MÁRTON PÉCSI • GEOMORPHOLOGICAL REGIONS OF HUNGARY

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STUDIES IN GEOGRAPHY IN HUNGARY, 6

The author's aim is to give a picture of the form groups constituting the individual regions in Hungary. Details on their genetics, structure and types are included. The elaboration of the principle and methodical approach of classification by regions is based on the author's extensive research who also established the taxonomical units in the various regions.

The relief properties, such as geostructural, morphological, litological, orographical, have been considered as decisive factors in this work. It is owing to this complex treatment of the subject that the hierarchy of the regions could be determined and their boundaries precisely delimited.

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Geographical Research Institute,
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by

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GEOMORPHOLOGICAL REGIONS OF HUNGARY

1. EVOLUTION OF THE MOUNTAIN AND BASIN STRUCTURES

Hungary is situated in the middle of a basin[1] surrounded by the Alpine, Carpathian and Dinaric mountain ranges. The roundish Pannonian Basin is a relatively recent form, due to the Tertiary subsidence of the Variscan basement, concurrently with the uplifting of the encircling mountains.

Prior to the evolution of the basin state, by the end of the Palaeozoic, the Variscan basement became considerably shattered; its surface was subsequently furrowed in the early Mesozoic by parallel marine troughs of northeasterly trend. It was in these troughs that the Triassic, Jurassic and Cretaceous limestones and dolomites of what are today the Hungarian Mountains came to be deposited. Most extensive in the Triassic, these troughs underwent a considerable regression in the Jurassic and Cretaceous; on the surface of Triassic rocks exposed to subaerial weathering, a needle-karst-type planation, as well as laterite and bauxite formation, took place under a tropical climate in the Cretaceous and partly also in the early Tertiary.

Intense volcanism in the Upper Cretaceous was preliminary to the folding up of the Carpathian mountainous frame and to the subsidence of the block-faulted Mesozoic in the intra-Carpathian zone and in the basin interior. In the Eocene, the previously peneplanated Mesozoic blocks subsided in a mosaic pattern. The present-day Variscan basement formed, on the other hand, connected masses intercalated between the Mesozoic troughs, also during the evolution of the Carpathian frame, although parts of it were inundated by the early Tertiary seas. Large portions of it rose, however, during the Oligocene (indeed, some blocks of it even during the Miocene) as medium-altitude planated mountain stumps above the Mesozoic zones under the present-day Little Plain and Great Plains.

The most intense subsidence, and the conversion into a basin basement, of the crystalline was likewise preceded by intense volcanism. This megastructural-morphological change — the inversion of the relief — had begun in the Miocene, on the Helvetian-Tortonian border. The volcanism occurred along the marginal faults of the basin in one of the largest young volcanic girdles of Europe. The representatives of this girdle on Hungarian territory include the Visegrád and Börzsöny Mountains, the Cserhát Hills, the Mátra and Tokaj–Zemplén Mountains. These were produced by repeated eruptions, generally growing younger from west to east, and definitely ending in the Pliocene. This process went on concurrently with the folding up of the Flysch

[1] This basin is variously called the Carpathian, Pannonian and Middle Danube Basin in geomorphological literature.

Carpathians and with their uplifting, balanced by the stepwise and gradually accelerating subsidence of the Pannonian Basin. With regard to its crustal structure, the Pannonian Basin has a highly peculiar, unique configuration, whose traits have only recently been outlined by geophysical investigations, seismic deep sounding in particular. According to the results of these, the crust is 20 to 24 km thick beneath the basins, thinner than the world average; the encircling mountain ranges which have grown out of the Alpine–Carpathian–Dinaric geosynclines have a crust 32 to 60 km thick. Below the basin, the Moho surface forms a closed dome. Above it, the geothermal gradient in the basin is rather high.[2] The crust is thinnest where subsidence was deepest. This considerable thinning of the crust, as well as the abnormally close spacing of the Conrad and Moho interfaces, has been partly attributed to Tertiary volcanism: subsidence has in turn been attributed to a mass defect beneath the crust, brought about by volcanism (Balkay 1959, Szénás 1968). A factor presumably contributing to the thinning of the crust in the basin may have been the denudation of the uppermost crustal zones. The vast bulk of the products of denudation was redeposited in the foredeeps and in the flysch zone.

Although the partial subsidence of the basin had begun in the Upper Cretaceous, the basin as a morphological feature came to exist only in the late Tertiary, at the time of the greatest extent of the Pannonian sea. It became a continental basin in the geomorphological sense during the Upper Pliocene and the Quaternary. Hence, in a tectonic and morphological sense the Pannonian basin is a young structural basin filled by marine, and subsequently by fluvio-lacustrine, fluviatile and eolian sediments, whose subsidence was partly due to the synorogenic crustal displacements of the Carpathian upfolding and to the volcanic eruptions in the intra-Carpathian volcanic belt.

2. TYPES OF GEOMORPHOLOGICAL REGIONS

Hungarian geomorphologists have as a synthesis of their previous research prepared in the last few years a general geomorphological map of the country. On the basis of this map, and using the methodological principles laid down by the present author, Hungarian territory was subdivided into a number of geomorphological regions (Pécsi and Somogyi, 1969). In modern times, when nature is being increasingly affected by the all-encompassing activity of human society, it has become indispensable to record the state of the relief and the qualitative and quantitative trends of the dynamic changes taking place on it, as well as to carry out general and detailed mapping of these, region by region.

An evaluation of the overall relief features resulted in the traditional distinction of six geomorphological macroregions[3]: (1) the Great Plains, (2)

[2] In the basin, temperature rises 1 °C per 18 to 20 metres of depth; the corresponding figure is 40 to 50 metres in the mountain frame.

[3] Some of these regions extend to a considerable depth beyond the frontiers, into the territories of adjacent countries.

the Little Plain, (3) the foothills of the Alps, (4) the hilly regions of Transdanubia, (5) the Transdanubian Mountains and (6) the Intra-Carpathian mountain chain and its intramontane basins.

Within the morphological macroregions of Hungary one can distinguish a number of types of geomorphological regions, each with a certain degree of homogeneity in constitution and evolution.

(a) The geomorphological regions of the Great Plains and the Little Plain have been grouped in three main types:

Floodplains and low alluvial-fan plains (1.1, 1.4, 1.5, 1.9, 1.10, 1.11, 2.1 in Fig. 1).

Alluvial-fan plains higher than storm flood level, covered with fluviatile deposits (1.2, 1.6, 2.2, 2.3, 2.4 in Fig. 1).

Alluvial-fan plains covered with eolian deposits (1.2, 1.3, 1.7 in Fig. 1).

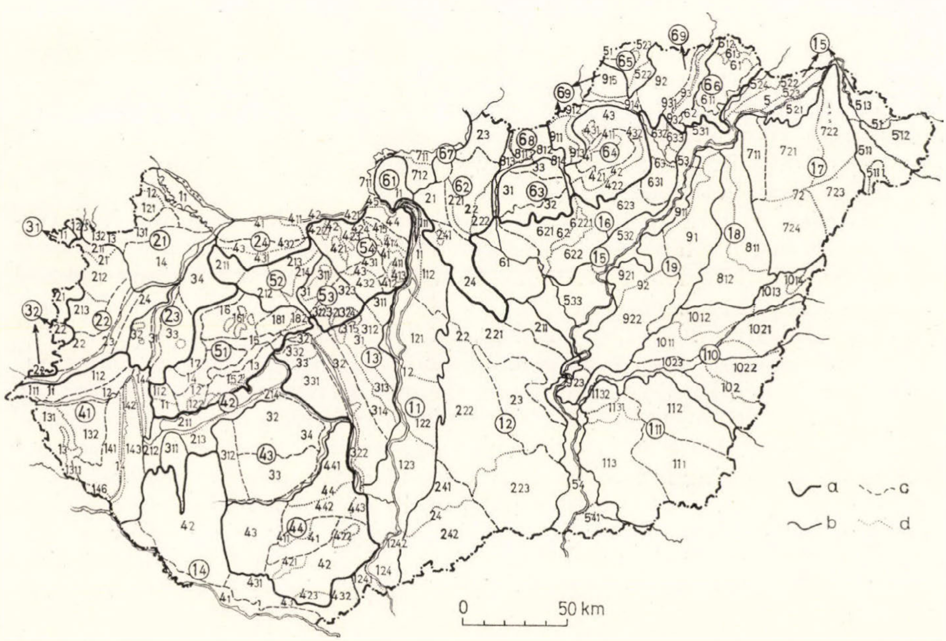


Fig. 1. Geomorphological regions of Hungary (after Pécsi and Somogyi, 1969)

1 — Great Plains; 1.1 — Danube Plain; 1.2 — Divide between Danube and Tisza; 1.3 — Mezőföld Plain; 1.4 — Drava Plain and plain of Inner Somogy; 1.5 — Tisza Plain; 1.6 — Northern Great Plains alluvial-fan plain; 1.7 — Nyírség; 1.8 — Hajdúság; 1.9 — Nagykunság–Hortobágy grassland; 1.10 — Berettyó–Triple Körös Plain; 1.11 — Maros alluvial-fan plain
2 — Little Plain; 2.1 — Győr Basin; 2.2 — alluvial-fan plain of Sopron and Vas County; 2.3 — Marcal Basin; 2.4 — terraced plain of Győr–Esztergom
3 — Foothills of the Alps; 3.1 — Sopron Hills; 3.2 — Kőszeg Hills, Vas County piedmont surface
4 — Transdanubian hilly regions; 4.1 — Hills of Upper Vas and Zala counties; 4.2 — Lake Balaton Basin; 4.3 — Somogy County Hills; 4.4 — Mecsek Mountains and Hills of Tolna–Baranya
5 — Transdanubian Mountains; 5.1 — Bakony; 5.2 — Hills in the foreland of the Bakony and Vértes; 5.3 — Vértes Mountain and Velence Hills; 5.4 — Dunazug Mountains
6 — North Hungarian Mountains and intramontane basins; 6.1 — Börzsöny Mountains; 6.2 — Cserhát Hills; 6.3 — Mátra Mountains; 6.4 Bükk Mountains; 6.5 — North Borsod Karst; 6.6 — Tokaj–Zemplén Mountains; 6.7 — Middle Ipoly Basin; 6.8 — Hills between Zagyva and Tarna Rivers; 6.9 — Sajó–Hernád Basin; *a* — limit of macroregion, *b* — limit of region, *c* — limit of subregion, *d* — limit of microregion. (For detailed decimal subdivision cf. the paper by Pécsi and Somogyi in *Földrajzi Közlemények*, 1967, pp. 285–304)

(b) The hilly regions, largely modelled in little consolidated Tertiary and Quaternary deposits, could be grouped in a single type (4.1, 4.3, 5.2, 6.9 in Fig. 1).

In certain instances, such hills constitute hilly-type regions together with smaller Palaeozoic or Mesozoic knolls (e.g. 4.4, hills of the Mecsek–Baranya region).

Hilly types of relief almost invariably accompany also the low mountains of the country, in the form of subregions or micromorphological regions, and combined with forms of the small intramontane basins, the dissected pediments and glacis of the mountain borders.

(c) There are three types of mountainous geomorphological regions:

Palaeozoic folded-imbricated and/or faulted type. An independent region of this type is the extension into Hungarian territory of the crystalline core of the Alps (3.1 in Fig. 1; Subalpine region).

Mesozoic, largely block-faulted, partly folded and imbricated type (5.1, 6.4 in Fig. 1). Connected with these units, there are small subregions or microregions of Palaeozoic crystalline rocks or young volcanics (5.3, 5.4, 6.5 in Fig. 1). These accessory elements are in a close structural and morphological connexion with the first-named dominating elements. A similar situation prevails in the Mecsek–Baranya region of low mountains embedded in a hilly region (4.4 in Fig. 1).

In the macroregion of the intra-Carpathian mountain chain and its intramontane basins, the late Tertiary volcanic mountains constitute independent geomorphological regions (6.1, 6.3, 6.6 in Fig. 1). The smaller and isolated volcanic units have been grouped with the hills of different nature among which they occur (5.4, 6.2, 6.8 in Fig. 1).

(d) Independent valley-type geomorphological microregions or subregions have been distinguished not only along the plains rivers (the Danube and the Tisza), but also in the valleys of the medium-sized rivers of the mountainous and hilly regions. These are usually small geomorphological units intercalated between and differing in fundamental traits from the adjacent regions. Small valleys usually do not attain the rank of an independent region or subregion: they can be valued as morphofacies groups or possibly microregions within a given region. The distinction of these valleys as independent morphological units is justified, not only by morphological principles, but also from the viewpoint of economic practice (cf. Fig. 1).

3. CHARACTERIZATION OF THE GEOMORPHOLOGICAL REGIONS HUNGARY

THE HUNGARIAN GREAT PLAINS

This morphological macroregion encompasses almost half of the country's territory. It does not everywhere stand apart sharply from its surroundings, either structurally or morphologically. Its evolution history and the aspect of its surface are more uniform than those of the other regions: it is a true plain, formed by the accumulation of Pleistocene and recent fluvial and eolian deposits.

