Southern Gemerids.

Some scientists believe the Darnó lineament to be a Pre-Miocene subduction zone (*Szádeczky-Kardoss, E.* 1973) and, although it is not supported by recent investigations, by *Stegena, L.-Horváth F.* (1978) the stratification bears several features of subduction.

In the opinion of *Pantó, G.* (1956) and *Hernyák, G.* (1977), the peculiar 'roof' structure of the Rudabánya Mountains was formed by overthrusts difficult to date.[2]

Balogh, K. and *Panto, G.* (1956) regards the Rudabánya Mountains an anticlinal structure of complete Lower and Middle Triassic record and dismembered by faults in its south-southeastern part. In the Rudabánya—Alsótelekes axis the mountains is covered by mineralized Triassic limestone, while Tertiary sediments occur on the flanks. The mostly Middle Triassic western-northwestern portion, which also show the impact of heavy tectonics, follows the strike of the Gemerids and can be considered their southernmost member.

There are a lot of questions to be answered concerning the structural place of the entire Sajó—Bódva interfluve and its Paleozoic–Mesozoic history. The macrostructural links of the Szendrő Mountains are neither clearly revealed. The thick Devonian—Lower Carboniferous limestone and shale series was folded in the Breton or Sudetan phase and by the late Carboniferous the surface had been uplifted, eroded and planated.

A *relatively uniform Variscan mountain structure* may have formed also in the Sajó–Bódva interfluve. This morphotectonic basement was tectonically and morphologically differentiated on the Permian—Triassic boundary.

The transgression beginning in the Triassic (in the Permian in the Rudabánya Mountains) extended over South—Gömör (Aggtelek—Rudabánya mountains) and the Bükk Mountains, but there are no traces for it in the Szendrő Mountains. The continuous sedimentation prolonged to the Upper Triassic was accompanied by weak volcanic activity (Ladinian stage). *Balogh, K.* (1951) presumes even younger sedimentation the products of which were destroyed by intensive tectonic activity and planation in the Upper Cretaceous.

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[1] This classic division seemingly contradicts to more recent plate tectonics hypotheses, but its use is supported by the limited opportunities of adaptation of plate tectonics to Paleozoic formations.

[2] As a continuation of the Darnó lineament, the Rudabánya Mountains is bordered by faults-(overthrust zones) of NE strike from northwest and southeast. The eastern zone of faults even divides the mountains itself into two units with the Bódva valley on the boundary.

In our present knowledge, the planated surface, which showed a relatively uniform evolution until the Upper Cretaceous, was affected by fundamental structural movements starting from the Laramian orogeny (e.g. the overthrust of the Rudabánya Mountains over the Szendrő Mountains). This resulted in basins (horsts and grabens) between subsided folds. First (in the Upper Eocene) these *partial basins* were small and *isolated* and the contiguous basin stretching over the Borsod Hills both to the west and east only formed from the Lower Miocene onwards *(Fig. 2.)*.

According to *Balogh, K. et al.* (1975) it was presumably a contiguous basin as the lack of Paleogen sediments can be explained by Pre-Miocene denudation. This statement is supported by the investigations of *Báldi, T.* (1980). *Kőrössy, L.* (1980) is of the opinion that the branch of sea lying here gradually shifte to the east and removed into a 'gap' in the Cserehát Hills during most of the Miocene.

Basins were filled by sediments, molasse in tectonical sense; bedding conditions indicate the differentiated, chequerboard pattern of the basement.

The Lower Miocene (Eggenburgian) thick neritic zone sediments (schlier), of terrestrial facies towards the marginal mountains, extended over not only the one-time basins, but the pediplain of the strip 'free of Paleogen' south-southeast of the Darnó lineament. These formations, mainly occurring between Putnok–Alsószuha–Szuhafő–Kelemér, had been regarded Oligocene (Kattian) previously. Recent investigations, however, support their Eggenburgian (Lower Miocene) age; this stage was formed uniting the former Kattian and Aquitanian stages. (Thus the areal extension of the thick Lower Miocene series grew at the expense of the Oligocene.)

The littoral calcareous layers forming the base conglomerate of the Lower Miocene transgression ('Bretka Formation') outcrop in some places in the area, e.g. at Trizs, Rudabánya, and Imola (*Báldi, T.* 1971, *Radócz, Gy.* 1973). The coal measures in the depressions of the strip of basement between the Szendrő and Uppony Mountains are named 'Felsőnyárád Formation' which is a substituent facies for schlier with Ammussia *(Fig. 3.)*.

It was on the northern and eastern margins that transgression was first succeeded by regression followed by the deposition of the lower rhyolite tufa series originating from the eruption centre at the Bükkalja. The advent of erosion on the mainland is indicated by the gravelly conglomerates formed in this period and, in an indirect way, the removal of the lower rhyolite tufa cover of the Szendrő Mountains (*Schréter, Z.* 1951). It is conspicuous that the series characterized by repeated brown coal layers and in the new terminology denominated Ottnangian (formerly Helvetian) only extends over the souther and southeastern part of the area and it is missing in the northern and middle portions or present in a very thin layer on the rises of the basement of chequerboard pattern. The lack of younger sediments is explained by *Szabó, J.* (1969, 1971) by the early filling of the basin and especially its northern part. At any rate, the period of accumulation ended in the late Lower Miocene levelled out the previous relief. The lack of the Carpathian schlier in the Borsod basin allows the conslusion that the subsidence of the basin came to an end during the Carpathian stage. Thus in the Badenian (formerly Tortonian), the regional distribution of sediments belonging here is debated, the middle rhyolite tufa[3] was a terrestrial formation

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[3] According to the investigations by *Hámor, H. et al.* (1980), their absolute age can be estimated at 16 million years.

