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DEVELOPMENT AND EVOLUTION OF KARST REGIONS IN HUNGARY

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I. Location and lithology

Open karst regions only cover 1,350 km² area in Hungary (1.45 per cent of total area). They form a much larger share of the area of low and medium-height mountains (ca 20,000 km² — almost 7 per cent). For this reason and because of their characteristic features and plant associations they strongly influence the landscape of most of our mountains.

Among the limestones the oldest is Carboniferous, while the youngest are of Pannonian (Upper Miocene) age (Fig. 1). The widest spread karst rocks in Hungary are Mesozoic limestones and dolomites, particularly of Triassic and Jurassic age. The most important karst regions are situated-in the NE part of the North Hungarian Mountain Range *(Bükk* and *Aggtelek-Rudabánya Mountains)*, in the *Western Mecsek Mountains* and the *Transdanubian Mountains*, which are also rich in Eocene limestones.

II. Evolution

The karsts of Hungary, irrespective of the rock type, fall into two basic groups according to their features:

1. Aggtelek-type karsts

These are little fractured, extensive *limestone plateaus*. They are equally *rich in surface and subsurface karst features*. The latter mostly include *swallow, spring and through caves* or the remnants of these (shafts, passages and rock arches). Besides gorges and lapiés fields on outcrops, other features such as *solution* and *swallow dolines* and uvalas are found on their surface. A small proportion of dolines are aligned on summits, below summits, and on the floors of shallow to medium deep, dry, limestone valleys. *Rows of dolines along valley floors* are the most marked feature of the Aggtelek-type karsts. The forms of Cretaceous-Paleocene paleokarsts have been almost completely destroyed by now. Hollows created by the solution effect of ascending thermal waters and precipitated travertines only occur along the marginal faults. This type includes the type karsts of the Aggtelek-Rudabánya Mountains, of the Bükk and Mecsek.

2. Bakony-type karsts

These are characterised by rows or groups of mountains, dismembered by rectangular fault systems into numerous, more or less isolated limestone and dolomite blocks elevated or subsided into various elevations. They are poor in surface karst features, usually only lapiés fields, sporadically karst marginal ponors, gorges and rarely dolines or doline-like negative forms. The latter are not aligned along valley floors. They are moderately rich in karst hollows of cold water origin and particularly rich (even in the dolomite and marl mountains) in *karst caverns dissolved or transformed by thermal waters*. Travertine deposits from thermal water are also abundant. They have preserved a good part of their Cretaceous-Paleocene paleokarst features — mostly under Cretaceous-Paleocene bauxitic or Eocene coal-bearing sediments. The group includes the karsts of the Transdanubian Mountains (Bakony, Vértes, Gerecse, Pilis and Buda Mountains), the Western Cserhát and the Villány Mountains.

Both the different and the similar characteristics of the two groups are explained by geologic evolution. The Mesozoic and Paleocene histories were substantially identical. Marine sedimentation in a position at much lower latitude (20—35° N) had stopped by the Mid-Jurassic. The folded and imbricated structures of the Early Kimmeridgian orogeny with local overthrusts uplifted in the middle Jurassic and under the hot humid tropical climate *karstic peneplains* developed on the rocks. Peneplanation, karstification and the formation of laterite and bauxite continued undisturbed until the advent of Austrian orogeny (in the Mid-Cretaceous). When this tectonic activity declined, a second phase of these processes began and lasted to the beginning of the Sub-Hercynian orogenic movements (in the Upper Cretaceous). Since our karst regions were located between 25—30° N in the Paleocene and Eocene, next to seas, climate remained favourable.