In the last two decades, prospect wells and geophysical surveys have added considerably to the knowledge of its geology. Data collected so far have revealed the basin basement to be a parallel system of northeast-trending buried faulted ranges of Mesozoic and Palaeozoic rocks. The Palaeozoic includes gneiss, clay shales and mica-schists, whereas the Mesozoic largely consists of dolomite, limestone and clay marls (Fig. 2). The basement is

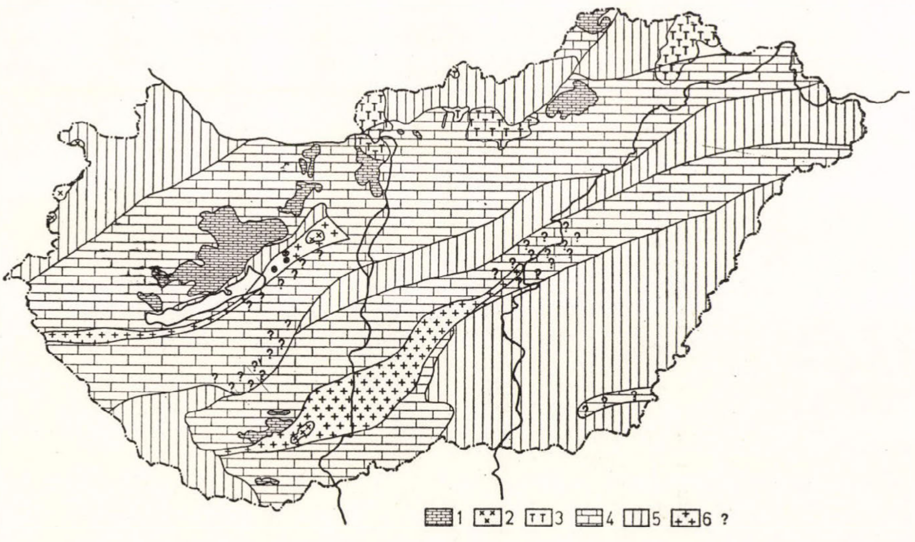


Fig. 2. Outline of the basement structure of Hungary (after J. Fülöp and V. Dank, 1967)

1 — Mesozoic, exposed; 2 — Palaeozoic (crystalline), exposed; 3 — volcanics, exposed; 4 — Mesozoic basin basement; 5 — Palaeozoic basin basement; 6 — crystalline basin basement; ? — supposed basin basement

rather shattered, with buried horsts, small basins and deep furrows dissecting its surface. This fundamental relief of the Great Plains formed for the most part a continental relief in the early Tertiary (Eocene, Oligocene, Lower Miocene). The Great Plains subsidence set in in the late Tertiary (from the Middle Miocene onwards) and intensified in the Pannonian stage. The process of basin evolution was interrupted in both space and time. Parts of the basin — the areas along the Upper and Middle Tisza — had already begun to sink in the Upper Cretaceous. The late Tertiary (mostly Lower and Middle Pliocene) foundering of the central portion of the basin is proved by Pannonian deposits directly overlying in places the crystalline basement. The rate of subsidence may be inferred from the thickness of the clayey, marly and sandy deposits of the rather shallow and none too long-lived Pannonian sea, which locally exceeds 3,000 metres and attains 1,000 metres over large areas (Fig. 3).

In the second half of the Pliocene, the uplifting of the basin rim cut off the Pannonian sea from the main body of the Mediterranean. At first, it was connected through the present-day Iron Gate with the Black Sea, but subsequently it contracted to a shallow lake similar to the Caspian Sea.

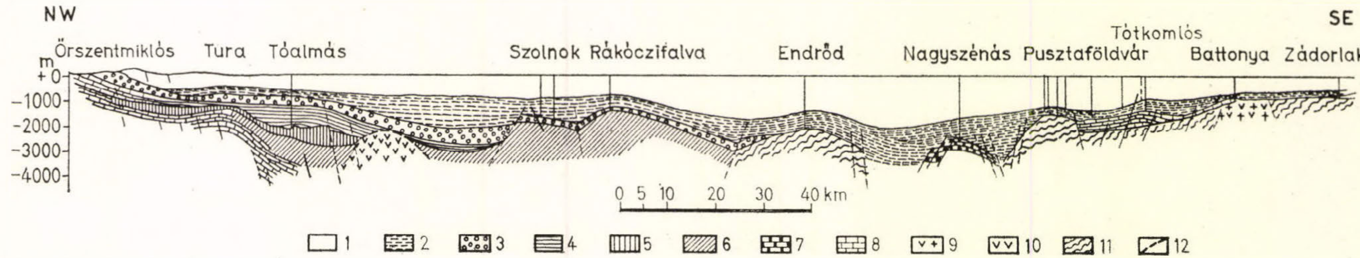


Fig. 3. Geological profile of the basin basement of the Hungarian Great Plains (after Gy. Kertai)

1 — Upper Pannonian sand, clay; 2 —Lower Pannonian clay, clay marl; 3 — Miocene clay, sand, conglomerate, tuff; 4 — Oligocene clay, sandstone; 5 — Eocene calc marl; 6 — Palaeogene and Cretaceous flysch; 7 — Jurassic marl; 8 — Triassic dolomite; 9 — granodiorite, slightly metamorphized; 10 — inferred igneous and metamorphic masses; 11 — Early Palaeozoic metamorphics; 12 — fault zones

This was then filled up by increasing amounts of waste brought in by the rivers running off the encircling mountain frame. The subsidence of the central part of the Great Plains basin also went on, however, after the full disappearance of the Pannonian sea. In the sub-basins, which subsided at unequal rates, several hundred metres of fluviatile and subaerial sediment came to be deposited over the Pannonian. The post-Pannonian sequence is thickest in the southern Great Plains where it is composed largely of Quaternary sands, clays and silts almost 1,000 metres thick. Observations indicate that the Great Plains subsidence is still going on today.

All in all, the evolution of the Great Hungarian Plains falls into two main chapters. In the first, the relief was the opposite of what it is today. Instead of the big basin, there were up to the end of the Mesozoic block-faulted mountains separated and dissected by grabens. It is in the second chapter that the basin of today gradually came into existence, as a result of a subsidence that had begun in the early Tertiary and went on accelerating and covering more and more space throughout the Neogene. The last brush strokes on the picture were the dissection by the Quaternary drainage network and the activity of the winds.

Alluvial fans higher than storm flood level
The Pleistocene alluvial fan of the Danube in the Great Hungarian Plains

The alluvial fans of the smaller streams issuing from the Transdanubian hills into the Great Plains, coalescing with that of the Danube, together constitute the divide between Danube and Tisza, which surmounts the floodplains of those rivers by some 50 metres. Most of this divide is covered with wind-blown sand dunes of northwest-southeast trend. At the end of the Pleistocene and in the early Holocene, these were blown by northeasterly winds out of the alluvial fan of the Danube. There still are some small spots where the sand is moving and the wind is producing fresh forms. However, the unbound dunes west of Kecskemét and in the southern part of the divide represent only vague traces of earlier conditions.[4]

On the divide between Danube and Tisza, there are, in addition to the wind-borne sand, some loess zones of northwest-southeast trend. There are three loess-covered microregions:

(a) the loessy hills of Gödöllő–Monor east of Budapest (6.24)

(b) the flat loess rises between Kecskemét and Nagykőrös (1.23)

(c) the loess rise of the Bácska (2.42) the southernmost portion of the divide.

The portion reaching into the outskirts of Budapest of the divide between Danube and Tisza is called the Pest Plain. In this microregion, even the

[4] Early in the last century, most of the dunes were covered by grassland that was at best good for grazing. Since then, however, the rolling sands have been stabilized by afforestation, and by the planting of orchards and vineyards. This activity has resulted in the formation of a layer of rich topsoil on the sands. On the divide between Danube and Tisza, between the longitudinal and parabolic dunes, there are wet and waterlogged areas. These undrained hollows once contained alkali lakes, drained since by a complicated system of ditches.

older Pleistocene alluvial-fan terraces of the Danube are uncovered. The most elevated and oldest of them is the Günz-pre-Günz gravel fan. In the Pest Plain, there are — not counting the floodplain surface of the Danube — four more Pleistocene alluvial-fan terraces (Fig. 4), proving that on the border of the Great Plains the formation of the gravelly alluvial fans of the Danube was a continuous process from the early Pleistocene (Pécsi, 1959).

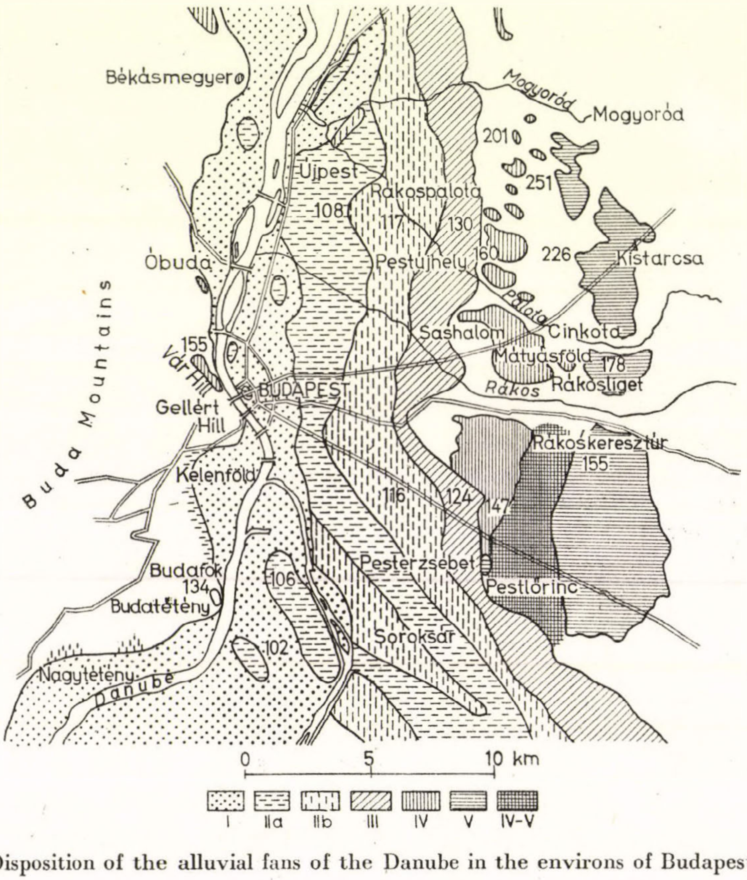


Fig. 4. Disposition of the alluvial fans of the Danube in the environs of Budapest

I — Holocene floodplain; IIa — Late Upper Pleistocene terrace (Würm); IIb — Early Upper Pleistocene terrace (Riss-Würm); III — Middle Pleistocene terrace (Riss?); IV — Early Pleistocene terrace (Mindel); V — Lower Pleistocene terrace (Günz-pre-Günz); IV–V — Terrace IV overlain by Terrace V

Morphologically the Mezőföld (1.3) is part of the Great Plains. It consists of older, Middle and Upper Pleistocene alluvial-fan zones of southeasterly trend with loess rises intercalated between them. Both types overlie Pannonian clay and sand, exposed in the steep bluffs looking down on the Danube, together with the overlying loess whose thickness attains 60 m locally (Fig. 5).

Alluvial-fan plain of the Northern Great Plains (1.6)

The northern border of the Great Plains is a string of alluvial cones formed in the Pleistocene by smaller streams. In the Holocene, the continued subsidence of the Great Plains resulted in the dissection of this connected alluvial-fan slope into interfluvial ridges. On the other hand, its lower portion in the Nagykunság (1.9) was cut off by the Holocene floodplain of the Tisza from its root region.

On the sunny, southerly slopes of the North Great Plains alluvial fan, there grow some of the most typical examples of the excellent fruits and grapes of Hungary. Conditions most favourable to wine growing exist in the vicinity of Gyöngyös and Eger.

Alluvial fan of the Nyírség (1.7)

The Nyírség is a large Pleistocene alluvial fan surmounting the third floodplain horizon in the Northeastern Great Plains. Its relief in many ways resembles the alluvial-fan plain of the Danube. It was deposited by rivers belonging to the drainage systems of the Tisza–Szamos–Kraszna on the one hand, and of the Bodrog on the other (Z. Borsy, 1961). This region was slightly uplifted against its surroundings in the early Holocene — or, in other words, its environment had subsided — and consequently it was bypassed by all the rivers which formerly traversed it. The fluviatile deposits of the alluvial fan are overlain in the eastern, more extensive part of the region by a thick cover of wind-blown sand. This sand cover has the highest rise of the Nyírség (and of the entire Great Plains), and reaches 186 m a.s.l. The central part of the Nyírség is likewise covered with wind-blown sand, but the surface is lower there and is dissected by a number of small northsouth-trending valleys between strings of dunes. In the Western Nyírség, the dunes are covered with a thin cloak of loess, gradually thickening towards the west. This cloak forms a transition towards the Hajduhát (1,8), to the west of the Nyírség, which is entirely covered by a continuous blanket of loess. The Nyírség of today is separated into two parts by a roughly east-westerly divide from which the parallel streams between the strings of dunes run on the one hand to the north into the Tisza, and on the other to the south into the Berettyó. Between these strings of dunes there are also here depressions with poor drainage, some of which contain peat bogs. The wind-borne sand of the Nyírség was moved largely by northerly winds. The surface of the sand has been stabilized by acacia woods, orchards, plantations of world-famous Jonathan apple-trees and by the cultivation of potatoes and tobacco.

Alluvial fan of the Maros River (1.11)

Situated in the southeastern part of the Great Plains, this surface of late Pleistocene and early Holocene river-laid waste hardly rises above the actual floodplains of the rivers. The main body of the alluvial fan consists of sand

and sandy gravel, overlain by very thin floodplain loess loam or sandy loam. Its flat, monotonous surface is diversified at most by a few derelict oxbows of the rivers once traversing it. Along the meanders and oxbows there are small patches of riverbank dunes. Since the sandy-gravelly deposits of the alluvial fan are close to the surface, ground-water is high and the loess loam covering the alluvia has been changed into alkali soils here and there. Most of the soil cover belongs, however, to the excellent chernosem and meadow chernosem groups.

Floodplain regions

The floodplain of the Danube in the Great Plains (1.1)

From Budapest to the southern frontier, the Danube is accompanied by a band of floodplain 20 to 30 km wide and 200 km long, sharply distinct morphologically from the surrounding regions. Before the middle of the last century, up to the institution of large-scale river conservancy works, this was continuous swamp and marsh. Its most typical landscape forms include oxbows and riverbank dunes, singly or in groups. Among the tangled web of filled-up meanders there are shallow isolated alkali depressions of various sizes (Fig. 5). The oxbows farther from the actual Danube bed became swampy in the cool Atlantic phase of the Holocene, substantial amounts of peat formed in them. Since the institution of river conservancy, the depressions of the Danube meanders and oxbows have dried up almost everywhere, together with the formerly waterlogged floodplain; the one-time "watery world", the wet meadows, have been replaced by ploughlands. Protected by man-made levees, the floodplain along the Danube has undergone a rapid anthropogenic transformation.

The floodplain along the Danube separated itself at the end of the Pleistocene and during the Holocene from the older Pleistocene alluvial fan of the Danube and from the Mezőföld. Its incision was probably triggered by a somewhat intenser subsidence of the Southern Great Plains. The borderline between the Danube floodplain and the Mezőföld is particularly sharp, a steep valley flank 30 to 50 m high.