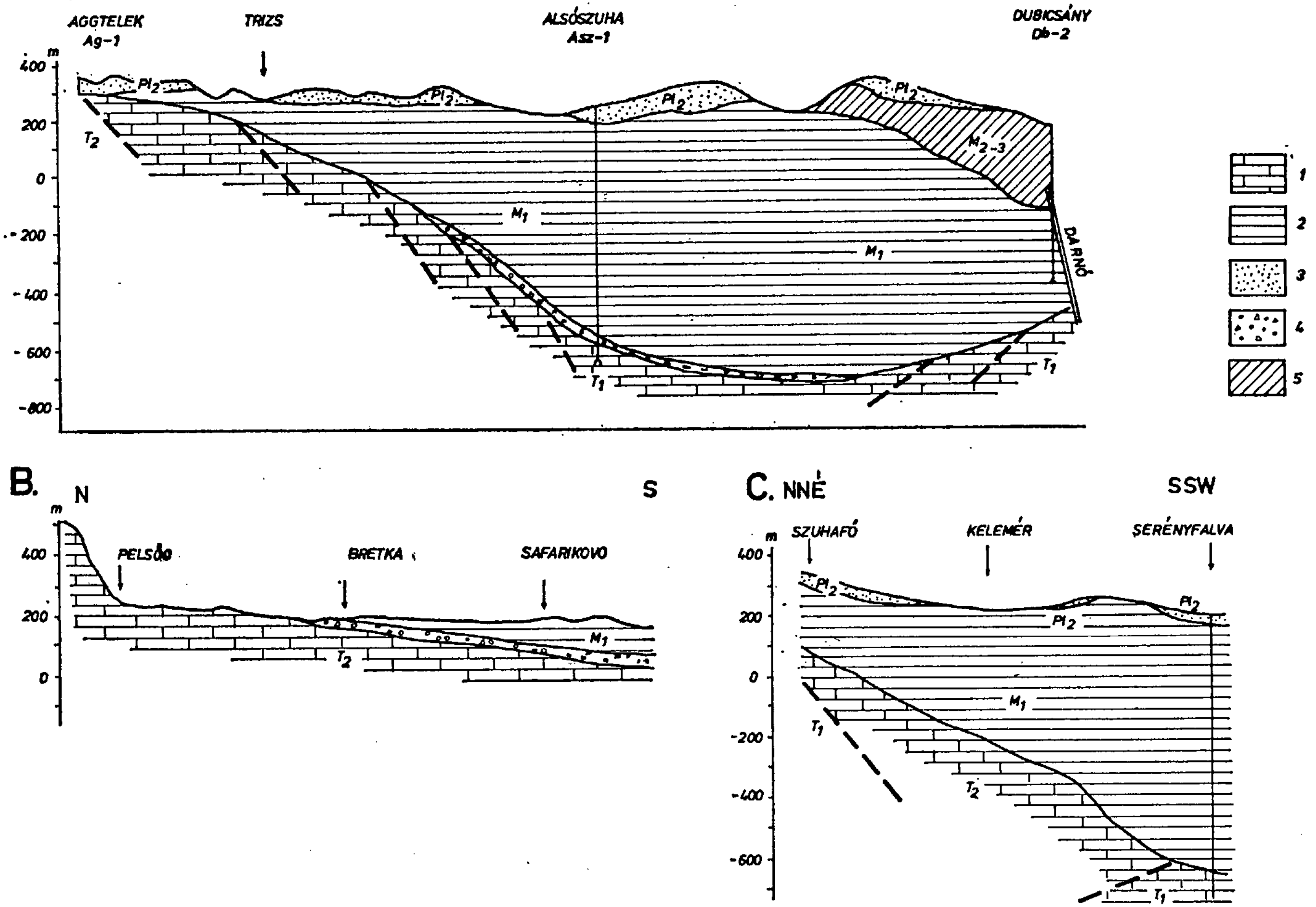

Fig. 3. The position of the Bretka Formation on the basis of several sections across the Sajó—Bódva Interfluve (made after the data from the Eötvös Loránd Geophysical Institute (ELGI) and the Hungarian State Geological Survey (MÁFI) and the sketches of Kozák, M. 1976 (A), Ovran, J. (B) and Balogh K. (C)).

1 = Triassic limestone and dolomite; 2 = schlier with ammusia; 3 = Pannonian sand, clay and gravel; 4 = base conglomerate; 5 = sand, clay and tuf.

on the more or less denuded Ottnangian surface. Denudation went on in the Sarmation, too, a marine facies is only found in the neighbouring Cserehát Hills (*Radócz, Gy.* 1969).

Traces of volcanic activity related to local centres of eruption and producing andesite tufa and large amounts of agglomerate can be found on the surface north of the Sajó river (and also to the south) between Putnok and Szuhakálló. (Andesite tufa in similar position in the Cserehát is 12.7 million years old by *Hámor, H.*) Sediments here are in hilltop position and presumably indicate the surface planated by the Ancient Sajó river. The layers, presently sloping to the north, disappear under the Pannonian formation at Felsőnyárád. The 'Sarmatian–Pannonian' quartz and schist gravels, described from many places in the area and mentioned by *Schréter, Z.* (1929) present several unsolved questions related to their origin and accumulation. They are on the surface not only on both sides of the Sajó valley, but on hilltops to the north and south of the Szuha valley. (What is more, they are found over most of the interfluve of the Sajó and the Szuha under clay veneer, in places in 50 to 60 m thickness.) It is probable that the poorly sorted gravels coming from the north once covered most of the basin floor. Regarding the features of Sarmatian—Lower Pliocene alluvial fan of the Sajó opening out from Pelsőc (*Lukniš, M.–Plešnik, P.* 1961), the alignment of the *flow of the Ancient Sajó in the direction of the Szuha valley* is also presumable.

The late Miocene mainland period continued almost through the Lower Pliocene. Compared to the Great and Little Plain, the Lower Pannonian formation here is of lesser thickness and facies diversity.[4]

There is no reliable picture as yet of the exact regional extension in the Sajó–Bódva interfluve of the layers of variegated clay and sand locally with thin lignite interbeddings which are regarded Lower Pannonian. According to *Bartha, F.* (1955, 1971) and *Pantó, G.* (1956) a major part of the layers belong to the Upper Pannonian formation, the more recent investigations by *Kretzoi, M.* the presence of the Lower Pannonian formation seems to be proven. The most numerous data interpretable also stratigraphically was supplied by the *Anthropoidea* find in the Pannonian of Rudabánya with lignite seams. In the opinion of *Kretzoi, M.* (1976) these belong to the Bódvaium of the Lower Pliocene. (Bódvaium, named after the Bódva river, represents the Rudabánya stratotype.) The paleogeographical reconstruction based on the fauna in the series point to a peculiar freshwater, terrestrial environment. It can be presumed that rivers running from the mainland flew into the Pannonian sea not being far and fingering into the southern part of the basin and stretching into the Cserehát 'Neogen gap' (*Kőrössy, L. 1971. Jámbor Á.* 1980).

The Pannonian transgression following the Bódvaium and advancing in southwestern direction first reached the margin of the Szendrő Mountains and only the Upper Pannonian marine—lacustrine and subsequently terrestrial series covered the later subsided extended middle and northern sections of the area together with the lower terrains of the Szendrő Mountains and partly the Rudabánya and Aggtelek Mountains. The series is directly deposited on Triassic or Paleozoic sediments in several places and overlies the Sarmatian—Pannonian upper rhyolite tufa or gravel in the centre of the basin. (The Upper Pannonian formation also includes a gravel

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[4] By the data of the State Geological Survey the Pannonian formation here has thickness es between 10 and 150 m, even regarding the Upper Pliocene—Pleistocene denudation, it is only a tenth of those in the basin centre.

bed which is separable only with difficulties from the Sarmatian gravels to the west of the Rudabánya Mountains.)

After the accumulation of the Upper Pannonian formation, sedimentation levelled out the inter-mountain unevenly subsided basin into a flat alluvial fan—accumulation topography. In the closed depressions between calacareous block lignite formation also took place and locally even concretions of paludal iron-carbonat precipitated. (The lignite layers interbedded into clayey—sandy sediments probably belong to the Sümegium.) With the exception of the upper Bódva valley, their extraction is not yet prospective today.

Pedimentation

At the end of the Upper Pannonian inner-lake delta and littoral stage, in the relatively subsided fore ground of the Rudabánya Mountains and partly the Aggtelek and Szendrő Mountains an ever broadening plain was formed of the accumulating alluvial fans accumulating offshore. On this gently sloping terrain water-courses built alluvial fans of the Sarmatian and Pannonian sediments; this was the initial phase of pedimentation. In the Sajó—Bódva interfluve pediments are found, almost without exception, in ruined remains; they originally formed on loose Neogen or locally Mesozoic rocks.

The gently sloping erosion surfaces today located at about 200 to 350 m a.s.l. on mountain margins and in basins, i.e. pediments were first described by *Pécsi, M.* (1962) in the Hungarian literature. In the initial phase of pedimentation the lower, accumulation sections of the half-planes developed more intensively. In accordance with the load transport of rivers, the development of the accumulation zone and the erosion zone alternatingly came to the fore. Subsequently increasing relative relief made the pediments dissect into intervalley ridges. Thus the intervalley ridges of hills as geomorphological surfaces 'may theoretically be regarded as remains of the Pliocene pediment as well as the initial surfaces of Pleistocene valley formation' (*Pécsi, M.* 1982).

The Upper Pliocene tectonic uplift of the mountain frame also promoted pedimentation as a favourable orographic condition. These forms probably formed under the influence of submediterranean climate, occasionally simultaneous to fluvial deposition.

Although the end of the pedimentation period cannot exactly be given, from some remnants of travertines overlying the pediments, their age can be concluded, though dating has broad limits. The travertine at the village of Szalonna (270 m a.s.l.) was dated Upper Pannonian by *Sümeghy, J.* (1924) and *Schréter, Z.* (1951) and Levantan by *Pálfy, M.* (1924); geomorphologically it overlies the pediment. Travertines in the Transdanubian Mountains are of similar position (*Kretzoi, M.—Pécsi, M.* 1979. *Scheuer, Gy.—Schweitzer, F.* 1981) and formed on the boundary of the Lower Villányium and Csarnotarium (about 3 million years ago).