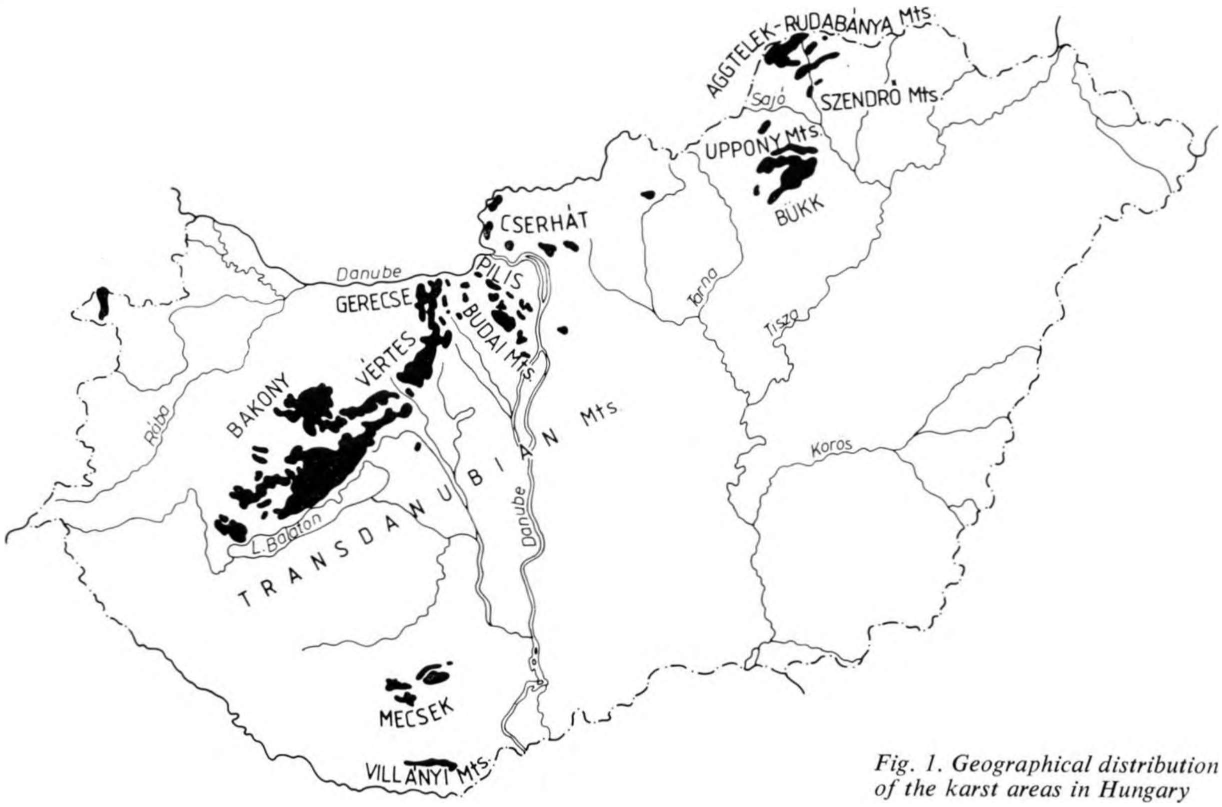

Fig. 1. Geographical distribution of the karst areas in Hungary

Then, however, the processes affected the imbricated and more dissected surfaces left over by Cretaceous tectonic movements.

Cretaceous to Paleocene bauxites have been preserved in the Bakony and Vértes in considerable amounts and smaller patches are also found in the Gerecse, the Buda Mountains, the limestone blocks of the Western Cserhát and the Villány Mountains. Cretaceous kaolinite traces are known from the Keszthely Mountains. The paleokarst features of the open-cast bauxite pits of the Bakony and Vértes Mountains attest to the karst regions being the areas with the most varied topography in the environs of flat planated surfaces in the Cretaceous and Paleocene. The low peneplains were staked by *cockpit and tower karsts* embracing *giant dolines*, intramontane karst levels and coastal karst plains with isolated cones and towers on the margin of peneplains (see Fig. 2). Having close surface and drainage links with their non-karstic neighbourhood, as a whole they must have been *true open mixed karsts* (Table 1, 2.1.1.) with marginal ponors and caves in addition to the mentioned forms. Under the imbrications of thinner, jointed and non-karstic rocks non-independent cryptokarsts formed (Table 1, 2.2.1.), while on top of limestone vaults and imbrications typical open independent karsts (Table 1, 1.1.1.) could form in isolated spots. As deep boreholes have traversed Mesozoic limestones with bauxite and karst hollows in several places, Cretaceous-Paleocene karsts must have occupied much larger areas than remain now.

Since the *Mid-Eocene* the evolution of the two types of karst diverged. Tertiary-Quaternary tectonic movements dismembered the Bakony-type karsts into horsts along an ever denser network of faults, while the Aggtelek-type was much less affected by fractures. The small tectonic units of Bakony-type karsts of chequerboard fault pattern began to move vertically in opposite directions or in the same direction but at different rates beginning in the Mid-Eocene. Consequently, during the marine transgressions from the Mid-Eocene to the late Oligocene, sediments of varying nature and thickness covered the blocks and paleokarsts of the Bakony-type karsts. After regression and uplift the sedimentary cover and the locally exhumed paleokarst were eroded or preserved to various degrees. As a result, the marine transgression from the middle Eocene to the late Oligocene changed the originally typical open mixed non-independent karsts (Table 1, 2.1.1.) into *non-independent karst covered* to various extents (Table 1, 2). After the sea receded, they turned into *partly covered*, locally *exhumde open mixed non-independent karsts* (Table 1, 2.3.).