The floodplain of the Drava (1.4)

Connected by the low hills of Inner Somogy — a plains-type geomorphological subregion — with the Lake Balaton depression, the extensive and broad floodplain of the Drava River joins the Danube floodplain beyond the frontier, in Yugoslavia. The lower section of the Drava floodplain is accompanied by a broad band of loess-covered low alluvial-fan plain, which likewise belongs to this region.

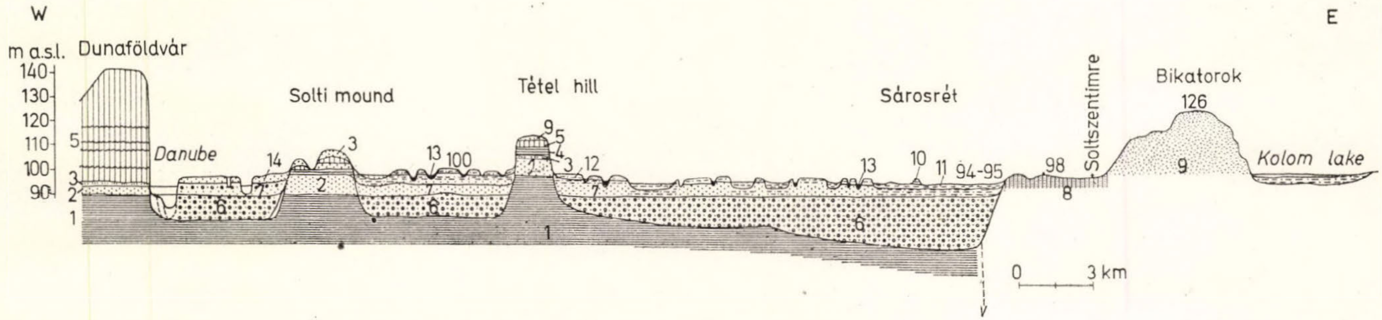


Fig. 5. Morphological profile of the floodplain of the Danube in the Great Plains (constructed by the author from data by M. Erdély and J. Sümeghy)

1 — Pannonian clay; 2 — Pannonian sand; 3 — Pannonian sandstone overlain by Pliocene red clay; 4 — red clay from the Plio-Pleistocene boundary; 5 — loess at Dunaföldvár, with the fossil soil horizon 4–5; 6 — Danube gravel (late Pleistocene), with grain sizes diminishing as distance from Danube increases; 7 — gravelly sand, sand, silty sand (Holocene); 8 — loessy sand; 9 — wind-blown sand; 10, 11, 12 — silty flood-laid sand, sandy flood-laid silt, yellow calcareous loess silt; 13 — meadow clay, muck; 14 — flood-laid sand

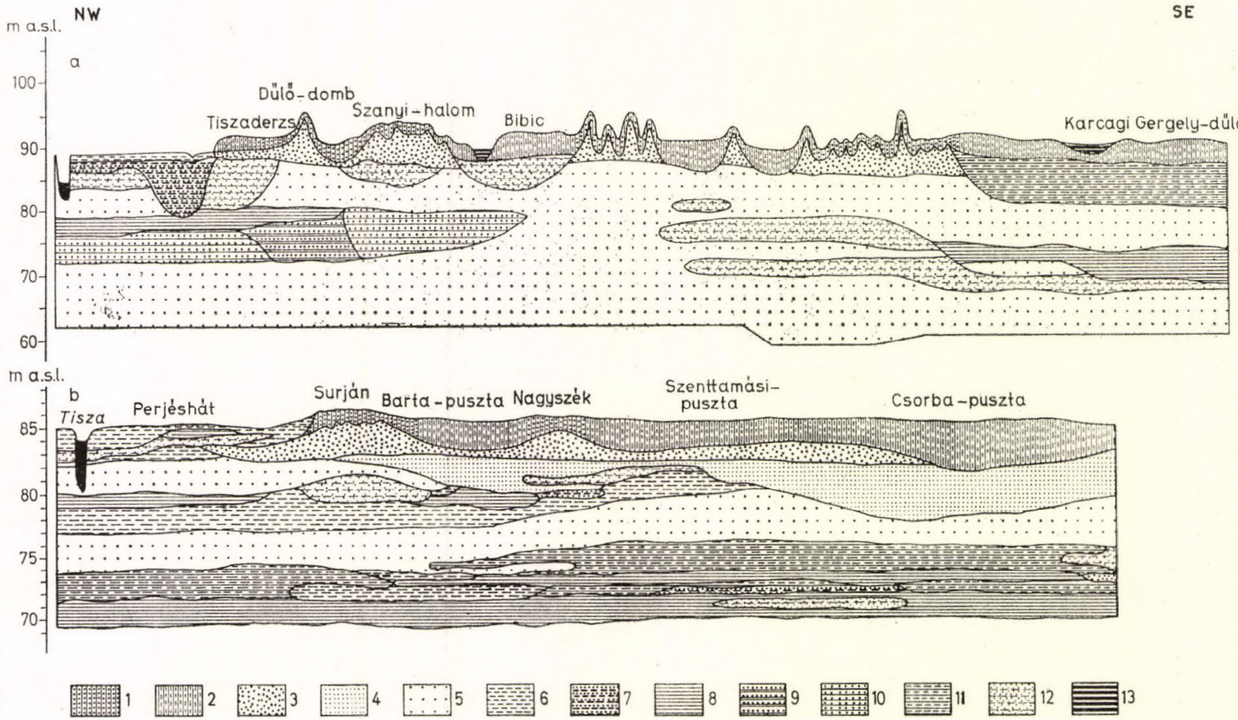


Fig. 6ab. Morphological profile of the middle Tisza section. *(a)* Geological profile between Tiszaderzs and the bounds of Karcag. *(b)* Geological profile between Perjéshát and Csorba-puszta (constructed by Z. Borsy on the basis of data from J. Sümeghy and his own surveys)

1 — loessy sand; 2 — floodplain loesses, loessoid deposits; 3 — wind-blown sand; 4 — fine-grained river-laid sand; 5 — fine- and medium-grained river-laid sand 6 — silt; 7 — sandy silt; 8 — clay; 9 — sandy clay; 10 — clayey sand; 11 — clayey silt; 12 — silty clay; 13 — meadow clay

The floodplain of the Tisza (1.5)

The part of the Tisza Floodplain on Hungarian territory falls into three geomorphological subregions.

(a) The Upper Tisza Floodplain, the wide Holocene alluvial fan of the Tisza and several of its tributaries, reaching down to the Tokaj Gate.

(b) The Middle Tisza Floodplain, joined by the floodplain fan of the Lower Zagyva, and broadening into the Jászság grassland. The Tisza modelled this section in the Holocene, along a structural graben; cutting off the southern part of the North Great Plains fans, the Tisza joined it to the rim of the Nagykunság–Hortobágy grassland.

(c) The Lower Tisza Floodplain, the broad floodplain valley of the Tisza between Szolnok and Szeged, rather deeper than the regions flanking it on either side, a reflection on the surface of the so-called Tisza Trench of the basement.

Except for this last section, the Tisza valley in the Great Plains is less well-defined than the Danube valley. Prior to conservancy, the Tisza roamed over a vast area and, in flood times, stepping out of its bed, transformed its floodplain into something of a small sea. Depositing huge amounts of silt, mud and sand, it gradually filled up and elevated its floodplain (Fig. 6). After the floods had run down, there remained many waterlogged areas in the deeper parts of the floodplain, which held marshes, swamp-forests, peat bogs, willow and poplar groves lending a colourful aspect to this part of the countryside.

The "undulous" Tisza often changed its bed, too. In the latest Pleistocene it still flowed south of the Nyírség, along the present Berettyó–ér towards the interior of the Great Plains. It was only in post-glacial times that it made the detour about the Nyírség. Emerging from the Tokaj Gate, during the Holocene it sometimes sought its course towards the south, across the Hortobágy puszta. Its course is indicated today by the Hortobágy-ér. (The Hortobágy puszta, almost as flat as a table, is largely covered by alkali soil types; this is why it is so forbidding.) After river conservancy, most of the cut-off oxbows filled up quite rapidly; the alluvia of the lower-lying and wetter parts of the alluvial plain were occupied by hayfields, meadows and pasturelands. The loamy steppe and meadow soils of the higher alluvial plain surfaces were turned into ploughlands. South of the Middle Tisza Floodplain there is an almost uninterrupted string of riverbank dunes dissected by majestic arcs of isolated oxbows. These belong to the Nagykunság–Hortobágy grassland, an isolated geomorphological region.

Plain along the Berettyó and the Körös Rivers (1.10)

There is a vast wedge-shaped alluvial plain penetrating into the interior of the Great Plains along the Berettyó and the Triple Körös. It is in effect a system of coalesced alluvial fans, whose base is mostly sand, covered with river-laid silt. Among the alluvial fans deposited by the roaming river branches, deeper-lying swamps and morasses developed. Prior to river conservancy works, the flood-laid silty waste of the meandering streams led to a gradual elevation of the river beds and banks. These natural levees enclosed small, basin-shaped, undrained depressions. Filled with water at flood times, the latter retained some of the water in the form of small alkali and salt lakes. In the dry summer seasons, most of these used to evaporate and contribute to alkali soil formation. Massive river conservancy works have also been carried out here: the one-time swamps are ploughlands and pastures today and the alkali lakes have left their traces merely as spots of alkali soils or alkali type meadow soils. These microforms together with the anthropogenic pre-Hungarian tumuli occur in almost all geomorphological regions east of the Tisza as accessory landscape elements.

The alluvial fans bordering the Great Plains and reaching deep into it carry huge volumes of ground and formation water. In them, particularly along the floodplains, subsurface water currents come to exist after the snowmelt and after the spring and early summer rains. In the long dry summer months, on the other hand, there is a marked shortage of water. It is something of a paradox, but nonetheless true, that most of the floodplains and alluvial-fan surfaces require irrigation in the dry periods. The water needed for irrigation is taken partly out of surface reservoirs constructed by damming off the rivers and partly out of artesian wells sunk into the subsurface strata containing formation water.

THE LITTLE PLAIN

Situated in Western Hungary, along the Danube where it enters the Carpathian basin and along one of its main tributaries, the Rába, the Little Plain can be subdivided morphologically into a low floodplain-level alluvial fan at its centre (2.1 in Fig. 1) and a dissected older alluvial-fan plain on the basin border (2.2, 2.3, 2.4). This latter constitutes a passage towards the east into the foothill surface (glacis of erosion) of the Transdanubian Mountains and towards the west into the similar features of the Alpine foothills.

The evolution of the Little Plain resembles in many ways that of the Great Plains. Its most important structural feature is the Rába line, to the west of which the basin basement largely consists of crystalline schists, a continuation of the crystalline core of the East Alps. East of the Rába line, the basin basement is composed of foundered fault blocks of Mesozoic rocks, the continuation of the Transdanubian Mountains (Fig. 7). The subsidence of the two different basement units was not uniform: the Mesozoic blocks had begun to sink earlier (in the early Tertiary), whereas the rapid subsidence of the crystalline basement began only late in the Miocene or Pliocene. Hence, in the western part of the basin, the crystalline was still on the surface in the second half of the Miocene. Deep drilling has proved the subsidence of this area to have taken place during the Pannonian transgression. This latter produced more than 1,000 metres of sediment from a landlocked sea. Subsidence slowed down at the end of the Upper Pannonian, and fluviatile applanation was intensified by the uplifting of the mountain frame. As a result, the sea retreated at a fast rate.

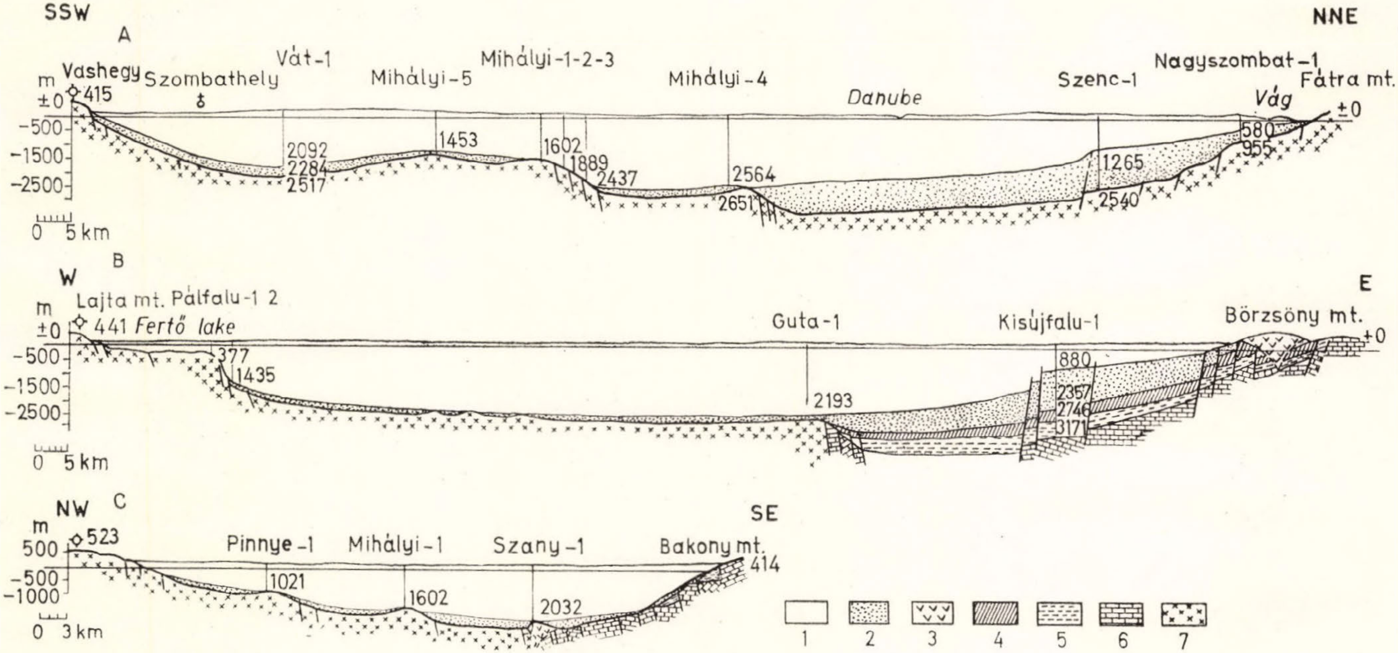


Fig. 7. Geological profiles across the Little Plain (after L. Körössy, 1958)