The same can be observed for the occurrences at Rudabánya (Nagy-hegy) and Meszes deposited on Upper Pannonian formations. The travertines at Alsótelekes and Szendrő (Határkút) mentioned by *Balogh, K.—Pantó, G.* (1952) and those found in the Rudabánya boreholes (*Harnos, J.* 1969) are presumable younger, Pleistocene formations (*Rónai, A.* 1975). They also belong to the strip of travertine which originated from karst springs issuing along fault-lines in the southeastern foreground of the Rudabánya Mountains. In some places (Szalonna, Szendrő) lukewarm karst water comes to the surface in ever decreasing amount (*Molnár F.* 1965).

The concretions of spherosiderite locally oxidized into limonite found in the Pannonian sesies around Szuhogy and Ragály formed through the removal and redeposition of the Rudabánya iron ores as it was already pointed out by *Pantó, G.* (1956). They may also be regarded as evidence of Pliocene 'pedimentation'.

Taking sides in the above questions is made difficult by the fact that travertine horizons were buried under sediments removed from summit levels of mountains; subsequently pediments, a part of them at least, were dissected into intervalley ridges lowering and eroded, while in other places the original pediment planes were preserved as geomorphological surfces.

Formation of the hills dissected by terraced valleys

The area between the Sajó and Bódva transformed into a hilly region in geomorphological sense during the Pliocene—Pleistocene epeirogenic uplift following the accumulation of the Upper Pannonian formation.

The rates of movements are indicated by the present positions of Upper Pannonian sediments with lignite deposits which lie at 260 to 270 m at Rudabánya, at 200 m at Szuhogy and at 160 m at Szendrő.

With the uplift of the Borsod Hills and the subsidence of the lower reaches of the Sajó river consequent erosional river valleys, mostly tectonically preformed, took shape in northwest to southeast direction (e.g. the Szuha, Csörgős and Imola streams). Some of the streams running from the terrains of unconsolidated sediments break through the mountains of calcareous rocks in *epigenetic* (and in places *antecedent!*) *valleys* (such as Ormos stream and Bódva river), others disappear in the ponors of the margin of the karst region which are aligned in a line of bathycapture (*Jakucs, L.* 1960) such as the streams of the non-karstic catchment of the Baradla or the Béke cave.

Terraces also attest to the Quaternary evolution of valleys which in places can hardly be separated from each other though due to the subsequent accumulation of slope deposits.[5] In some reaches of the Sajó and Bódva valleys it was still possible to distinguish several terraces. According to *Láng, S.* (1949), *Péja, Gy.* (1956) and *Bulla, B.* (1962) terraces No II—VI and II—V can be identified in the Sajó and Bódva valleys, respectively, which were formed 'in a broad structural trench'.

My observations show that the Sajó valley has no terraces on its right bank; terraces in largest number can be found between Sajókaza and the river-mouth and between the national border and Putnok on the left bank. There are as much as 7 terraces identified in some places.

In the exposure of the Putnok brickyard, research has indicated the presence of terraces No III (169 m and 174 m a.s.l., 16 to 21 m above the present valley-floor) and No IV (182 m and 30 m). Terrace No III is covered with loess derivate and fossil soils. By paleontological investigations loess can be related to the Uppony or the

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[5] The cyclic subsidence of base level is indicated by the travertine horizons at 150 to 270 m traced along the Bódva valley (*Alföldi, L.* 1975).

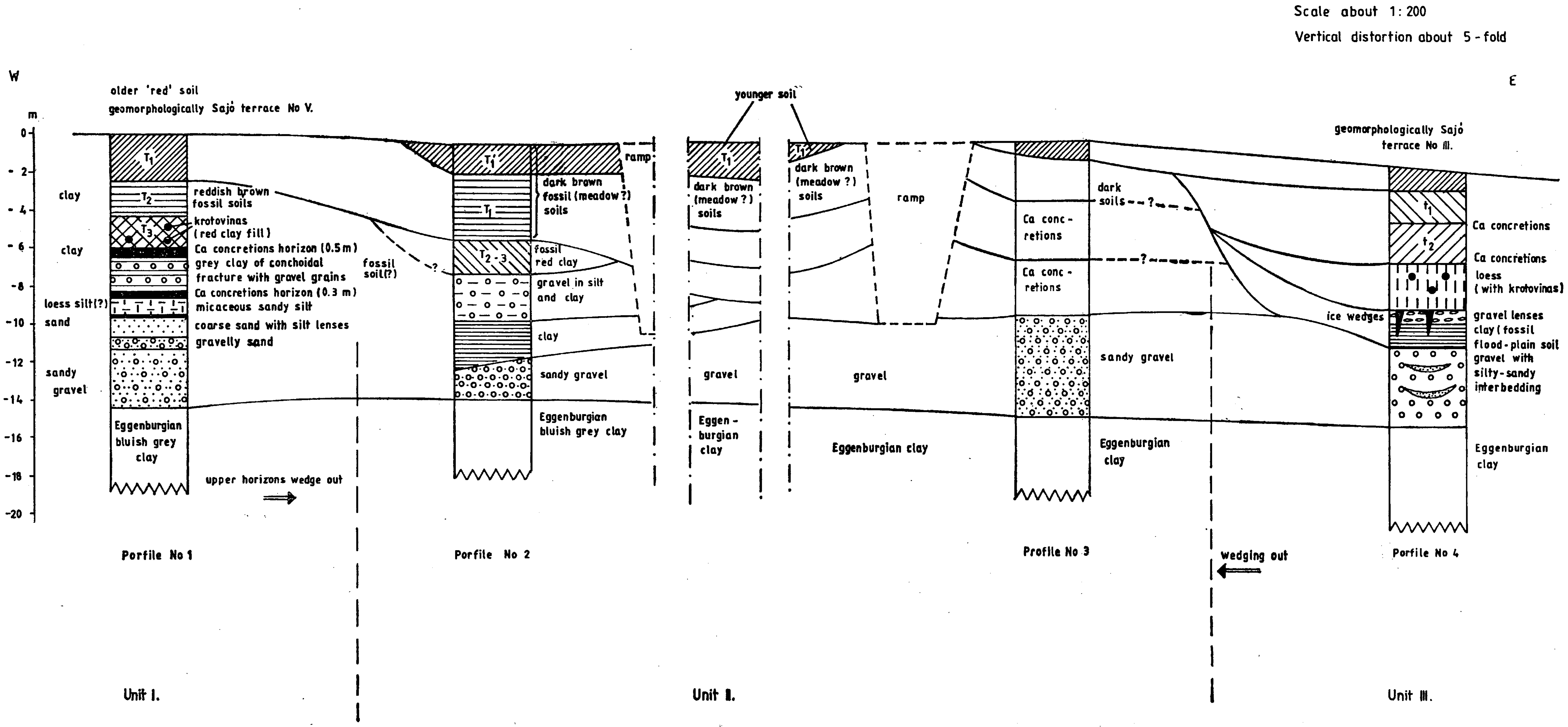

Fig. 4. Some profiles of the rock and accumulation terraces of the Bódva river. (*) In the upper part (to 20 to 22 m depth) of the sequence disclosed by boreholes deposits derived from loess, reddish brown clayey and fine sandy layers alternate (Rónai, A. 1961)