The less fractured Aggtelek-type karsts were much less affected by sea-level fluctuations. Although it is possible that for a short period of time the whole of the Bükk was submerged under the Upper Eocene sea at its largest extent but it is more probable that it remained land even then. It is a fact, however, that *between the Upper Eocene and Middle Miocene* the Bükk experienced a much

Classification of karsts formed by percolating cold water

longer *land period* and provided a setting for longer denudation than accumulation. There are no traces of early Tertiary sedimentary cover in the Aggtelek-Rudabánya and Mecsek Mountains. Their Cretaceous-Paleocene paleokarsts retained their *typical open mixed non-independent* karst nature all over the Eocene and Oligocene, while karstification went on.

By the late *Upper Oligocene* and *Lower Miocene* both types of karsts had reached their Carpathian locations and integrated into that. Both were *land surfaces* at that time. As a consequence, as attested by borehole data, the area of partly covered and exhumed open mixed non-independent karsts expanded over their present area.

Left without a cover, the bauxite mantle and features of Aggtelek-type tropical karsts have been eroded by the late Oligocene—early Miocene or modified under the influence of climatic change caused by the northward shift. This explains why only traces of bauxite or cockpit or tower karst can be found in the Bükk, Aggtelek-Rudabánya and Mecsek Mountains.

The Ottnangian-Carpathian stages of the Middle Miocene were periods of marine transgression and burial in all Hungarian karst regions. The open mixed non-independent karst of the Bükk, Pilis, Western Cserhát and Aggtelek-Rudabánya Mountains, mostly exhumed in the Lower Miocene, were not only covered by marine sediments but predominantly by Middle and Upper Miocene tuffs and tufites and, in the Aggtelek-Rudabánya Mountains, by alluvial fans. The Miocene subsidence of Aggtelek-type karsts took place without major dismemberment by faults, only marginal faults reactivated and grew in number. The trend of tectonic activity remained the same for Bakony-type karsts also, dismembering continued and covering became uneven again.

By the Badenian burial had slowed down in all Hungarian karst regions and stopped by the Sarmatian. Under the mediterranean climate of the Upper Sarmatian — Lower Pannonian subaerial denudation exhumed small parts of non-independent karsts. Since Lower Pannonian animal bones were recovered from the Esterházy Cave (Vértes) at 204 m altitude and in a doline at 370 m altitude the SE Bükk margin Lower Pannonian marine clay of original bedding was discovered, it seems certain that the rejuvenation of the karsts in Hungary, gave continuous *Tertiary-Quaternary karstification dating back to the Upper Sarmatian.* In that period the present drainage of the low and medium-height mountains and the then mostly covered karst regions began to evolve.

The Pannonian transgression laid deposits over the margins of karst exhumed in the Upper Sarmatian — Lower Pannonian. Ar the same time in the inner parts, due to reduced relief and aridification of climate in the Upper Pannonian, slow exhumation of cryptokarsts and buried karsts went on. When the Pannonian sea contracted into a lake and climate became more humid in the Pliocene, exhumation accelerated everywhere. The forces working against it were only basalt effusions and

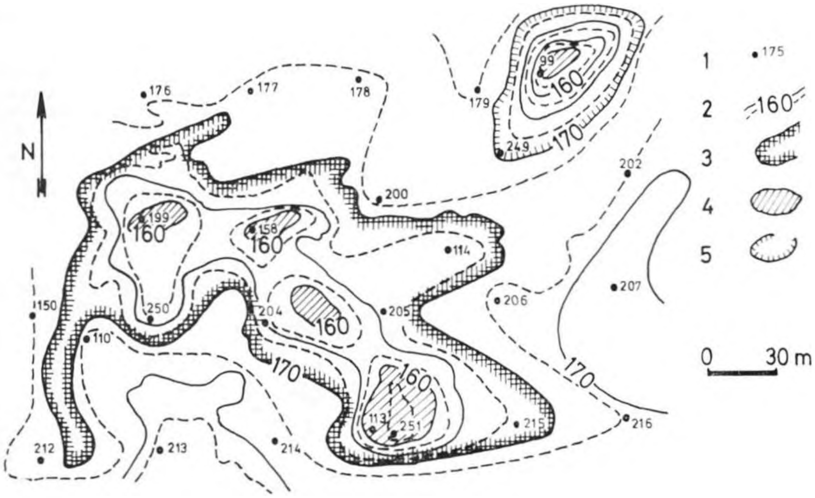

Fig. 2. Karstic surface on dolomite N of Halimba (Bakony Mountains). 1 = no. of borehole, 2 = line of levels (m), 3 = uvala, 4 = deepest part of a doline, 5 = doline

tephra scatters and dust accumulation in the glacials. Since the Upper Pannonian phases of uplift and calm alternated, climate fluctuated and the changes can be detected in the altitude, relative positions, shape and dimensions of karst features, and the sediments and paleontological-archaeological finds in their fills.