(A) through the western Little Plain basin,
(B) through the Little Plain between the Leitha and Börzsöny Mountains,
(C) between Sopron and Pápa.
1 — Pliocene and younger deposits; 2 — Miocene sedimentary rocks; 3 — volcanics; 4 — Oligocene; 5 — Eocene;
6 — Mesozoic; 7 — Palaeozoic

In the Upper Pliocene, the Danube and its tributaries, emerging onto the Little Plain, deposited a great deal of sand unconformably over the Pannonian deposits. The streams had first flowed southward through the Little Plain, towards the present-day Drava valley, and filled up the Little Plain depression. This Upper Pliocene, Astian filling extended over the entire

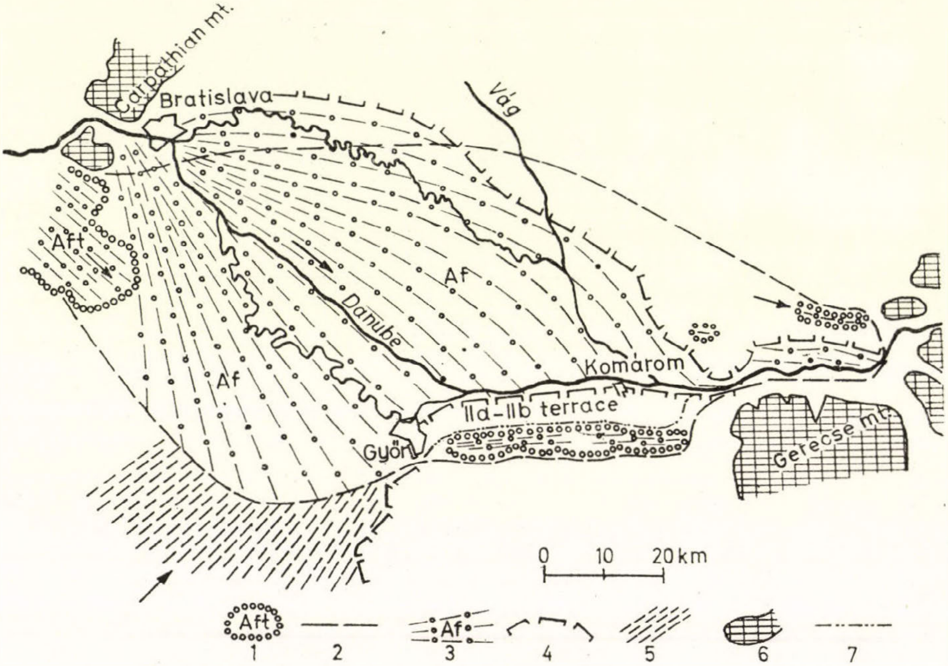


Fig. 8. Alluvial fans of the Danube in the Little Plain (after M. Pécsi, 1964)

1 — remnants of the older alluvial-fan terrace (Aft) of the Danube; 2 — supposed extent of the older alluvial fan, formed from the beginning of the Pleistocene to the end of the Mindel; 3 — extent of the younger alluvial fan (Af) of the Danube; 4 — limit of the younger alluvial fan, formed from the Mindel–Riss interglacial to the present; 5 — alluvial fan of the Rába, Répce and Marcal; 6 — mountain frame; 7 — limit of terraces IIa, IIb and locally III between Győr and Komárom

Little Plain area, up to the feet of the Transdanubian Mountains, and indeed also farther south and southwest, onto the Transdanubian Hills.

This extensive sandy deposit, locally preserved in thicknesses up to 200 m, was according to some workers (E. Szádeczky-Kardoss, J. Sümeghy) a product not of the Ancient Danube alone, but the joint deposit of the Alpine–Carpathian drainage, penetrating into the area of the one-time Pannonian sea (i.e. the product of a fluviolacustrine sedimentation).

On the western and eastern margins of the Little Plain, a basaltic volcanism took place in the Upper Pannonian, and then also in the Upper Pliocene and Lower Pleistocene. Simultaneously the Transdanubian Mountains underwent an uplifting which diverted the Danube and its tributaries to the east, towards the Visegrád gorge. (In a manner not as yet cleared in all detail, the Rába shifted its alluvial fan to the northeast, the Danube to the east of the sandy alluvial fan deposited in the Upper Pliocene.) In the Visegrád gorge, the Danube presumably used the pre-existing Ipoly–Garam valley to break through the Transdanubian Mountains which were still rather low at that time. It is since the late Pliocene and the beginning of the Pleistocene that the terraces of the Danube can be traced in the section across Transdanubia and through the Transdanubian Mountains.

The forms dominating the present-day surface of the Little Plain include the Pleistocene terraced alluvial fans and floodplain-level waste fan plains of the Danube, the Rába and their tributaries.

Alluvial fans of the Danube (2.1, 2.4)

Young floodplain-level waste fan plain. The enormous alluvial fan of the Danube in the Little Plain can be subdivided into two generations. The younger, floodplain level fan — whose modelling is still continuing today — extends from Bratislava to Komárom for a distance of more than 100 km and is 60 to 80 km wide. Most of it is on Czechoslovak territory (Fig. 8).

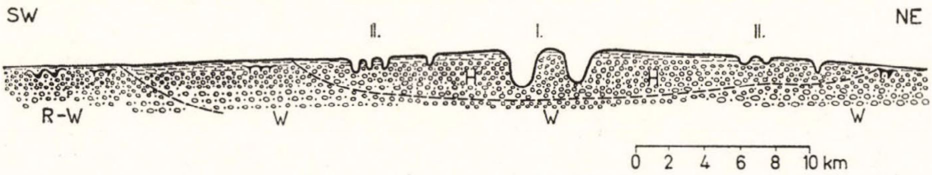


Fig. 9. Morphological profile of the Little Plain fan of the Danube (after M. Pécsi, 1968)

I — main branches with alluvial banks; II — side branches, meandering; H — Holocene gravel; reworked Quaternary alluvia; W — Würm gravel with traces of cryoturbation; R–W — gravel of the Riss and of the Riss–Würm interglacial, with traces of several phases of cryoturbation

Its Hungarian portion includes the Szigetköz (2.11), the Hanság and the Moson Plain. (2.12). In the central parts of the latter, the deposits of the Danube are 200 to 250 m thick. The sandy coarse gravels form a normal stratigraphic sequence since the Middle Pleistocene. The main branch of the Danube now flows along the elevated axis of the alluvial fan and it is only on the margins of the fan that the Upper Pleistocene cryoturbated gravels are exposed on the surface (Fig. 9).

Older alluvial plain. In Austria, west of the Little Plain, the Parndorf Plateau is a remnant of the older alluvial-fan terrace of the Danube. It lies about 50 metres above the actual floodplain-level fan. Up to the Middle Pleistocene, it was connected with the alluvial-fan terraces of early Pleistocene age situated east of Győr, most of which form terrace islands today (see Figs. 8 and 10). At the time when this older fan was being formed, the Danube entered the Little Plain through the Bruck Gate on the border of the Leitha Mountain, rather than at Devin, through the *Porta Hungarica*, where it does today. This fan was deposited throughout a longer span of time, presumably the entire Lower Pleistocene, while three terraces were being incised in the Visegrád gorge. On the basis of its fossils, the alluvial-fan gravel was deposited in a horizontal as well as in a vertical sequence, during several phases of glaciation and deglaciation.

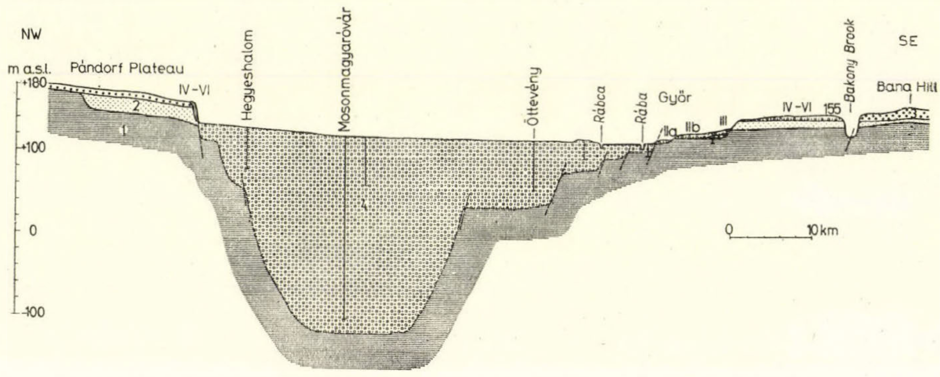


Fig. 10. Morphological profile across the Győr Basin (after M. Pécsi, 1958)

1 — Pannonian; 2 — Upper Pliocene cross-bedded sand; 3 — older alluvial-fan gravel; 4 —l argely gravelly-sandy river-laid deposit filling the Győr basin; IIa to VI — Danube terraces

Alluvial fan of the Rába and its tributaries (2.1, 2.2)

The Rábaköz, the floodplain-level waste fan plain of the Rába (2.14), merges into the low waste plain of the Danube. On the other hand, the older fan of the Danube merges into the actual alluvial fan terrace of the Rába in the Kemeneshát region. However, the Alpine tributaries of the Rába have also developed a double alluvial-fan surface, a higher early Pleistocene (2.21) and a lower-terraced, younger one (2.22). This latter is the Sopron–Vas gravel sheet plain.

Marcal basin (2.3)

Similarly to the Rába, the Marcal and its tributaries have bipartite alluvial fans. The lower, younger Pleistocene levels are more extensive; of the older ones there remain just a few remnants and outliers. The alluvial-fan plain of the Marcal basin is, contrary to the Győr basin, a half-basin of accumulation and denudation, not one purely of accumulation. In the Early Pleistocene, the Rába first eroded the surface of the Marcal basin, then deposited an alluvial fan on it. After the subsidence of the Győr basin, the Marcal and its tributaries incised themselves even deeper and removed at least 100 to 150 metres of Pannonian sand and clay.

This landscape includes — among its typical forms — some basalt-capped monadnocks, a few of which rise more than 100 m above the basin bottom. The basalt lavas of the Upper Pliocene have preserved some remnants of the ancient relief.

To the south and west of Lake Balaton, down to the broad alluvial plain of the Mura and Drava there is a rolling surface composed of several more or less independent regions, comprehensively called the Hills of Transdanubia. Geologically it is a Transdanubian appendix of the Pannonian basin. Its basement is an alternation of zones of Palaeozoic crystalline and Mesozoic sedimentary rocks, more or less parallel to Lake Balaton. Some of it is very deep (more than 4,000 m beneath the hills of Western Zala). It is overlain by a marine Tertiary, largely Pannonian, in thicknesses usually ranging from 500 to 2,000 m. Mostly known from drill cores, some of these deposits crop out also on the flanks of the deeper valleys. In contrast to the Great and Little Plains, Transdanubia had risen rather than subsided after the retreat of the Pannonian sea; this resulted in a more intense dissection of the landscape and in the hilly modelling of its surface. In the Transdanubian hills, just as in the Little Plain, the Pannonian is overlain by 100 to 200 metres of cross-stratified fluviatile-lacustrine sediment, mostly sand, overlain in its turn by a gravel sheet spread by the Rába and Mura, the streams emerging from the Alps, in the late Pliocene and early Pleistocene. The flat surface of that time was the initial plane of the valley modelling that set in in the Pleistocene. The Transdanubian hills, uplifted in the course of the Quaternary, were thoroughly dissected by streams running towards the Zala–Balaton drainage system on the one hand, and towards the floodplains of the Danube and Drava, on the other. In the process, the Upper Pliocene, Astian cross-stratified sand became intensely worn down. In the valleys, fluviatile sand and gravel came to be deposited during the Quaternary, while the slopes grew a thick cover of loess. In the western part of the Zala region, there formed, instead of the typical loess, a brown earth or loam on the more moisture-rich forest-covered hilltops.

South of the Western Balaton basin, in Inner Somogy, fluviatile activity was dominant up to the end of the Pleistocene. In the early Holocene, and to some extent also at the end of the Pleistocene, the wind blew dunes out of these fluviatile sands. This region is consequently of a plains rather than a hilly character.

The hills of Upper Vas and Zala (4.1)

South of this terraced fan situated among the valleys of the Rába, Mura and Lower Zala, and of the Upper Zala Valley, respectively, the valleys and the broad interfluvial rises acquire a southerly trend. It is particularly in the eastern part of the Zala region that so-called "meridional valleys" are typical. These valleys dissect the region into flat-topped parallel (meridional) rises of fairly uniform height (200 to 300 metres). This peculiar morphology elicited several hypotheses from workers in the region. Some contended that they were due to fluviatile erosion along structural lines. Others maintained them to be of a deflationary origin, with the rises between them representing yardangs. It is, however, difficult to prove the northerly winds necessary to model such forms. The valley flanks are covered with a thick cloak of stratified loamy loess of deluvial and solifluidal origin. Locally this cloak reaches down beneath the actual straths, thus proving that mass wasting also played a part in modelling the valley flanks. Early in the Holocene, on the other hand, the poorly drained straths held swamps and peat bogs. (see: Geomorphological Map of Hungary).

Somogy Hills (4.3)

This region, situated south of Lake Balaton, resembles the preceding one in many respects, but its meridional valley system is interrupted by younger and more sharply defined valleys perpendicular to the meridional set. The relief thus has a checkerboard-like aspect. The east-westerly valleys are rather asymmetric and stepped. The north flanks are steep, the south flanks gentle and covered with a thick slope loess dissected by broad flat derasional valleys. The highest interfluvial rises had once (in the Upper Pliocene and Lower Pleistocene) been the gently sloping piedmont (glacis of erosion) of the Transdanubian Mountains. It was only during the Middle and Upper Pleistocene, concurrently with the formation of the Balaton depression and the valleys parallel to it that they were dissected by structural and erosional processes.