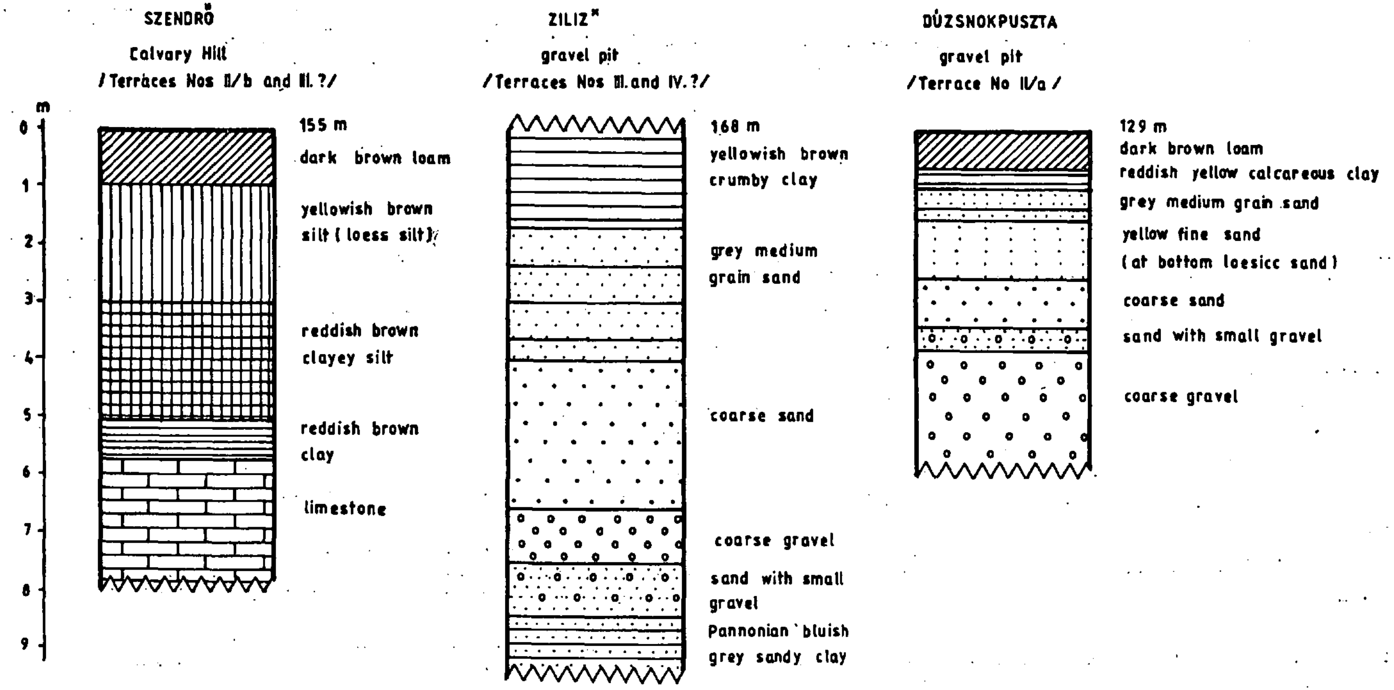

Fig. 5. The terraces of the Sajó as disclosed in the Putnok clay pit

Castellum phases. Upon the terrace No IV pediment material deposited from the north–northeast (occasionally interfingering); it is also covered with fossil soils. To the north of the pit the Templomdomb at Serényfalva and to the the northeast Lódombpuszta represent, in my opinion, terrace No V of the Sajó river (192 to 194 m

Pict. 1. In the Putnok clay pit the gravel series of the Sajó terrace is covered with loess an fossil soil (see Fig. 5., section IV)

a.s.l. and 40 to 42 m relative height). *Láng, S.* (1949) described it as Sajó terrace No IV. There is another surface distinct (e.g. between Bekényhegy- and Miklóspuszta) which seems to be a Sajó terrace, but its material has not been examined yet. The fourth, uppermost Pleistocene terrace described by *Schréter, Z.* (1953) and the terrace No VI identified by *Láng, S.* (1949) between Putnok and Tornalja (Šafarikovo) at 250 to 260 m a.s.l. is rather a Pliocene denudation surface (pediment remain) than a fluvial terrace. Less dissected is the Sajó terrace No II/b at 8 to 10 m above the present valley floor, running all along the valley. The lowest terrace No II/a is, in several places, situated *below* the present valley floor (*Rónai, A.* 1975).[6] This fact and the lack of terraces along the above-mentioned section together point to various accumulation–erosion conditions in this short stretch of the river (*Fig. 5., Pict. 1.).*

In the broad tectonic basins of the Bódva valley, primarily on the right bank, well-developed series of terraces *easy to parallelize with each other* are observed (Fig. 4. and 7.). On the right side of the valley terraces No II/a (at 3 to 4 m relative height), No III (16 to 18 m) and No IV (24 to 32 m) are *gravel terraces*, while No II/b (9 to 11 m) and locally No III are *rock terraces.* The lower terraces converging with the left-bank terraces of the Sajó are mainly buried under loesslike sediments or 'red clays', the higher ones are covered with glacial loam in 3 to 8 m thicknesses. On the left side of the basins, the dissected remains of terraces Nos II and III can be traced (*Rónai, A.* 1961, *Szabó, J.* 1982). The higher surfaces, however, similarly to the situation on the opposite side, coincide *(Fig. 6.).* The analyzed profiles do not contradict to the burial of terrace No II/a under to valley-floor also in certain sections of the Bódva valley.

Narrow floored *erosional–derasional* valleys are highly typical of the Borsod basin built up of unconsolidated deposits; they are *asymmetric* for their majority.

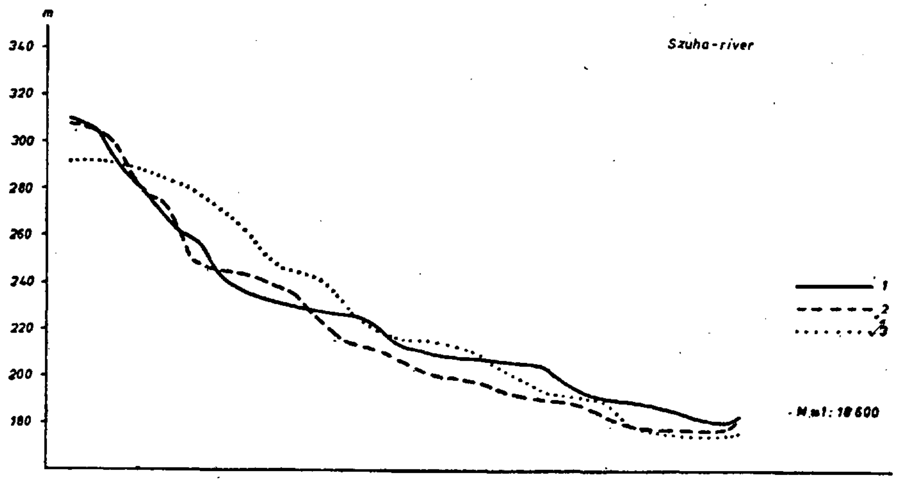

Fig. 6. Superimposed orographic sections from the Szuha valley (direction 50 degrees)
Vertical distortion 8.3-fold
Scale 1:16,600

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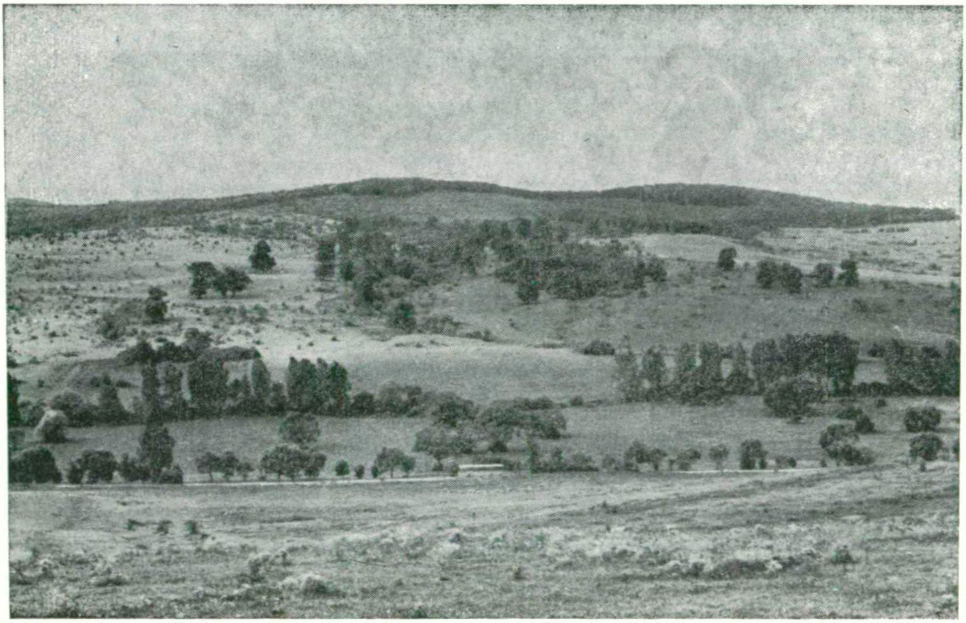
[6] In boreholes deepened into the valley-floor of the Sajó river Upper Pleistocene—Holocene gravel beds are poorly separable. Their thicknesses are 6 to 8 and sometimes 12 to 14 m.