Climatic oscillations affected the Aggtelek- and Bakony-type karsts equally. In the late Pliocene and in the Pleistocene interglacials, when temperature, precipitation, soil and vegetation conditions were similar to the present day weathering products and also karstification were governed by rainwater and streams. In colder periods karstification went on at a slower rate, the predominant process of exhumation was frost action and gelisolifluction. The latter played an important role in blocking ponors and dolines, filling them and destroying uplifted caves. Dust accumulation and permafrost efficiently to hindered this slow karstification and elimination of covered karsts.

In the impact of tectonism the differences between the Aggtelek- and Bakony-type karsts still exist. In the Bakony-type karsts — particularly in the Transdanubian Mountains — faults were rejuvenated, new ones added to them and, consequently, ascending thermal waters formed more and more caves, not only in limestone but also in dolomite and marl blocks. The stages of uplift can be reconstructed from spring caves located in levels above each other and terrace-like travertine horizons (Fig. 3).

The unfractured Aggtelek-type karsts show hollows or travertines along their marginal faults. Over their extensive plateaus and broad ridges, the exhumation of covered and partly covered karsts and the formation of Pliocene-Quaternary features were primarily due to the drainage network formed on non-karstic cover rocks. Where streams cut down to the karstifying rocks, depending on the position of the karst water table, they were either superimposed on the karstic rocks or ponors were formed without a previous valley (Fig. 4).

As a result of the rapid drop of karst water levels in stages of uplift, the bathycapture of streams of antecedent valleys, and the headward erosion of the site of bathycapture characteristic swallow doline rows were produced (Fig. 5). The valleys superimposed over exclusively karstic rocks lost their surface catchments (through the erosion of non-karstic cover sediments) and became shallow, or medium deep, dry, low-gradient karst valleys with usually swallow doline rows. As depressions infilled, their deeper soils and richer vegetation remained to be the main lines of karstification and new dolines emerged on their floors, particularly solution dolines while dried-out sinkholes kept on broadening and deepening through solution.

In the Aggtelek-Rudabánya Mountains and the Bükk, dolines are common, both in larger number in antecedent valleys and independent of them. In the Mecsek dolines not associated with valleys are rare, they are 'hanging' over the valley floor doline rows in summit or subsummit positions. They constitute, together with the shafts of summit and dry spring caves opening higher than the floors of valleys with doline rows, the older generation of features in the Aggtelek-type karsts, already existing before the Upper Pliocene.

As exhumation advanced, the surface drainage of covered karsts was also fed by already existing big karst springs. The drainage related to them may have formed by the late Pliocene and inherited over the limestone surfaces in the early Pleistocene. The last date for bathycaptures was the Villányian stage of the Lower Pleistocene.

As the non-karstic cover became dissected and diminished, the catchments of antecedent valleys were reduced in area and they and their doline rows became dry for longer periods. (The only exceptions are those valleys or valley sections which