The Lake Balaton depression (4.2)

The broad depression of northeast-southwest trend of Lake Balaton is in effect a basin between the Transdanubian Mountains and the Somogy hills. It is a graben depression formed by repeated subsidence. Its southwestern part presumably assumed its present form as early as the Lower Pleistocene, whereas the rest did so only late in the Pleistocene. The south shore of Lake Balaton is lined with lakeshore dunes and sand bars. These separate from the main body of the lake undrained basins which turned into peat bogs in the Holocene.

The Mecsek and the Tolna–Baranya Hills (4.4)

The Tolna–Baranya Hills (4.44) lie south of the Kapos River valley. To the south they pass almost imperceptibly into the horst-type mountain island of the Mecsek (4.41). The latter, however, looks down with a steep, stepped slope onto the Pécs Plain in its foreland. Constituting a southern cornerstone of this region, there is near the frontier the small Villány hill group, likewise consisting of Mesozoic limestones. Between the two Mesozoic ranges, adjoining the southern foothill of the Mecsek, the Mórágy block (4.422) is a granite mass, an element of the crystalline basement.

The Mecsek is a locally folded and universally faulted mountain of southwest-northeast strike. The Villány group (4.423), of a similar structure, has on the contrary a west-east trend and an imbricated structure. The sub- and microregions lying west and north of the Mecsek of the Tolna–Baranya region are intensely dissected low plateaux, consisting of Pannonian clays and sands wearing a thick loess blanket. Beneath the loess there is locally a rather thick bed of Pleistocene river-laid sands.

The crystalline massif constituting the basement of Transdanubia underwent a process of shattering and wearing down in the late Palaeozoic. In the Mecsek area of today a basin depression had formed on its surface. This was inundated by the sea which then deposited a large amount of sand and gravel rather rich in radioactive substances, eroded from the encircling crystalline hills. The red and varicoloured sandstones formed in this way occupy a large area in the Western Mecsek. They are of Permian age. In the meantime, the marine trough further deepened eastward, off a zig-zagging crystalline shoreline, and a Liassic sequence of a total thickness of some 800 metres, containing several coal seams, came to be deposited in slowly subsiding shallow embayments of the sea. The western part of the mountains had already been laid dry by that time. By the end of the Mesozoic, the entire Mecsek emerged as a dry land, but it was only much later that it detached itself morphologically from the crystalline areas surrounding it. Up to the Upper Cretaceous, the Mecsek, more extensive than today, was planated under a tropical climate. This process may have resulted in lateritization and bauxitization, as proved by the bauxite deposit in the Villány Hills. In the Upper Cretaceous, a lively volcanism took place simultaneously with the folding of the Carpathian frame. Of the doleritic eruptions there are today just a few remnants and necks left. In the late Tertiary, the Mecsek

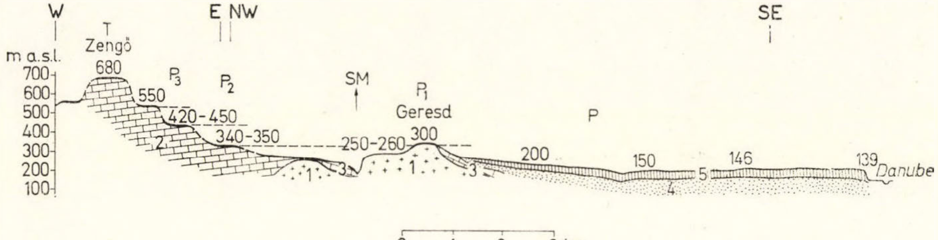


Fig. 11. Morphological profile of the planated surface in the Mecsek Mountains foreland

T — remnants of Upper Cretaceous tropical peneplain; P_1 — Upper Pliocene piedmont surface, dissected, and remodelled in the Pleistocene; P_2 — remnants of a Lower Pannonian bench of abrasion; P_3 — remnants of Helvetian bench of abrasion; P — Pleistocene glacis piedmont surface; SM — submontane basin. 1 — Paleozoic granite; 2 — Jurassic limestone; 3 — Helvetian, Tortonian beds; 4 — Pliocene (Pannonian) beds; 5 — slope loess

Block and its surroundings definitely detached themselves from the surrounding Palaeozoic crystalline masses and the foot of the Mecsek was repeatedly inundated by the sea. The borders of the insular mountain mass were covered with marine deposits and in the shore zones benches of abrasion still distinctly visible today came to exist. After the retreat of the Pannonian sea, a long gentle foothill surface — a glacis of erosion — developed in the southern foreland of the Mecsek. Sculptured in little consolidated marine

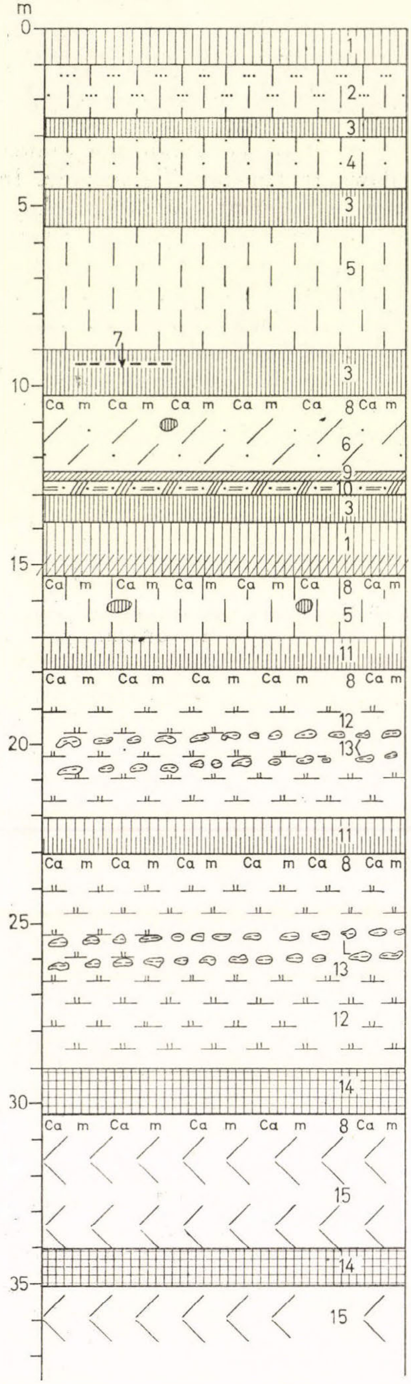


Fig. 12. Profile of the loess bluff at Dunaszekcső, north of Mohács (after Gy. Scheuer)

1 — chernosem-brown forest soil; 2 — loessy sand; 3 — chernosem type soils; 4 — sandy loess; 5 — unstratified true loess; 6 — sandy slope loess; 7 — bits of charcoal; 8 — horizon of lime accumulation; 9 — loessy soil, slopewashed (loessy semipedolite); 10 — sandy-clayey semipedolite; 11 — rust-brown steppe soil; 12 — clayey loess (loess loam); 13 — calcareous concretions; 14 — red clayey soils; 15 — limeless clayey loess

deposits, it reached down to the Villány Hills (Fig. 11). The piedmont surface, further elevated during the Pleistocene, was dissected by the streams flowing down from the central mass into broad interstream rises. The northern and southern foreland of the Mecsek became two distinct hilly regions. The mountainous area degraded to a hilly type landscape surrounding the Mecsek underwent several cycles of valley incision and lateral erosion, slope deposit and loess formation. The blanket of loess and loessoid slope deposits, 20 to 50 m thick, is subdivided by several fossil soil horizons, as many as six in some places. Of these, the older (and deeper-lying) ones are usually red clayey soils which reflect a considerable Mediterranean climatic influence (Fig. 12).

THE TRANSDANUBIAN MOUNTAINS

Regional subdivision

The individual block-faulted horst units of the Transdanubian Mountains are separated by smallish basins and grabens of northwest-southeast strike, perpendicular to the main trend of the mountains. The largest single unit is the Bakony, situated north of Lake Balaton (Fig. 1, 5.1), and delimited against the Vértes (Fig. 1, 5.3) by the Mór graben. Farther east and north there are the fault blocks and intercalated basins of the Buda–Pilis–Gerecse group (Fig. 1, 5.4). It is to this latter group that we have joined the volcanic range of the Dunazug ("Danube nook"), although in forms and constitution it differs from them. The conspicuous valley gorge of the Danube divides the Dunazug unit more sharply from the Intra-Carpathian volcanic girdle than they are connected by morphological similarities.

Structural and morphological evolution

The Little Plain and Great Plains basins are separated by the Transdanubian Mountains. This range has, just like the Mecsek mountains, a crystalline basement. The long marine trough of northeast-southwest trend that developed late in the Palaeozoic was mainly filled with a sequence of Triassic limestones and dolomites, of more or less pronounced South Alpine affinities. Most of this trough was laid dry at the end of the Triassic, but its northern side was inundated by the Jurassic and Cretaceous and then also by the Tertiary seas. Along the mountain axis, the individual structural units performed a complicated ballet of subsidences and upliftings irregular in space and time.

In the Cretaceous, however, the surface of the mountains was still rather uniform. Under a tropical climate it was deplanated to a low but extensive peneplain. This is proved by the bauxites and laterites widespread in the mountains. From the Upper Cretaceous onwards, in the phases of orogeny that resulted in the folding up of the Carpathians, the Transdanubian Mountains underwent block-faulting with the development of graben subsidences and horst-type karsted hills. In the Tertiary, the blocks uplifted to various

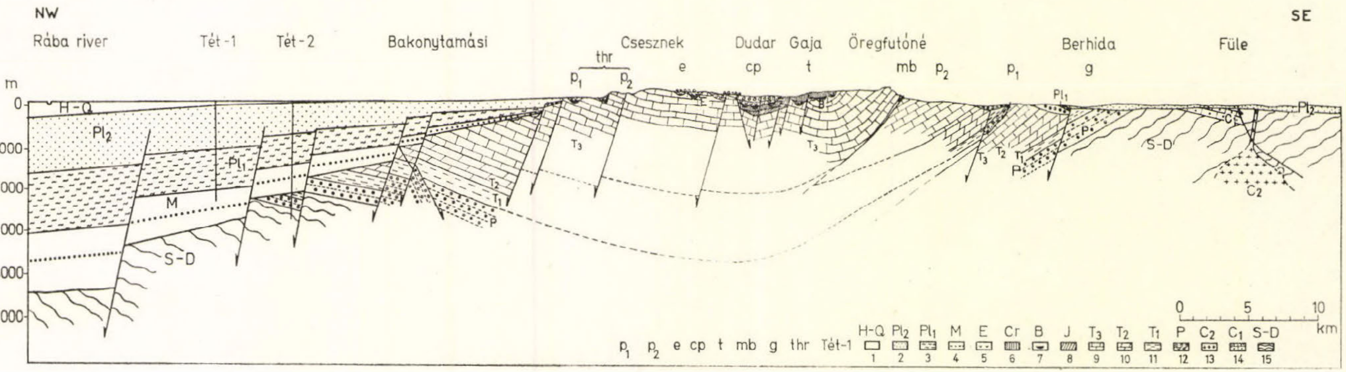


Fig. 13. Profile across the Bakony Mountains (after Gy. Wein, 1969)

1 — Holocene-Pleistocene river-laid sand and gravel and flood-laid soils; 2 — Upper Pannonian sand and clay; 3 — Lower Pannonian (Pliocene) clay marls; 4 — Miocene gravels and sand (in the Dudar basin, including the Upper Oligocene); 5 — Eocene coal seams and carbonatic rocks; 6 — Lower Cretaceous (Aptian-Albian-Cenomanian) limestones and calcareous marls; 7 — bauxite and related formations; 8 — Jurassic limestones; 9 — Upper Triassic dolomites and limestones; 10 — Middle Triassic limestone; 11 — Lower Triassic aleurolite, marl and limestone; 12 — Permian sandstones and conglomerates; 13 — Upper Carboniferous granite prophyry; 14 — Lower Carboniferous conglomerate and clay shales; 15 — Silurian-Devonian phyllite and crystalline limestone; t — uplifted remnant of tropical peneplain; cp — cryptoplane; e — exhumed peneplain, locally covered with a Miocene gravel sheet; mb — mountain-border bench; p_2 — Pannonian bench of abrasion; p_1 — piedmont surface (pediment); g — Pleistocene piedmont surface modelled in little consolidated sediment (glacis); thr — remodelled tropical peneplain in threshold position; Tét–1–2 — prospect wells

altitudes were worn down and partly turned into marginal half-planes, while the graben-type intramontane basins were being filled with waste. The surface elements in threshold position were covered with gravel sheets derived from the north and south, from the crystalline regions which at that time were still higher than the Transdanubian Mountains region. This state of affairs continued up to the end of the Miocene. It was at the end of the Miocene, and even more in the Pliocene, that the Transdanubian Mountains rose above their surroundings. Their present-day mean altitude of 500 m, however, is the result of late Pliocene and Pleistocene uplifting.

Two members of the Transdanubian Mountains, notably the Bakony and Vértes, possess highly similar structures composed of several more or less isolated blocks. The rocks constituting them, largely Triassic limestones and dolomites, have a general northwesterly dip. In the southern forelands of these mountains, Palaeozoic rocks are exposed. In the Bakony, the Lower Triassic overlies a Permian sandstone which in turn overlies a Carboniferous phyllite (Fig. 13). Indeed, south of the Balaton even the granitic basement is at a quite small depth below the surface. South of the Vértes, on the other hand, the basement granite constitutes a batholith rising above the surface in the form of the Velence Hills. The Vértes and the Velence Hills are separated from one another by a shallow graben. One peculiar difference between the Bakony and the Vértes is that in the southwestern part of the Bakony and in the so-called Balaton Upland, a rather large-scale basalt volcanism took place during and after the Upper Pannonian crustal movements. The extensive basalt covers were subsequently worn down to monadnocks.

The blocks and intercalated graben basins of the Gerecse Mountains are arranged in a north-south-trending pattern. In the Eastern Gerecse, however, and in the Buda–Pilis Mountains, the relief-controlling structural lines strike northwest-southeast, i.e. perpendicularly to the main trend of the Transdanubian Mountains. From the Upper Cretaceous onwards, graben subsidences took place along these structural lines, with horst blocks left standing between them. In the grabens, Eocene–Oligocene and Miocene seashore deposits accumulated.