The only exception is the Imola valley which could be explained by the subordinate role of coarse (gravelly) load in its water-course. Typical *derasional valleys* broaden the heads of the Kelemér, Szuha, Imola and Csörgős streams. The last two of them approach to the margin of karst region with their side-valleys. (It is assumed by some that the Imola stream is in hydrogeographic link with the karst through the Ördöglyuk ponor - Szabóczky, P. 1978).

In the valleys and tectonic valley basins of the hilly region 4 or 5 surfaces, among them 2 or 3 accumulation terrace can be differentiated. Upon them, disregarding the mentioned exceptions, there are significant mantles of neither (typical) loess nor extended travertine, they are generally covered with glacial loam.

In the valleys of the basin centre (Szuha and Kis valley) terraces No II/b can be followed all along, the ('main') terraces Nos II/a and III can be identified only locally *(Fig. 6.)*. (The archaeological age of fossil soils just below the surface in the Szuha valley, found to be Early Holocene - *Szlabóczky, P.* 1970, allows the 'lack' of terrace No II/a.) The identification of older terraces and surfaces is made difficult by the slope deposits accumulated by intensive derasional processes, slope levelling and the thick mantles of regolith or solifluctional loam. The merging or cryoplanational lowering of surfaces can best be demonstrated on the example of the terraces Nos II/b and III in the Szuha valley *(Pict. 2.)*. The higher terraces and the locally lowered pediments are scenes for the redeposition of Sarmatian—Pannonian gravelly sediments. Slope processes transformed these terraces into 'valley glacis'.

It is striking that the influence of mass movements still active and intensive is best manifest on the steeper southern and western slopes of the valleys in the Borsod



Pict. 2. Terraces and surfaces in the section of the Szuha valley between Alsószuha and Dövény. The higher terraces (surfaces) are indistinguishable from each other due to cryoplanation.

basin. In my observations it may have resulted in the disappearance of terraces on some valley sides.

Paleozoic—Mesozoic low mountains are generally characterized by *karst corrasional valleys* or *erosional-corrosional gorges.* Such are the Telekes[7] valley, distinctly showing the fault-lines in the Rudabánya Mountains or the Jósva valley formed along the axis of the 'Jósvafő anticline'. These valleys are adjoined by shallow karst erosional–corrosional dry valleys formed above the karst water table. Water-courses are only found in them during snow melt or heavy rainfalls.

As it has been hinted at, several valleys coming from the Neogene surfaces cut through the low and flat horsts bordering the Borsod basin. The epigenetic water-gaps of the Ormos and Rét streams with 'Umlaufbergen' are erosional (in contrast to the erosional–derasional type of the upper reaches). The Bódva valley can also be divided into stretches of different origin.

The section of the Bódva valley between Bódvarákó and Perkupa and the Szendrőlád erosion gorge, regarded antecedent by *Bulla, B.* (1962), formed in a Middle Pleistocene graben. The upper section, the Upper-Bódva basin, shaped in Pannonian sediments.

The valleys cut into horsts usually have no terraces because of the few coarse load. There is a surface only in the section of the Jósva valley between Jósvafő and Szinpetri which can be considered the rock terrace (meander terrace) of the Jósva stream. The sides of these valleys are steep (above 12 or 17 per cent) and often barren cliffs along faults. Although terraces are missing, the intensity of valley cutting can be deduced from various signs of terrace (or surfaces). They are the levels of spring caves[8] along the Bódva, Telekes and Jósva valleys and the travertine horizons of valley-side (slope) type related to the thermal karst springs of the Bódva valley (*Scheuer, Gy.—Schweitzer, F.* 1981).

Derasional relief evolution

Mass movements on hillslopes, besides erosional processes, are of decisive role in the formation of relief in the Borsod Hills.

Slope conditions and relief in general have provided a 'favourable' situation for mass movements on hillslopes. The increasing ratio of smaller slope categories, if there is no decrease in ruggedness and relative relief, can be considered the result of Pleistocene landslides (*Szabó, J.* 1982). (While in the Pleistocene frost action had an increased role, today great winter precipitation can, in this respect, be regarded the most important climatic factor.) The lithological endowments in the area also favour slope movements. Slides are mainly related to the bedding planes as preformed sliding planes of valley slopes of unconsolidated and stratified sediments.

The derasional processes are *also active in recent times* (with lower intensity). They resulted in peculiar mat-like forms of slides mainly under Pleistocene periglacial conditions, on the mantle of clayey—detrital slope deposits.

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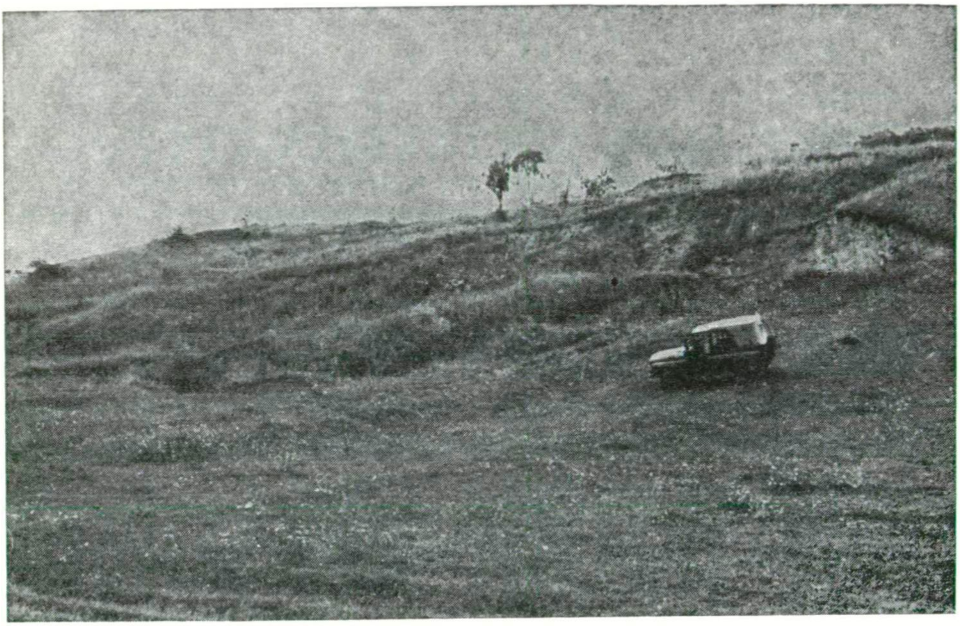
[7] According to *Leél-Őssy, S.* (1952), in the early Pleistocene the Telekes basin had its outlet towards Szuhogy.

[8] On the basis of data by *Jánossy, D.* (1973) and *Kordos, L.* (1974) at least 5 such levels can be distinguished. The latter author believes the caves in the uppermost, 320 m levels are the oldest (Middle Pliocene) in Hungary.

The alteration of slope processes in space and over time and their combinations makes the dating of movements difficult. It seems very probable, however, that the Serényfalva and Kelemér slump systems of large areal extension (in my opinion landslides) analyzed in detail by *Péja, Gy.* (1956, 1962) date back to the lane Pleistocene[9], while the sliced and layered slides on the steeper southern slopes of the inner parts of the basin form even today (*Pict. 3, and 4.*).



Pict. 3. Young sliced landslide northwest of Trizs

Among slope processes, the destruction of soils through derasion affects large areas with gully erosion and slope wash are the decisive processes (Ragály and Szuhafő).