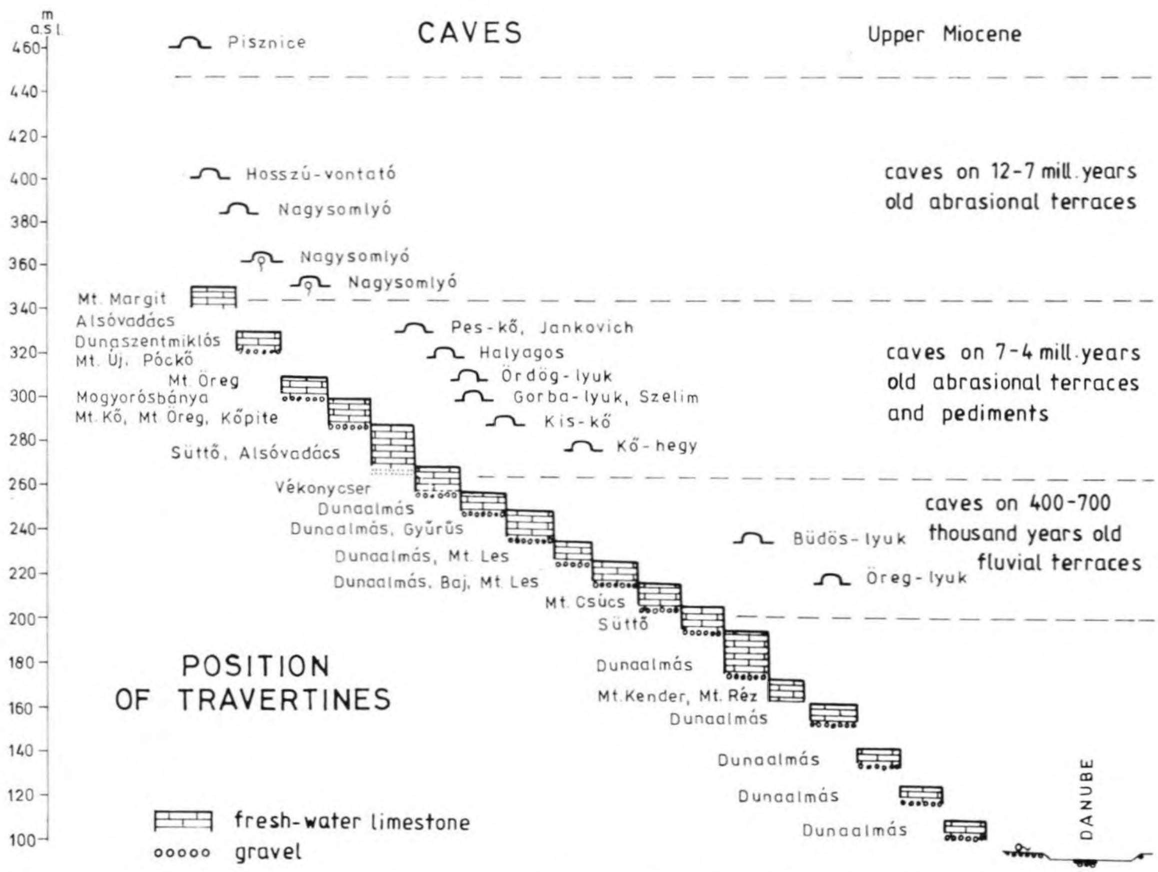

Fig. 3. Connection of the travertines and cave levels in the Gerecse Mountains (after F. Schweitzer)

were superimposed over impermeable non-karstic rock zones.)

During the glacials dust accumulation and permafrost conditions reduced the rate of exhumation and they even gained in area temporarily. With no infiltration, almost all the meltwater and summer precipitation easily found its way from frozen limestone slopes into the valleys and revived the rows of sinkholes there. In winters when strong and prolonged frosts precede the formation of snow cover, a similar effect of frozen soil (only seasonally and for shorter periods) can be observed even today. After thaw the exhumed open karsts became covered ones usually for 4—5 days, but sometimes for one or two weeks. The temporary catchments become functioning ones and snowmelt accumulates in ponds and sinks noisely.

The exhumation of covered and partly covered karsts, governed by surface drainage, is only characteristic of the Aggtelek-type karsts. Over the small limestone and dolomite horsts of Bakony-type karsts large surface drainage networks could not develop even under covered conditions. This is the main reason why there are no karst valleys with doline rows there and the sporadic swallow and solution dolines only occur on the most extensive blocks.

As for the medium-height mountains of Hungary in general, the Plio-Pleistocene uplift of Bakony-type karsts can also be estimated at 250—400 m. Parallel with the multi-stage uplift, relative karst water levels sank and new spring cave levels formed and dry caves began to be destroyed. In the glacials with intensive frost shattering their remuval was particularly rapid, culminating in the last (Würm) glacial.

The recent revival of karstification began in the Atlantic stage of the Holocene (7000 BP). Under somewhat warmer and more humid climate than at present the further exhumation of still covered and partially covered karsts started, blocked ponors opened, infilled dolines cleared of sediment and helped by the CO_2 produced in the brown or locally black rendzinas and red clay paleosols of oakwoods with rich undergrowth, surface and subsurface karst features developed further and became more abundant. These processes, although at a slower rate, are still active today.

III. General description of karst regions, with special regard to their surface features

1. Aggtelek-type karsts

Aggtelek–Rudabánya Mountains

This is the Hungarian portion of the most characteristic and largest karst region of the Carpathian Basin, the Gömör-Torna karst. It is subdivided into the Aggtelek and Szalonna karsts.

The more extensive *Aggtelek karst* is a mostly exhumed, although some remnants are covered, mixed non-independent karst, developed on an originally open and then buried mixed non-independent karst (Table 1, 2.3.4). It is built up mainly of Triassic limestone with some dolomite, shale and sandstone. The S margin is mantled by Upper Pannonian marine sediments.

The larger part, N of the Kecső and Jósva streams, the Haragistya, Nagy-oldal and Alsó-hegy are SE continuations of the Szilice karst in Slovakia. The surface features — because of its more homogeneous lithology — hardly show its nature of mixed karst. There are ridges at 400—600 m altitude with conspicuous lapiés fields, hanging dolines, shafts and some uplifted spring caves. They are divided by broad, dry blind valleys with doline and uvala rows. Coalescing karst valleys often form wider, polje-like sections dotted with a dense network of dolines and uvalas. The most important shafts and swallow caves are found on the Alsó-hegy plateau.