Types of planated surfaces

Despite the intense structural dissection, the summit levels of the horst blocks of various altitude of the Transdanubian Mountains turned out to be due to a process of planation. Besides the summit levels of planation, these blocks carry on their flanks narrow marginal ledges and benches[5], and the block mountains as a whole are surrounded by broad foothill surfaces. These latter are partly pediments sculptured in dolomite and partly glacis of erosion modelled in little consolidated Tertiary deposits.

[5] The marginal benches due to planation are in part remnants of ancient piedmont surfaces whose base levels of erosion were the Lower and Middle Pliocene seas; others are terraces of abrasion. The process of abrasion is convincingly documented in the forelands especially of the Bakony, Vértes and Mecsek.

The summit levels of various altitudes, due to planation, were interpreted in various ways by various workers. According to Bulla (1962), a continuous tropical planation took place on the exposed Palaeozoic and Mesozoic blocks from the Upper Cretaceous to the Middle Pliocene. According to Pécsi (1969), on the other hand, the continuous tropical planation of the Transdanubian Mountains went on only up to the beginning of the Eocene, and the surfaces of planation themselves are polygenetic in origin, because the remnants of a Tertiary terrestrial gravel sheet encountered even on the summit levels of these mountains suggest that the gravels had been transported by streams coming from the neighbouring crystalline mountains onto the Transdanubian Mountains region which by that time had already undergone tropical planation. Hence, the Mesozoic regions were in the Miocene the forelands, pediments and indeed the pediplains of the Palaeozoic crystalline mountains. In the Pliocene, when these crystalline mountains had foundered, the Transdanubian Mountains emerged as an archipelago from the Pannonian Sea. Along the shores of this latter, benches of abrasion came to exist, which today constitute mountain-border benches or steps.

There is no proof for a continued tropical planation beyond the beginning of the Eocene. The tropical climates of the Jurassic and Cretaceous gave rise to needle karst forms and laterite and bauxite deposits widely distributed over the mountain blocks (Bakony, Vértes, Gerecse, Buda Mountains). Today, these forms are encountered at the graben bottoms, covered with Eocene limestones and also other sediments. An analysis of the structure of the Transdanubian Mountains, the correlate deposits indicative of the modes of deplanation (laterites and bauxites) and their redeposited varieties, including also the disposition in space of these correlate deposits, has revealed tropical planation to have extended in the Cretaceous most probably over the entire Transdanubian Mountains region. This vast low tropical peneplain was uplifted to various altitudes by the differentiated structural movements — block upliftings and subsidences — that took place from the Upper Cretaceous onward. The individual blocks can, on the basis of their distinctive present-day morphological positions, be subdivided in five groups.

Cryptoplane

Elements of a planated surface remained unworn only on those blocks which in the Eocene had subsided to be covered by a complex of limestones. This cover then protected them from further wear. Some blocks sank deeper during the Tertiary, giving rise to small intramontane basins or foreland basins. It is these forms that are included in the group of cryptoplanes (Fig. 14). In the karst hollows of the Eocene-covered needle-karsted cryptoplanes there are substantial bauxite deposits especially on the margins of the Bakony and Vértes. The types of cryptoplane were established and documented as a result of the exposures occurring in the bauxite mines.

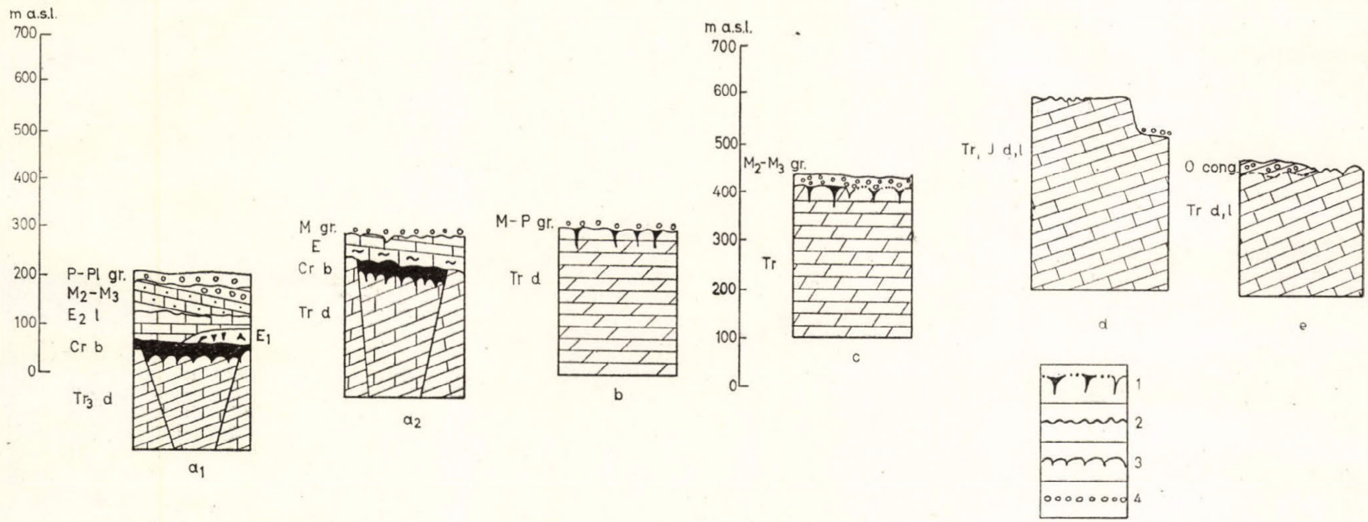


Fig. 14. Schematic position of the tropical planated surfaces in the Transdanubian fault blocks (after M. Pécsi, 1968)

a_1–a_2 — buried tropical surface remnant on the mountain border or in an intermontane graben; b — low threshold surface with traces of tropical weathering, truncated by subsequent pedimentation; c — uplifted but still covered tropical surface, pedimented when the Tertiary gravel cover was being deposited on it; d — uplifted tropical surface remnant, fully truncated in the Tertiary; e — semiexhumed, uplifted surface remnants, pediplanated in the Tertiary (e.g. Oligocene) in the forelands of the crystalline massifs: their subsiding portions wear a conglomerate cover; P–Pl gr — Pliocene–Pleistocene gravel; M_2–M_3 — Middle Miocene marl, limestone and gravel; E–E_2l — Middle Eocene limestone; E_1 — Lower Eocene dolomite detritus; Cr b — Upper Cretaceous bauxite; Tr d — Triassic dolomite; M gr — Miocene gravel; M_2–M_3 gr — Middle and Upper Miocene conglomerate; O cong. — Oligocene sandstone and conglomerate; Tr–J d, l— Triassic–Jurassic dolomite, limestone. 1 — Remains of a tropical weathering, with kaolinite and red clays; 2 — unconformity; 3 — needle-karsted remnant of a tropical surface; 4 — gravel rags on the surface

Tropical planated surfaces in threshold position

Some blocks carrying remnants of the Cretaceous planated surfaces now occupy the position of piedmonts or low rises in the Bakony, Vértes and Gerecse. This group includes further the low-lying fault blocks of the Southern Bakony and Balaton Upland, too. The tropical forms and weathering products have mostly been worn down, but there are traces of them in spots. Locally the tropical laterite and red residual clay is restricted to joint fissure fillings. Elsewhere there are on the surface small spots or scattered pebbles of a Tertiary gravel, usually consisting of red-tinted quartz. This suggests the ancient tropical surface to have undergone a pedimentation in subsequent times.

Tropical planated surface uplifted to summit-level position

This group includes those highest blocks of the Bakony and Gerecse whose surfaces bear no trace of tropical forms or correlate deposits (Kőris Hill, Papod, Tés Plateau, Nagy-Gerecse, etc.). However, on the lower levels surrounding them (400 to 500 and 200 to 250 m) there are in the mouths of dry valleys remnants of redeposited red tropical clays. The planated summit levels, presumably modelled in the Upper Cretaceous by tropical planation, were considerably worn down in the Tertiary. However, data on the depth and modes of erosion are not yet sufficient.

Buried blocks in uplifted position

The uplifted remnants of a tropical surface of planation within this group are covered by a more or less thick sequence of sediments or a sheet of gravel (see Figs. 13 and 14). They are consequently covered despite their elevated position (semiexhumed surfaces). The gravel sheet up to the Upper Miocene was dumped from the surrounding crystalline mountains onto the lower-lying portions of the tropical surface, presumably in the course of a process of pedimentation. These elements of the relief were then uplifted to their present altitudes by the Pliocene and Pleistocene structural phases (e.g. Farkasgyepü in the Bakony, some blocks of the Buda–Pilis Mountains, the Romhány block in the Cserhát, etc.).

Exhumed blocks in summit-level position

In the Buda and Pilis Mountains and in the Cserhát Hills east of the Danube bend there are Mesozoic blocks uplifted above their surroundings which were once covered by Oligocene sandstones and conglomerates. Some of them have been completely exhumed since, however.

The conglomerate locally directly overlies the tropical needle karst, contributing to its wear. The lithologic composition of the gravelly deposit suggests a derivation from a nearby crystalline mountain.

The presence of gravelly correlate deposits in the Transdanubian Mountains and its borders reveals that tropical planation could not have been continuous throughout the Tertiary. The Lower Oligocene conglomerate, the Upper Oligocene gravelly sand, the Aquitanian and Burdigalian gravels of the Lower Miocene, the gravels of the Helvetian and Tortonian prove the processes of pedimentation that took place in the foreland of the Palaeozoic crystalline mountains, then still rather high and undergoing repeated vertical movements. True, correlate deposits indicative of a tropical or subtropical weathering — kaolinite-bearing varicoloured and red clays — did come to exist in other periods of the Tertiary. Still, in certain stages of the Eocene, Middle Oligocene and Miocene, deplanation on the structurally displaced, sinking or rising relief by tropical planation must have been restricted to brief episodes. The left-over forms and correlate deposits suggest surface evolution to have been a polygenetic one, with repeated pedimentation dominating the episodes of tropical planation.

Mountain-border half-planes

In the Pliocene, the main agency of relief modelling on the borders of the mountains rising above the Pannonian sea was abrasion resulting in mountain-border half-planes. After the retreat of the Pannonian sea, pedimentation and glacis formation resumed their dominant role on the margins of the continuously rising blocks. These forms of planation were, however, dissected into interfluvial ridges by processes of valley sculpture in the warmer climatic phases of the Quaternary. Another episode with a climate suitable for pedimentation and glacis formation set in in the Upper Pliocene, when under a warm semiarid climate pedimentation was dominant, whereas in the cold and dry periglacial climatic phases of the Pleistocene, relief modelling by cryoplanation was the most extensive process. This is why, on the gentle slopes of the foothill areas, terraces, pediments and glacis of cryoplanation are fairly widespread.

Minor forms of erosion and accumulation

In the fault blocks, largely consisting of limestone and dolomite, of the Transdanubian Mountains, fault-controlled karst valleys are rather frequent. Most of them are dry over most of the year, and their flanks are as steep as those of a canyon in some sections. On the flanks of almost every block there are lapiès slopes and dry caverns hanging above the valley bottom. On the mountain borders, hot karst springs of big yield tend to occur, particularly in the Buda Mountains. Active since the end of the Tertiary, these springs have given rise to travertine-covered half-planes matching the levels of the one-time floodplains in the forelands of the respective mountain sections. There are instances of up to five travertine levels at various altitudes on top of terrace deposits (Figs. 15 and 16).

The absence of big connected cave systems has been attributed to the tectonic shattering of the rocks constituting these mountains. This is why in the limestone basement of the intramontane basins there are huge water-bearing cavities. Inrushes of water from these cavities are a constant menace to coal and bauxite mining in these basins. The slopes and basin topographies

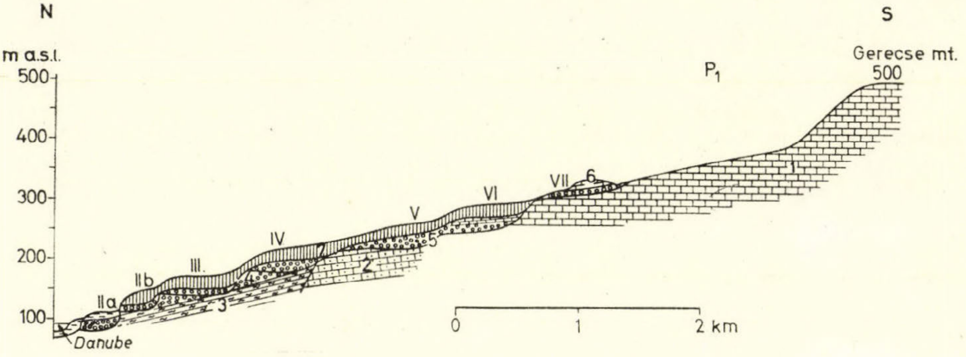


Fig. 15. Danube terraces on the northern border of the Gerecse Mountains (after M. Pécsi, 1964)

P_1 — Upper Pliocene pediment; IIa—IIb — Würm and Riss–Würm terraces; III — Riss terrace; IV — Mindel terrace; V — Günz terrace; VI — Pre-Günz terrace, travertine-covered (coeval with Danube glacial phase); VII — Upper Pliocene terrace, travertine-covered; 1 — Mesozoic undivided; 2 — Cretaceous sandstone; 3 — Eocene marl; 4 — Oligocene conglomerate; 5 — terrace gravel; 6 — travertine; 7 — slope loess

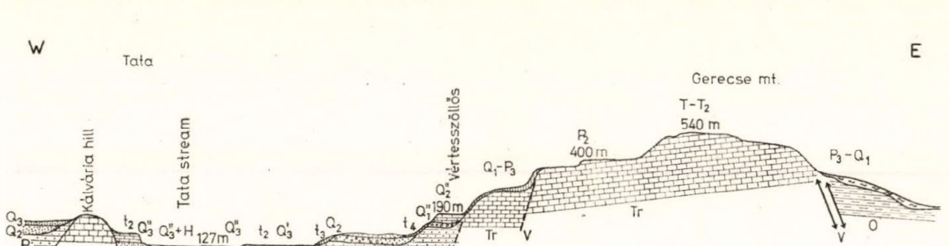


Fig. 16. Geomorphological profile across the western block-faulted part of the Gerecse Mountains and of the terraces of the Tata Stream (Pécsi, 1969)

Tr — Triassic limestone; Tr + J — Triassic and Jurassic limestone; O — Oligocene sand and clay; P_2 — Upper Pannonian (Pliocene) sand and clay; Q_1 — Early Pleistocene terrace (gravel); Q_2 — Early Pleistocene travertine; Q_3 — Upper Pleistocene travertine; Q_3' — Upper Pleistocene terrace gravel and sand; Q_3'' — Late Upper Pleistocene river-laid sand and gravel; $Q_3'' + H$ — floodplain deposits of the Tata Stream
$T-T_2$ — surface of planation, covered with rags of a Tertiary gravel sheet, presumably the remnant smoothed by pedimentation of a surface once in the piedmont region of the ancient crystalline mountains; P_2 — abrasion benches of the Pannonian (Pliocene) sea; P_3-Q_1 — Upper Pliocene–Lower Pleistocene glacis surface; Q_1-P_3 — Upper Pliocene — Lower Pleistocene piedmont; t_1-t_4 — Pleistocene terraces of the Tata Stream. The remains of "Vértesszöllős Man" (early Pleistocene) and the remnants of his implements and hearth were found in this horizon

of these mountains are smoothed by mountain-type slope loess cloaks of varied thickness. This type of loess has the peculiar lithologic feature that the fine-grained stratified loess packs constituting it are separated by rhythmic intercalations of sand or rock debris. The relief covered with loess or loessoid deposits bears typical derasional valleys. Deep loess gullies modelled by erosion, due to anthropogenic influences, are quite numerous locally. Microforms due to Pleistocene ground frost, deflation, cryoturbation and solifluction are classified as accessory elements of the landscape.