A part of the slides on the Sajó—Bódva interfluve evolve through specific stages of development in accordance with geological and relief conditions; they constitute a derasional succession. The process usually begins with mechanical suffosion, subcutaneous erosion and it can be approximated that through the stages of gully erosion and ovrag (dell) formation it reaches the stage of sliding. *Pict. 5.* shows the surface affected by gully erosion near Ragály (Nyolcrendes-tanya).

On the southwestern slopes of the valleys in the basin and in the dells connecting to the main valleys slides of various types are observed which, with the exception of landslides affecting extended areas (Serényfalva and Zádorfalva), have a sporadic pattern. The most frequently met type is of sliced slides (Imola and Szuha valleys) but lobate slumps are also common (e.g. near the villages of Rónyapuszta and Alsó-

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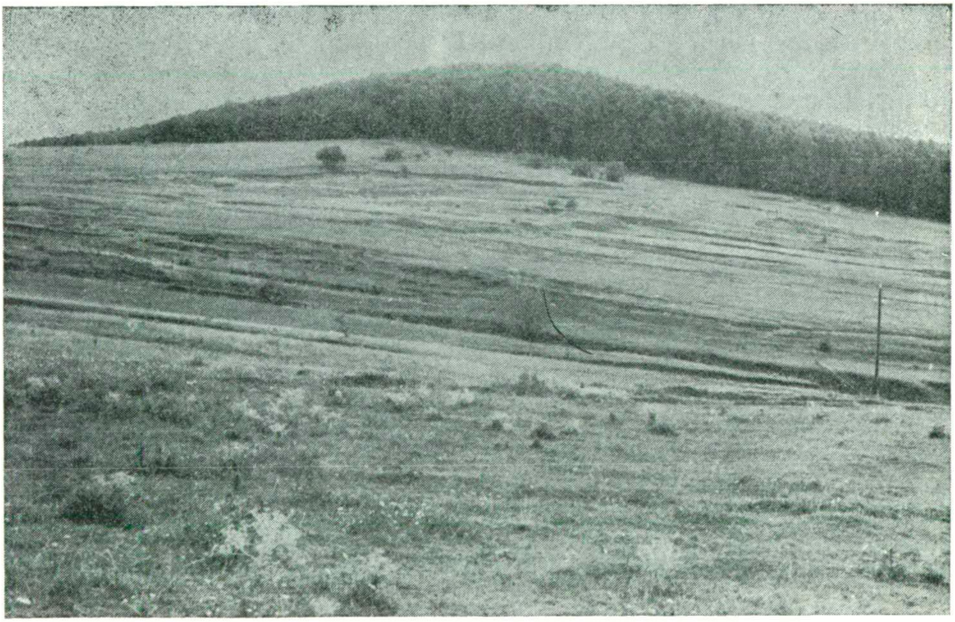
[9] On the basis of palynological analysis of the peat bogs of the Mohos lakes, *Zólyom., B.* (1952) put the origin of the lakes to the late Pleistocene.

Pict. 4. Fossil landslides on the eastern side of the Kelemér valley



Pict. 5. Surface formed by gully and stream erosion in the valley of the Csörgős stream (Nyolcrendestanya)

szuha). These types cause relatively little damage and their prevention is easier. It is disadvantageous for cultivation that the utilization of the surface is restricted over areas with sliding hazards several times larger than the unstable surfaces.

For the prevention of slides and conservation of slopes on unconsolidated sediments in the basin it has to be taken into account that movements take place on sliding planes at little depths. It is observed that the sliding plane is not always clayey, occasionally it can be associated with sand or gravel. (In the previous case sliding is induced by the wetting of a sand layer of less than 1 m depth and the resulting disequilibrium.) On slopes with only a thin soil mantle, materials in large amounts are displaced owing to fros heaving and regelation (soil creep).

Similarly to other hilly regions in Hungary, the Borsod Hills also experienced derasion al valley formation (*Pécsi M.,* 1964, *Szilárd, J.* 1965, *Ádám, L. et al.* 1969 – *Fig. 17.*).[10]

In the glacial stages of the Quaternary, the intensification of solifluction and cryoplanation on valley slopes promoted the formation of derasional valley formation. They presented 'a transitional stage between the dissection of slopes by linear erosion and their lowering by planation' (*Pécsi, M.—Kerekes, S.* 1973). Derasional valleys further shaped not only the remains of the Pliocene pediments, they also formed a narrow pediment in the foreground of mountains of solid calcareous rocks.

The majority of derasional valleys of smaller length forming a dense network further developed by erosion in the late Pleistocene and the Holocene. Typical derasion valleys were those which adjoined to the erosion head and lower-order erosion valleys. (They are often combined with slides of various types.)

The absence of loess in the basin is associated by some with derasional processes. According to Rónai, A. (1975) the remains of loess sporadically found on pediments and terraces indicate an old extended loess mantle. In my opinion *there formed no* thicker and contiguous loess mantle in the Borsod Hills, since the periglacial derasion processes of the Quaternary highly differed in appearance and outcome withslopes of various exposures. (This also applies to Pleistocene–Holocene colluvia and deluvia which also proves continuous as opposed to secondary slope deposit reworking.) In contrast to areas in the centre of the basin, the more humid climate of the Sajó—Bódva interfluve must also be kept in mind.

In the Sajó–Bódva interfluve typical loess is only found on the left-bank terrace of the lower reaches of the Sajó river (south of Ziliz). Loess-like deposits, loess derivates, however, occur on the Sajó and Bódva terraces as well as on the pediments. Most of the surface is mantled with regolith and glacial loam which can be regarded the 'substituent facies' for loess.

Karst forms

During the Pleistocene the Aggtelek and the Rudabánya Mountains were exhumed again or the karst water table gradually sank. On this surface peculiar and diverse set of karstic landforms evolved. The karstic forms of the planated surface, which give a group of *forms* determining the type of karst, differ in the Aggtelek, Rudabánya

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[10] A simplified version of the original map on 1:25,000 scale.

and Martony Mountains (Szalonna karst).[11] This can be best explained with the different *structural* and *morphogenetic* conditions of the mountains rather than with their lithological differences. It is undoubted, however, that lithological features have *restricted* karstification. Such are the iron ore indication of the Rudabánya Mountains and the outcrop of Lower Triassic shales in the Aggtelek Mountains, also traceable by karst springs.

a) The set of karst forms is most complete in the Aggtelek Mountains. Considering the whole of its surface, the Aggtelek *Type B* karst form group is typical for the mountains (*Jakucs, L.* 1971), but the eastern part bears signs of *Type A,* authigenic karstification.

Leél-Őssy, S. (1960) refered Hungarian karst regions into the 'Transdanubian' and 'North-Hungarian' types. The types were mainly defined on the basis of orographic position and geomorphology. *Jakucs, L.* (1977) considered further structural-morphological, lithological, geodynamical and biological factors and the 'Transdanubian' and 'Aggtelek' types defined by him are really geomorphological types. The Transdanubian type is characterized by few surficial corrosion forms, peculiar hydrothermal karst phenomena and strong tectonic preformation. In contrast, the Aggtelek type karst has a developed pattern of dolines and cave formation is allogenic.

The surface corrosion phenomena mostly indicate intensive karstification, well observed in the lapiés fields in the vicinity of Aggtelek. Morphogenetically it is to be emphasized that *lapiés forms,* most of them generated *under* soil cover and were later exposed on the surface by sheet wash. Root lapiés, wide-spread in the area, give evidence to more extended vegetation cover in earlier times and also indicate the decisive role of biogene factors in karstification, underlined by *Jakucs, L.* (1971).

Among the micro- and mesoforms in the karst region, the dolines are undoubtedly the most typical features. Most of them are of *corrosional origin* and, as it has been pointed out by *Jaskó, S.* (1935) they are independent of the underground system of karstic hollows. On their floor ponors sometimes form and thisis reflected in the topography of the dolines.