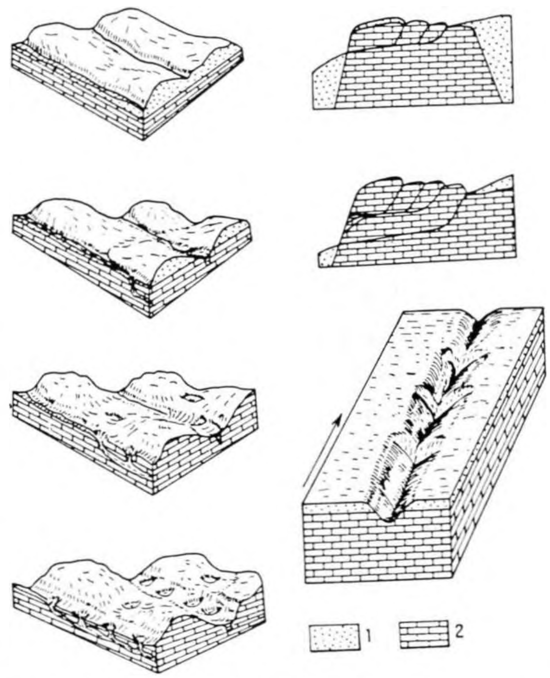

Fig. 5. Valley of epigenetic water course of covered karst transforming into a row of dolines through repeated bathycapture (L. Jakucs 1968. A. Hevesi 1978). 1 = non-karstic rock cover, 2 = limestone

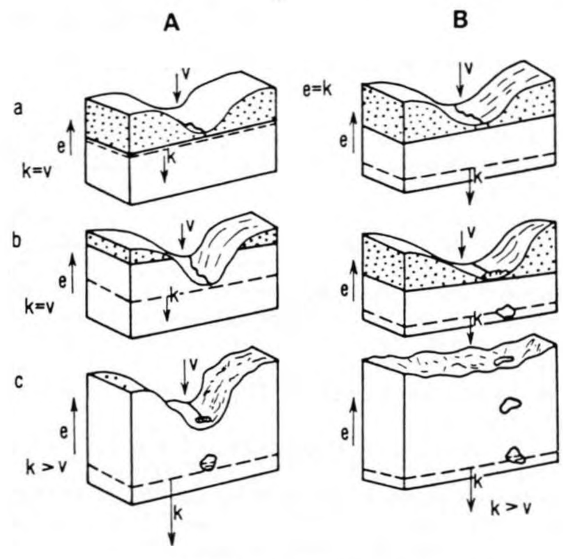

Fig. 4. The ways of inneritance of drainage on non-karstic surface over karstic rock. 1 = non-karstic rock, 2 = limestone, 3 = karst water table; e = uplift, k = sinking karst water table, v = downcutting

Among the high-yielding karst springs at the southern foot of the Haragistya-Nagy-oldal, the Big and Small Tohonya springs and the Kossuth and Vass Imre caves are worth mentioning. The only permanent water-course of the inner karst area is the Ménes stream. It follows a narrow shale zone within limestone terrain and breaks through a splendid limestone gorge (Vár-völgy) towards the Bódva valley. Its channel is interrupted by fine travertine steps.

The smaller portion of the Aggtelek karst S of the Kecső—Jósva valley is the *Galyaság*, a ridge of 300—480 m altitude. The W half is built up of Triassic limestone and encircled by Upper Pannonian marine deposits on the S and SW and Triassic shale and sandstone terrain on the E and SE. Its karst shows the characteristics of both partially exhumed and open mixed non-independent karsts. Major intermittent and permanent water-courses reach it from the non-karstic neighbourhood and resurgent blind valleys end in typical karst margin ponors (Bába, Ravasz- and Zombor-lyuk, Vizetes ponor). In the past the streams had more abundant water and sediment discharges carved and dissolved the longest through caves with dripstones in Hungary (Baradla, Béke Cave — Fig. 6).

The inner parts of the limestone ridges of the Galyaság are characterised by lapiés fields, shafts and hanging dolines on crests and between the

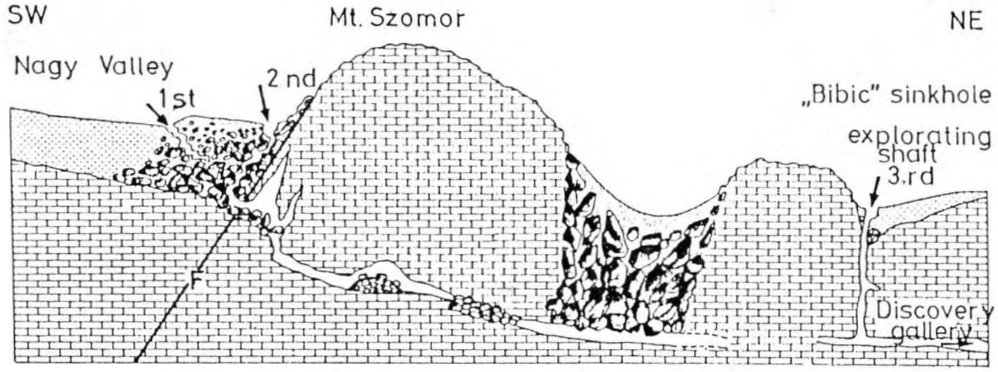

Fig. 6. Natural entrances of the Béke Cave (Aggtelek Karst)

crests karst valleys with doline rows and uvalas. As with all Aggtelek-type karsts the brown and black rendzina soils (accordant with present climate and vegetation) only occurs on the summits.