NORTH HUNGARIAN OR INTRA-CARPATHIAN MOUNTAINS

This mountainous region of Hungary includes two rather different structural and morphological types of mountains.

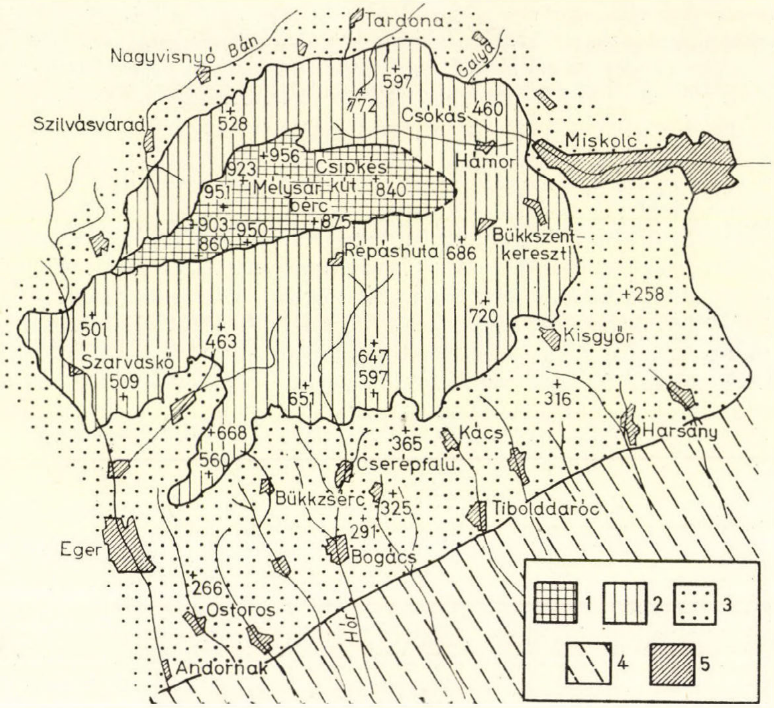
Of the Mesozoic blocks wedged in between the volcanic mountains, the Bükk and the North Borsod Karst are most extensive (Fig. 1, 6.4, 6.5). Both overlie a Palaeozoic base. Their history of evolution much resembles that of the Transdanubian Mesozoic Mountains. The central planated plateau of 900 m mean altitude of the Bükk Mountains is surrounded by a lower level planation and by a broad but dissected foothill surface. The latter is in its turn surrounded by zones of glacis of erosion and accumulation (Fig. 17). Whereas the North Borsod Karst is of the exhumed and partly of the threshold type, the Mesozoic blocks of the Western Cserhát are uplifted planated blocks covered with an Oligocene conglomerate (cf. Fig. 1, 6.21, and geomorphologic map).

The Bükk and the North Borsod Karst carry the most typical karst forms of Hungary; the most frequent ones include dolinen, uvalas, lapiès fields, sinkholes and spring caverns. In the Bükk Mountains caverns with abundant remains of a Palaeolithic culture (Szeleta, Subalyuk caverns) have been discovered. Of the numerous caverns, the most famed one, the 22 km long Aggtelek cavern with its magnificent stalactites and huge halls is in the North Borsod Karst.

Remains of the Late Tertiary stratovolcanoes of the Intra-Carpathian volcanic girdle

The Intra-Carpathian volcanic elements of the Northern Hungarian Mountains were produced by Miocene volcanism. Early Tertiary, largely Eocene volcanism also left some traces, but this was an insignificant precursor to the large-scale Neogene volcanism, which produced one of the most extensive volcanic regions of Europe. The volcanic eruptions exhibited a shift in time, growing younger from west to east. The mountains near the Danube bend are Middle Miocene in the main; the Tokaj–Zemplén Mountains (6.6) are Upper Miocene to Lower Pliocene. The volcanoes mostly belonged to the stratovolcanic type. Lava effusions were interrupted by repeated scatterings of ash, locally indeed with the dominance of scatter products. The Visegrád Mountains (4.4), the Börzsöny (6.1), the Cserhát (6.2) and the Mátra (6.3) largely consist of andesite lavas, tuffs and agglomerates. Farther east, in the foreland of the Bükk, and especially in the Tokaj–Zemplén Mountains, rhyolite also played an essential role besides andesite and in some mountain groups it even gained the upper hand.

The volcanic hill groups of the Danube bend, the Cserhát, and to some extent also the Mátra had constituted tall stratovolcanoes at the beginning



a

b

Fig. 17ab. Morphological profile of the Bükk Mountains and its foreland (constructed by Z. Pinczés)

a.1 — High Bükk, Miocene upper planation level; 2 — Middle Bükk, Miocene middle planation level; 3 — Lower Bükk, Upper Pliocene piedmont (glacis of erosion); 4 — alluvial fan of the Bükkalja (glacis of accumulation); 5 — habitations; b.I — High Bükk; II — Middle Bükk; III — Low Bükk; IV — alluvial fans of the Bükkalja (Q_1—Q_2); V — idem (Q_3); VI — alluvial plain of the Tisza (H_1)

of the Tortonian, but by the end of that stage they were already substantially worn down. Their environments were covered up to the 400 to 500 m level of today by nearshore deposits of the Upper Tortonian sea. The summit

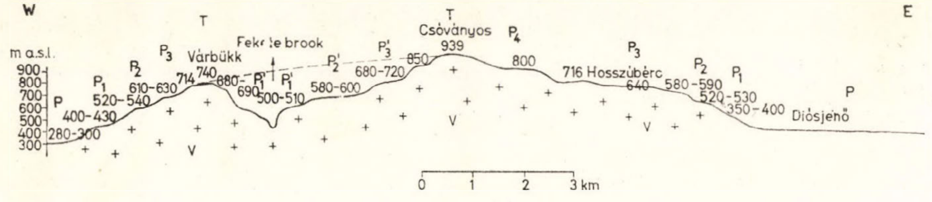


Fig. 18. Morphological cross section of the Börzsöny Mountains (after M. Pécsi, 1963)

T — remnant of Upper Miocene (Tortonian) level of planation; $P_{2,3,4}$ — inferred Sarmatian–Pannonian piedmont steps; P_1 — Upper Pliocene piedmont surface; P — foothill surface (glacis of erosion), remodelled in the Pleistocene; $P'_{1\,2\,3}$ — intramontane piedmont steps; V — Helvetian–Tortonian volcanics

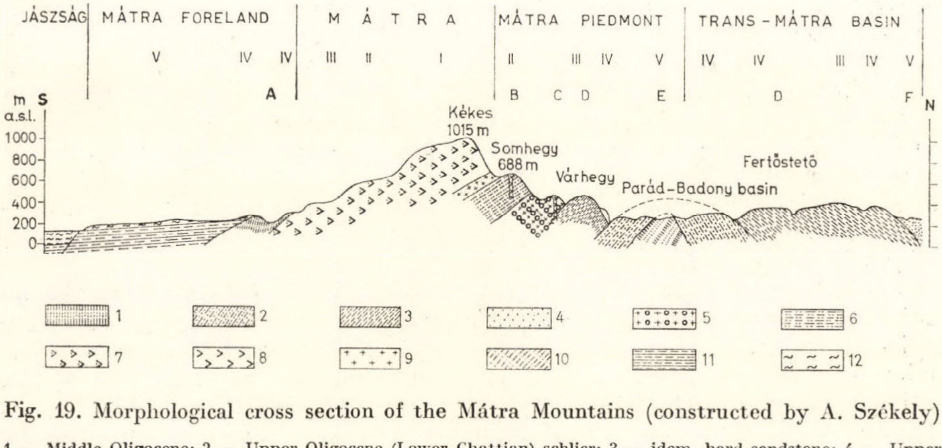


Fig. 19. Morphological cross section of the Mátra Mountains (constructed by A. Székely)

1 — Middle Oligocene; 2 — Upper Oligocene (Lower Chattian) schlier; 3 — idem, hard sandstone; 4 — Upper Oligocene (Upper Chattian), less consolidated schlier; 5 — Lower Miocene sediments (varicoloured clay, friable sandstone, Lower rhyolite tuff, lignite seams); 6 — Helvetian schlier; 7 — subvolcanic bodies (laccoliths, dykes) etched out by differential erosion; 8 — Tortonian volcanics (andesite agglomerate, tuff, rhyolite tuff); 9 — Sarmatian deposits (clay marl, etc.); 10 — Upper Pannonian brackish clay and sand; 11 — Quaternary (alluvial fans, slope deposits, loess, etc.); 12 — Middle rhyolite tuff; I — Sarmatian level of planation, summit level; II — Lower Pannonian mountain-border bench; III — Upper Pannonian mountain-border bench (middle bench); IV — Upper Pliocene piedmont surface (glacis); V — Quaternary surfaces of denudation and accumulation; A — structural basins of the Mátraalja; B — upper laccolith set; C — lower laccolith set; D — Upper Chattian sandstone bench; E — basins of denudation of the Mátralába; F — basins of denudation of the Trans–Mátra region

levels rising above said altitudes can be considered the structural remnants of the ancient centres of eruption. These had undergone a substantial subtropical planation (presumably a pediplanation) in the Tortonian, and also in the Sarmatian.

After the Tortonian, the levels which today lie 350 to 400 m a.s.l. probably were the piedmont-type forelands of the Intra-Carpathian crystalline masses (today on Czechoslovak territory). The streams flowing through them deposited on them a gravelly waste produced by processes of pedimentation. The Pannonian sea formed embayments reaching far north between the mountains of today; some of the mountain-border benches might be due to its abrasive activity.

All the volcanic mountains are surrounded by a more or less broad outward-sloping foothill surface sculptured in little consolidated sediments, beginning at altitudes of 200 to 300 m a.s.l. (Figs. 18 and 19). The foothill began to develop in the Upper Pliocene. Subsequently, in the Pliocene and Pleistocene, it was strongly dissected by the streams running off the mountains towards the subsiding Great Plains.

Since the Intra-Carpathian stratovolcanoes had risen over little consolidated early Tertiary clayey and sandy marine deposits, the thinner lava sheets and dykes surrounding the central masses of the volcanoes were deeply worn down. In the Cserhát Hills, for example, there are locally only traces of some dykes exposed on the surface. In the northern forelands of the ancient volcanoes, there is a hilly region consisting of loose sediments, part of which is of a basin character. This is the region separating the Intra-Carpathian volcanics and the Mesozoic mountains intercalated between them from their Slovakian counterparts. This is how the broad Sajó and Ipoly basins came to exist, more or less along the Hungarian–Slovakian frontier. The slopes and flat interfluvial rises of the broad valleys are covered with a thick blanket of Pleistocene loamy slope deposits.

In the hilly regions, the warm-humid phases of the Pleistocene resulted in intensified valley sculpture, whereas the cold-humid phases gave rise to large-scale solifluction. In the cold-dry phases, processes of cryoplanation and deflation were dominant. In the southern forelands of the mountains facing the Great Plains there is a broad zone of fluviatile alluvial fans and of glacis of accumulation covered with slope loesses.

In the North Hungarian Mountains, as well as in the Transdanubian Mountains, periglacial pediments and glacis of erosion are among the more conspicuous forms. Their evolution was closely connected with the cold semiarid climates of the Pleistocene. Their transformation (remodelling) was, on the other hand, due to the peculiar types of valley modelling in the Pleistocene. By and large, the mountains of Hungary were areas of degradation during the Pleistocene. Under the periglacial climates, the higher levels of the mountains underwent a profound cryofraction which locally resulted in the formation of ledges and terraces of cryoplanation. On the exposed, hard rocks, a great deal of eluvial debris could form, and the slopes were covered with stone fields and rockflows. The finer waste produced by cryofraction was repeatedly reworked by the wind, meltwaters and solifluction. It was finally deposited as eolian loess, slope loess and deluvia at the feet of the mountains and in the intramontane basins.

VALLEY TYPES

After a mountainous or hilly section of varied length, most Hungarian rivers traverse smaller basins or extensive plains. There are three fundamental morphogenetic valley section types:

(1) terraced valley sections in the mountains or hilly regions,

(2) valley sections with alluvial-fan terraces in the forelands of the mountains and on the basin borders,

(3) floodplain-type valley sections in the basins, unterraced or with one or two low terraces of accumulation.