In the Aggtelek Mountains, especially in its western part, the detailed morphometric investigation of 64 dolines (*Mezősi et al.* 1978) showed that the orientation of dolines corresponds to the predominant north-northteast to south-southeast and east to west tectonic faults and fissures, but the asymmetry caused by bioclimatic factors is also reflected in the groudplans of dolines, i.e. slopes of western and southern exposures are gentler and longer. (The reason for this is to be found in the different thermal and moisture conditions of slopes of different exposure and, through the biogene properties of soils, indirectly in the way of doline evolution dependent on exposure — *Jakucs, L.* 1971, *Bárány, I.—Mezősi, G.* 1977). It was observed that the relief ratio for string dolines along one-time valley axes (cepth per average diameter) is less, generally below 0.1, than for plateau dolines. The result seemingly contradicts our previous expectation that the deepest dolines (of higher relief ratio) should belong to string dolines of more intensive development. This can be explained with the retardment of their evolution occurring after a time due to the clayey regolith washed down from doline slopes; solution intensified along the margins (became lateral), the doline lowered down in an autogerulated way (*Mezősi, G.* 1980) and oc-

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[11] The last of them has not been investigated in detail; thus the forms are assessed here only in outline.

Table 1.

RESULTS OF THE MORPHOMETRIC INVESTIGATION OF DOLINES; TYPES OF DOLINE

	I. String doline type	II. Plateau doline type	
		a. on dolomite	b. on limestone
Density of dolines per km^2	11—13	32—36	7—9
Total doline area in percentage of the karst area	23	32	31
Average doline area per km^2	0.01$^+$	0.002	0.016

$^+$uvalas

casionally merged into an uvala. At the same time, because of their relatively low rate of development, plateau dolines were able to preserve their higher relief ratios for a longer period.

The dolines of the Aggtelek Karst were typified by their morphometry and morpholithogeny and their regional distribution was mapped *(Table 1.* and *Fig. 8.).*

The western part of the Aggtelek Karst is characterized by *extended allogenic cave systems* (Baradla, Béke, Szabadság and other caves). In their origin the leading role was played by Upper Pannonian gravels deriving from the non-karstic catchments of the caves. The investigation of deposits of assumably original (in situ) position accumulated on the terraces of flood-level platforms of passages in the Béke cave indicates their time of origin in the Würmian (*Mezősi, G.* 1976). It is probable that the formation of hollows can be dated back to the Günz/Mindel Interglacial.

The eastern part of the karst region (Alsó-hegy) is an independent orographic and karst hydrological unit. On the surface large plateau dolines and corrosional avens developed from them are found (above 50 in number). On the Nagy-fennsík (Great Plateau) there are the deepest avens in the country (the Vecsem-bükk and Almás avens) which are connected hydrogeographically to the karst springs along the Torna stream (*Sárváry, I.* 1971).

The most debated formation in the mountains is the *terra rossa* deposits dated as Quaternary from their position. The *terra rossa* (or *terra fusca*) mantling the surface locally in 10 m thickness can partly be regarded as a product of karst corrosion (*Jakucs, L.* 1964, *Zámbó, L.* 1970) and, therefore, it is of *Pleistocene age.* (It is locally deposited on the fragments of the red clays overlying the Upper Pannonian gravels of the adjacent area from the south which have been reworked over the karst surface.) At the same time, the weathering, erosion and removal over this area of the volcanic tufas in the neighbouring areas must also be taken into account.

Recently, *Jakucs, L.* (1977) describes Lower Cretaceous fossil cone karst in the uvala of the Vörös-tó (Red Lake) at Aggtelek which were exhumed from below the Cretaceous *terra rossa* and are under further karstification today. In my opinion, too, the mountains had undergone tropical planation by the late Cretaceous. It can be assumed, however, that the development of the Medve (Bear) cliffs near Vörös-tó was governed by the mutual effect of local variance in rock structure (*Scholz, G.* 1972) and doline evolution.

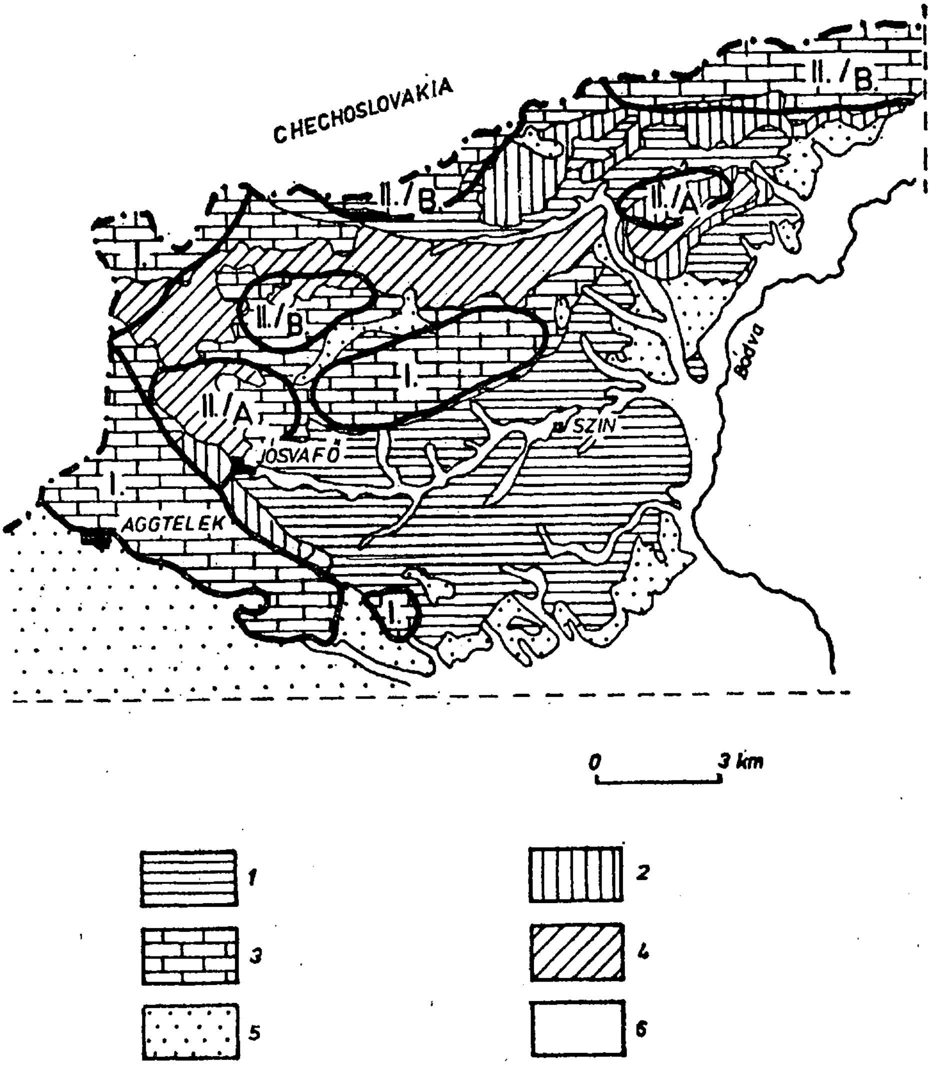

Fig. 8. Types of doline of the Aggtelek Karst.
1 = Lower Triassic (Kampilian) limestone and argillaceous schist; 2 = lower Triassic (Gutenstein) limestone and dolomite; 3 = Wetterstein limestone; 4 = Wetterstein dolomite; 5 = Pliocene gravel and sandy gravel; 6 = extended Holocene fluvial deposits; I = doline series; II = plateau doline (A = dolomite subtype, B = limestone subtype.)

b) In the Rudabánya and Martony Mountains, owing to the above detailed lithological and structural reasons, a form assamblage different from the Aggtelek one was shaped. Its karst phenomena bear the features of the 'Transdanubian' authigenic type, especially typical in the Martony Mountains. The peculiar lapiés forms and the dolines on the Dunna-tető are accompanied by hydrothermal cave formations, primarily avens (e.g. the Szárhegye aven). As a consequence of the uplift of the mountains as a horst and its tectonic dismembering, ponors with non-karstic catchments could not form; only spring caves were shaped which adjust to the current base level (e.g. Telekes valley).