However it is notable that slopes, karst valley floors, dolines and uvalas are mantled by rendzina with red clay and terra rossa-like paleosols of still debated origin. The swelling red clays are often compacted into impermeable layers and lead to the formation of lakes in sinkholes, the largest of them are the Aggtelek and Vörös Lakes.

A smaller, almost idependent part of the Aggtelek-Rudabánya Mountains lies to the S of the Aggtelek karst, stretching from Rudabánya to Tornaszentandrás, the *Szalonna karst.* It rises to 300—500 m above sea level from its mostly Plio-Pleistocene marine-subaerial sedimentary environs, bordered by fault scarps. Its horst is built up of Triassic limestone, dolomite and shale and the hot and lukewarm springs and travertine precipitations at its foot also make it resemble to the largest Bakony-type karsts.

The tectonically preformed valley of the Bódva divides it into two uneven wings. As a whole, both are mostly exhumed, but with small areas still covered mixed non-independent karst, originally open mixed, then buried under Pannonian sand, Pliocene gravel and Pleistocene loam (Table 1, 2.3.4). Its small area explains why it shows less abundance of surface karst features. On the broad ridges of its wider NE wing some shafts open (Szár-hegy) and karst valleys with dolines along their floors start from among the crests of the Szár-hegy and Dunna-tető area; on reaching the fault scarp margin of the karst they continue with intermittent streams and dry gorges of very high gradient. The dripstone caves below the karst water level in the Esztramos, an isolated hill to the N of the NE flank, have already been destroyed by stone-quarrying.

The narrower SW flank of the Szalonna karst shows even less karst phenomena. The only spectacular feature is the antecedent limestone gorge of the Telekes stream, probably developed from a cave.

The Szendrő Mountains of Devonian-Carboniferous sedimentary and metamorphic rocks in the SE neighbourhood of the Aggtelek-Rudabánya Mountains is now being exhumed from its Pliocene cover by the water system of the Rakaca stream. With the exception of some antecedent gorge section cut into Carboniferous crystalline limestone, which are not true karst features, no other karst phenomena are worth mentioning.

Bükk

On the Carboniferous-Permian-Triassic-Jurassic limestones and dolomites as well as Eocene limestone and calcareous marl, originally open, then buried and now exhuming, only partially covered mixed non-independent karsts are found (Table 1, 2.3.4). Most or its karsts were formed on the exhuming planated surface, originally denuded under the tropical climate of the Cretaceous-Middle Eocene, partly buried and partly further planated in the early Tertiary and substantially modified in the S and N Bükk as well as the E and NE margin of the Bükk Plateau by abrasion. Even today warm and lukewarm karst springs of large discharge issue along the marginal faults and the travertine deposits (at Mónosbél, Eger, Latorút, Diósgyőr, Mályinka and Bélapátfalva) clearly mark the boundaries of the mountains. Travertines deposited from cold water are also numerous, one of them, the Lillafüred accumulation incorporates Europe's second largest hollow system in travertine.

The Bükk is well-studied by archaeologists, paleontologists and sedimentologists. The distinction between the two spring cave and doline generations of Aggtelek-type karsts rests mainly on the results of cave excavations in the Bükk Mountains. They have identified Upper Pliocene spring cave and hanging dolines, at least Lower Pleistocene valley doline rows and Riss spring caves.

Among the parts of the mountains, the Bükk Plateau and the SE-Bükk are true karst regions, while the N- and SW-Bükk are microregions only made more diverse by karsts.

The uplifted *Bükk Plateau* of 22 km length and 0.5—6 km width is the highest lying and largest contiguous karst region (120 km² area) of Hungary. Most of the plateau is built up of easily karstifying Triassic-Jurassic limestones. Its Permian bituminous and Triassic cherty limestone and dolomite is of medium to poor susceptibility to karstification. Its mixed karst nature is due to Triassic-Jurassic shales, Triassic porphirites and diabase appearing in long and narrow stripes. It is in two parts, the Great and Little Plateaus, separated by the Garadna valley following Carboniferous-Permian shales and sandstones. These partially covered, non-independent karsts differ in their height and, consequently, in the degree of their exhumation.