The best-developed terraced valley section is that of the Danube in its passage through the Transdanubian Mountains. Here six to seven terraces can be distinguished in certain valley profiles. The higher and oldest terrace (denoted VII) is Upper Pliocene: it lies about 200 m above the actual floodplain level. The lower terraces denoted VI to II have been placed in the Pleistocene (Fig. 15).

There is no other seven-terraced valley section except that of the Rába where it passes from Austria into Hungary, but that section is rather short. The terraces pass there into the Lower Kemeneshát alluvial-fan terrace of the Rába (2.24). The Upper Pliocene terraces No. VII of both the Danube and the Rába are sculptured in the border of, or merge into, a glacis gently sloping from the mountain border or a pediment cut in hard rock. The latter are attributed to processes of planation under the Upper Pliocene semiarid climate.

In the valley sections through the Transdanubian Mountains and the hilly regions, 2 to 4 terraces can usually be traced (Fig. 16). Most valley slopes are asymmetric, partly for structural reasons, and partly owing to different climatic exposition. The slopes of southerly exposition are extensive flat surfaces. Often there are terraces of cryoplanation on both valley flanks. The alluvial straths are rather broad in most cases.

The rivers traversing the North Hungarian Mountains emerge broad valley gates into the Great Plains. Along these river sections, a plain type relief penetrates deep to the north. These broad valleys and valley basins are in most cases independent geomorphological microregions, which cut up the mountain range into individual regions. On the gentle valley slopes, 3 to 5 Pleistocene terraces can be traced over rather short intervals.

The rivers emerging from the mountainous or hilly regions, incising into their Pleistocene alluvial fans, have sculptured broad valleys with alluvial-fan terraces. The alluvial fan of the Danube on the border of the Great Plains is subdivided into 4 or 5 terraces, whereas in the alluvial fans of the smaller streams the number of terraces is less, and their altitude decreases as the basin is approached: they converge with the floodplain and then dive under it, to continue beneath the surface as river-laid waste in normal stratigraphic succession. In such cases the streams have no valleys to speak of; locally even their beds are uncertain and they frequently shift their course.

The climatic control of incision by erosion on the one hand, and of the modelling into a terrace of the valley bottom, on the other, during the individual periods of glaciation and deglaciation is a much discussed problem of Carpathian Basin geomorphology. It is impossible to give a correct and unequivocal answer without reference to the local tectonic trends and river grades. The fact that the surfaces of the river terraces of the last glaciation exhibit frequent ice wedges and phenomena of cryoturbation and that in the valleys the terrace material is overlain by slope deposits and loess suggests that the incision initiating terrace sculpture took place at the end of the rather

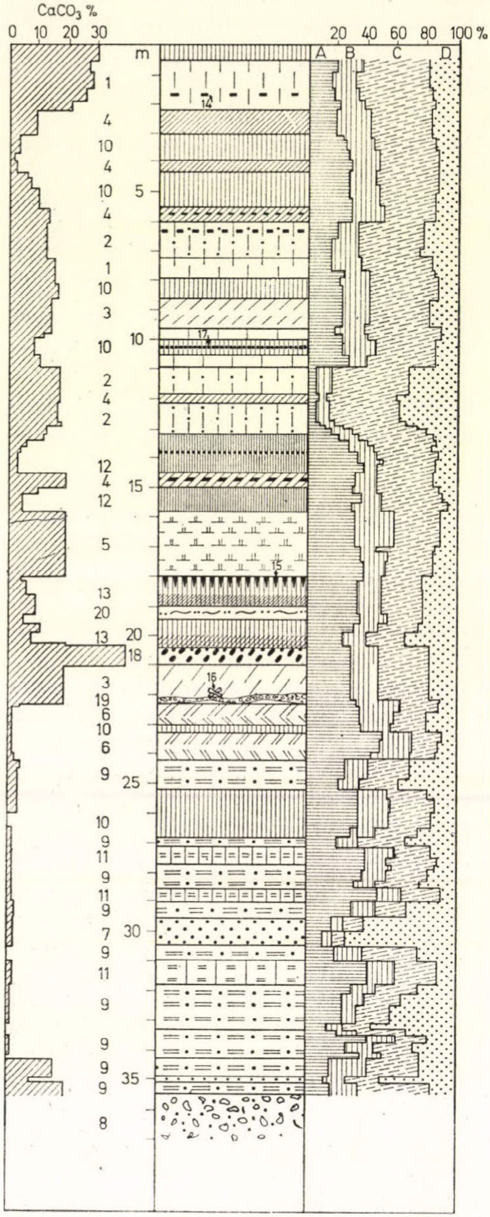


Fig. 20. Loess bluff of Basaharc, overlying the second terrace above floodplain level in the Hungarian Mountains section of the Danube

1 — loess; 2 — sandy loess; 3 — slope loess; 4— semipedolite; 5 — clayey loess; 6 — limeless clayey loess; 7 — river-laid sand; 8 — river-laid sand and gravel; 9 — sandy clay and silty sand; 10 — slightly humified horizon; 11 — muck; 12 — chernosem type soil; 13 — chernosem brown forest soil; 14 — calcareous concretion; 15 — cryoturbation; 16 — vertebrate fossil find; 17 — charcoal; 18 — alluvial limestone bench; 19 — level of denudation; 20 — transitional level
A — clay; B — silt; C — loess; D — sand

humid interglacial preceding the glaciation, i.e. in the anaglacial phase. This is of course valid only in those cases where there is no overriding structural control. This has to be analyzed and proved separately in each particular case, however.

Generalizing our research results concerning these problems, we may state that, as opposed to the other megaregions of Europe, accumulation and erosion wrought by the streams of the Carpathian Basin were not affected either by the damming-up effect of the continental ice cap or by the eustatic fluctuation of the sea level. The feature peculiar to the Carpathian Basin is the repeated intense subsidence of the basin and the similar uplifting of the encircling mountain ranges.

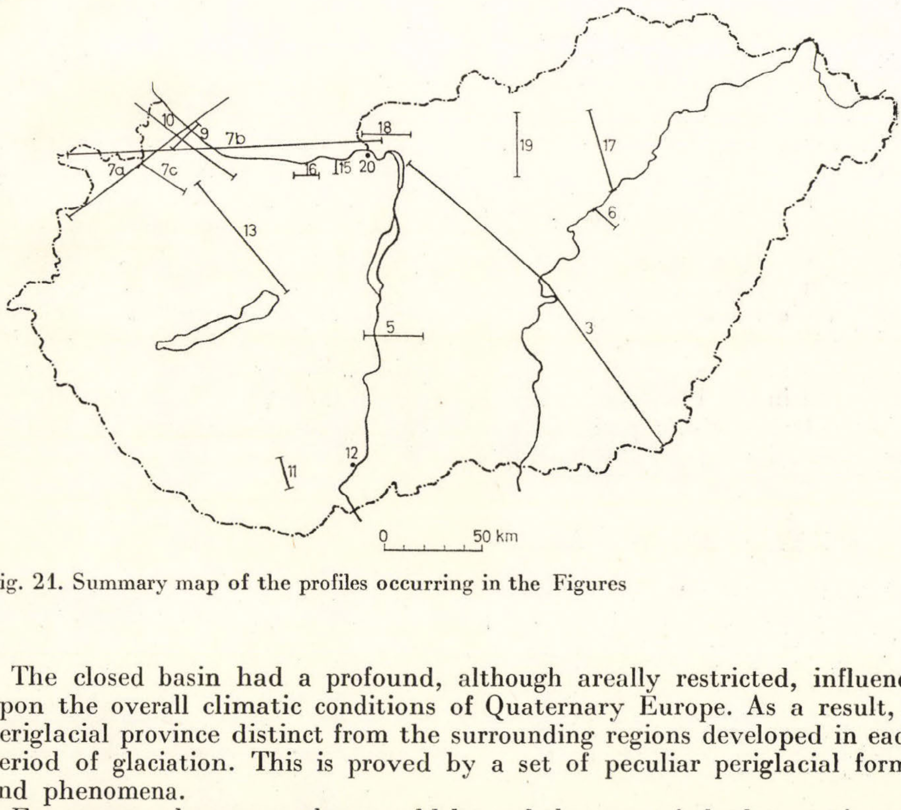


Fig. 21. Summary map of the profiles occurring in the Figures

The closed basin had a profound, although areally restricted, influence upon the overall climatic conditions of Quaternary Europe. As a result, a periglacial province distinct from the surrounding regions developed in each period of glaciation. This is proved by a set of peculiar periglacial forms and phenomena.

For structural reasons, there could be and there was indeed a continuous accumulation in some of the interglacials, in the plains and border zones of the basin. It reacted also on the river valleys emerging into the plains from the mountains or hills. Conversely, in episodes of rapid and intense basin subsidence, erosional valley deepening could take place also during the periods of glaciation. However, the latter possibility existed in the valleys of big water yield only, where the streams were large enough even under a glacial climate.

In the Pannonian Basin, surrounded on all sides by mountain ranges, an alternation during the Pleistocene glaciations of dry-cold continental and cool-humid oceanic climatic influences can be demonstrated. In the interglacials, on the other hand, there was a similar alternation between a temperate continental influence with more abundant precipitation than is the rule today and, particularly in the southern part of the basin, a Mediterranean influence. This is indicated in the exposures of loesses and slope deposits by various fossil soils, climatically controlled sediments and phenomena of solifluction in various successions (Figs. 12, 20).

Although the Hungarian mountains within the Carpathian Basin are of a rather small extent on a continental scale, they provide, owing to their peculiar geomorphological and geological conditions, key examples to several fundamental problems of morphology. Thus e.g. the Carpathian Basin is, as distinct from the surrounding regions, a peculiar facies region of Pleistocene periglacial landscape modelling and sedimentation. It is to be regarded as a separate regional province within the Eurasian Pleistocene periglacial zone.

In summary, we are of the opinion that in the Hungarian Mountains there are among the surfaces of planation remnants of a tropical peneplain, uplifted to various orographic positions (cryptoplanes, exhumed and summit-level peneplain elements, etc.). Remnants of early Tertiary pediplains, Pliocene levels of abrasion can be recognized on the borders of the mountain blocks; in their forelands, there are dissected or remodelled Upper Pliocene piedmont surfaces, glacis of erosion, Pleistocene periglacial pediments and glacis of erosion and accumulation. The streams emerging from the mountains deposited alluvial fans reaching deep into the plains which underwent a continued subsidence in the Pleistocene: this resulted in the formation of vast floodplain-level alluvial-fan plains in the central parts, and of terraced alluvial fans on the borders of the basins.

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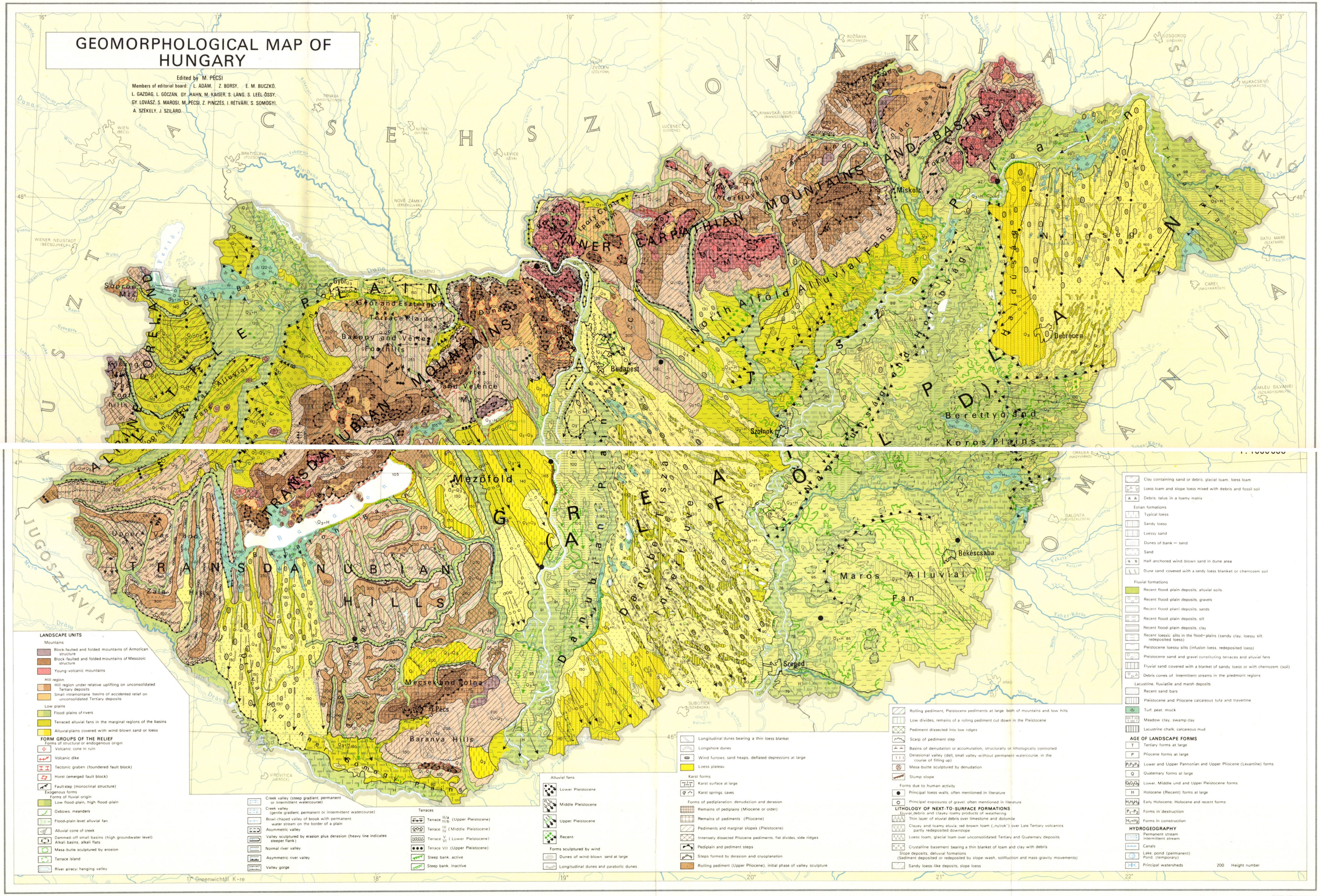

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