Relief types[12] and geomorphological surfaces

The relief of the Sajó–Bódva interfluve of heterogeneous morphogenetics was referred to the geomorphological mesoregion of 'inner-Carpathian mountains of medium height and series of basins' by *Pécsi, M.—Somogyi, S.* (1967). In a *structural-morphological* sense it belongs to the folded (faulted) Alpine overthrust zone in 'inner' position. It is bordered by the Slovenské Rudohorie in the north, the Uppony-Szendrő Mountains in the southeast (they are old tectogene massives), and the planated horsts of the Bükk Mountains formed on folded–faulted structure (*Pécsi, M.* 1975). The central Tertiaty intermountain basin is open to the west and communicates with the Rimaszombat basin (*Demek, J.—Strida, J.* 1971).

In the terminology of relief types I intended to use term in accordance with the categories introduced for the Transdanubian and North-Hungarian Mountains by *Pécsi, M.* (1969, 1974, 1981), *Pinczés, Z.* (1970, 1977), *Székely, A.* (1970, 1977) and *Leél-Őssy, S.* (1979), as far as I was allowed by the features of the region.

I differentiated between three, typologically different relief units in the Sajó–Bódva interfluve which can be further divided.

A) The Szendrő Mountains in the eastern–southeastern corner of the region is a *peneplanated Paleozoic block mountains of tectogene* (folded–faulted) *structure* in a morphogenetical sense.

The stratification of the building materials (metamorphic sandstone, shale and limestone) of the mountains of northeast to southwest strike (east to west in the north) indicates a seemingly uniform and continuous cycle of sedimentation. The ages of formations are debated, it seems probable, however, that the northeastern and the southwestern series is older (Devonian) than the central member of Lower Carboniferous age (*Mihály, S.* 1976. 1978).

This massive is a Variscian remain and as such it is the oldest member in this topography of mountains of medium height. Its surface underwent planation in the late Paleozoic and again in the Cretaceous and later it was buried under various Paleogen and Neogen sediments. Since the second half of the Neogen it reached a threshold and then a pediment position and was gradually exhumed. Bulla, B. (1962) interpreted the flat, truncated surface as a Neogen peneplain.

In our opinion it is an old buried peneplain which was only transformed by pediplanation in the Pliocene. The exhumation of the dismembered mountains was not complete as it is attested by the Miocene cover sediments of the southeastern part. The late Pliocene pediment relief acquired, due to the movements of uplift in the Quaternary, hill and locally low mountain positions. By the late Pleistocene slopes

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[12] Relief type is conceived as a broader category than orographic type. The former is not only a morphographic evaluation of relief, but includes the aspects of genesis and structural morphology *together*. In this sense the term 'relief type' is almost synonymous to 'geomorphological type'. For the scale of the investigation in the present study 'relief type' is, for most of the cases, to be understood as 'relief subtype'.

were covered by a thin veneer of loam and locally loess. (As it is observed, for instance, in the exposure of the Szendrő stone pit.)

B) In a structural-morphological sense, the Rudabánya and Aggtelek Mountains are *peneplanated Mesozoic horsts of folded-faulted* (in some opinions nappe) structure which were repeatedly buried and exhumed in the Tertiary. Due to the Tertiary tectonic movements, they were dismembered into blocks of independent evolution (and various degrees of denudation). (They are primarily characteristic of the Martony Mountains.) For their different geomorphic evolution and position they represent a relief subtype different from the previous. Orographically they are low mountains now.

Their generalized evolution can be summarized as follows:

In the first part of the Mesozoic they were geosynclines which became land surfaces from the Upper Triassic and underwent tropical subhumid peneplation until the middle Cretaceous. The low, 'karstic' tropical peneplain was heavily dismembered by intensive faulting in the late Mesozoic.

Although climatic conditions remained to be favourable for a (regional) planation covering the whole area of Hungarian mountains, heavy tectonic movements turned them into the pediments of the northern and southern, more elevated crystalline mountains. Thus geomorphologically it can be assumed that peneplanation ended with pediplanation.

In a subordinate extent in the Paleogen and mainly in the Neogen they were buried under sediments of various thickness and quality. They were sculptured into *partly or completely exhumed low mountains of horst-and-graben structure* as a result of tectonic movements restricted to individual blocks and the subsequent erosional activity. The old horsts, after the removal of their late Tertiary sediment mantles were subjected to pedimentation.

According to the investigations by *Láng, S.* (1955, 1978) and *Jakucs, L.* (1964) the earlier supposed Pliocene karstic peneplanation had neither climatic nor karst hydrological conditions (the latter because of the high karst water table).

Also considering the differences in orography and evolution, the following types of horsts are differentiated (sometimes in combination with one another:

a) uncovered peneplanated horsts in summit position covers the *completely exhumed* plateau of the Aggtelek and Martony Mountains which underwent *intensive karstification* in the Quaternary.

b) Medium elevated peneplanated horsts include the central mass of the Rudabánya Mountains preserved by ore indication ffom which the obe-time Paleogen cover has been completely removed during the Tertiary–Quaternary,

c) semi-exhumed peneplanated horst reshaped by pedimentation with mosaic of Oligocene and Miocene sediments of various thickness (e.g. the margin of the Rudabánya Mountains).

These relief subtypes often occur in different orographic positions, but it does not mean that they differ morphogenetically. (Thus the higher elevation of a surface does not necessarily indicate older age.) It would have been erroneous to differentiate between them on the basis of their elevation. There interpretation seemed feasible applying *Pécsi*'s principle of buried and exhumed surfaces (1975, 1981).

To identify geomorphological surfaces on uncovered horsts and to date their resculpturing were difficult tasks. In investigations directed to this end we had the

Fig. 9. Major geomorphological surfaces of the Sajó—Bódva Interfluve, Scale 1:100,000
1 = terrace no II/a; 2 = terrace no II/b; 3 = terrace no III, travertine horizon; 4 = terrace no IV, travertine horizon; 5 = terrace no V; 6 = Upper Pliocene pediment (in some places red clay formation); 7 = surfaces of lower interfluvial ridges and derasion steps, remnants of older pediments; 8 = higher summit surfaces of hills and interfluvial ridges (initial surfaces of Quaternary valley formation); 9 = remnants of Neogen peneplains; 10 = semi-exhumed peneplanated horsts transformed by pedimentation (covered with Paleogen sediments); 11 = medium uplifted planated horsts (exhumed in the Tertiary and Quaternary); 12 = completely exhumed, intensively karstified uncovered planated horst in summit position; 13 = remnants of peneplains of Paleozoic formations buried and exhumed several times, 14 = major strip mine

general geomorphic evolution of the Hungarian Mountains and its interpretation as a useful starting point *(Fig. 9.)*.

C) About 60 per cent of the are between the Sajó and the Bódva rivers is occupied by the Borsod Hills of Oligocene and primarily unconsolidated Neogen sediments and relief sculptured in the Quaternary. Structurally it is a young *inter-*

mountain basin of the North-Hungarian Mountains and geomorphologically a *relief type of erosional-derasional hills.*

As a consequence of Pleistocene erosional-derasional processes and the subsidence of base level in the Sajó valley the Borsod basin was dismembered into a sequence of low longitudinal intervalley ridges of northwest to southeast strike. Thus on the late Pliocene surface of low relief, the Pleistocene uplifting and denudation produced two and locally three geomorphological surfaces. Just because of these processes larger contiguous plateau surfaces could not form. The only exceptions are the surfaces of eruptive materials between Kelemér and Szuhakálló which are possibly remains of the *Pliocene denudational surface.* Upper Pliocene *pediments* provide the link between the Borsod basin and the neighbouring horsts. In the Pleistocene they were dissected into *low intervalley ridges* by various erosional processes (see *Fig. 9.).*

The above outlined relief types got into their present positions mainly by tectonic movements. Upon them peculiar, tectonically preformed exogeneous forms and frequently repeated groups of forms sculptured which took final shape through erosional-derasional processes.

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