The 300—400 m higher *Great Plateau* (at 600—950 m above sea level) was mantled once by Middle to Upper Miocene tuff, tufite and Pleistocene dust, the remnants of which form red and orange clays only preserved in the dolines of karst valleys. It is now mostly exhumed open mixed non-independent karst (Table 1, 2.1.2.). The lower, E part of the *Little Plateau* (350—750 m) is still mantled by 1—3 m clayey weathering material with intermittent water-courses and even permanent small streams. Exhumation, the bathycapture of water-courses and the headward shift of the site of bathycapture can be still detected at some places.

In spite of the differences, the Great and Little Plateaus show some similar features. Antecedent dry karst valleys of low gradient superimposed over the limestone and bathycaptured through sinkhole rows are the most typical landforms. Between them on both plateaus, lapiés fields, hanging dolines, shafts and abandoned spring caves are seen on crests and summits. The characteristic features of the open mixed non-independent karsts (Table 1, 2.1.2.), the blind valleys with resurgent streams on karst margins are only secondary, but not insignificant elements (the Jávorkút, Bolhás and Létrás sinkholes).

Some 'records' from the Bükk Mountains:

1. The deepest cave of the country, the Istvánlápa cave, is found here (—250 m).

2. The highest elevated, now abandoned spring cave (Köris-lyuk, 930 m above sea level), hanging doline (at Istállós-kő, 950 m), shaft entrance (Kis-Kőhát shaft, 920 m) and active swallow cave (Bánkúti-visszafolyó, 870 m) are all on the Bükk Plateau.

3. Due to its uplifted position, the largest number and highest diversity of abandoned caves, hollow remnants (stone arches and passage sections), most numerous on the face of denudation scarps of marginal crests (Tar-, Három-, Tamás-, Magos- and Sólyom-kő).

4. The longest active swallow cave of Hungary, the Létrás water cave and the only true collapse doline, the 15 m deep Udvar-kő are found here.

5. The largest of the karst polje-like features with dolines and uvalas also lie on the plateau (Nagymező, Zsidó-rét, Létrás.

The 450—720 m high *SE-Bükk* is characterised by broad stripes of Triassic-Jurassic limestone, narrow zones of shales and diabase and porphirite of the same age. The water-courses arriving from non-karstic terrain mostly reach its NW half. As a whole it was originally open, then buried, and now largely exhumed, only in small part covered mixed non-independent karst (Table 1, 2.3.4.). The NW half has become almost completely exhumed open mixed non-independent karst (Table 1, 2.1.2.).

The height difference between the floors of stream valleys and the average karst water level did exceed the range of karst water niveau previously and in some cases it is still less. Therefore, the valleys continue their course over limestone. However, some of the streams are bathycaptured on arriving at the valley section in limestone. The latter include the resurgent streams with the highest discharge, the sinkholes are the best-developed karst margin ponors (Pénzpatak and Diós-patak ponors). The streams which reach the limestone terrain at lower altitudes mostly carve gorges, the floors of which do not have permanent swallow dolines because of the range of karst water levels (in the Balla and Pazsag valleys). A outstanding example of karst water range is the Gyertyán valley catavotre, which functions as a sinkhole at medium and low karst water levels, while it is a spring, when karst water rises substantially above the average niveau. This is the only catavotre of the mountains and also of Hungary.

Over the broader limestone zone of the SE part of the SE-Bükk hardly any water-course arrives from non-karstic terrain. Therefore, features here resemble the Bükk Plateau with hanging dolines, shafts on broad flat ridges with dry karst valleys with doline rows and hanging valley torsos between them.

The entire SE-Bükk is rich in caves of various types, abandoned passages and gorges formed from collapsed caves. At its SE foot karst springs mixed with thermal waters recharge a spring cave developed into a broad, health bath (at Miskolctapolca). Along the S margin is the only important Eocene limestone stripe with some dolines and caves.

Although Triassic-Jurassic limestones outcrop only in places in the 400—700 m high SW-Bükk between slates and diabase (basalt) and gabbro masses of similar age, this mountain section is rich in caves and limestone gorges. As a whole it is a non-independent karst buried under shale series of varying thickness and heavily jointed (Table 1, 2.2.1.). In isolation limestone areas rise with karst forms of open mixed non-independent (Table 1, 2.1.1.), partially covered, exhumed or exhuming non-independent (Table 1, 2.3.) and exhuming open independent (Table 1, 1.2.) karsts.

The spectacular limestone gorges and the caves opening on to them have mostly been destroyed by stone-qaurrying. Some evidence however for the origin of the gorges through the collapse of caves still survive. Among the caverns the Hajnóczy cave indludes the oldest paleontological finds of the

Bükk Mountains. The Nádasbérc shaft opening in slate and continuing in limestone provides a perfect demonstration of the cryptokarst nature of the SW-Bükk and the sinking of karst water table in intermittent karst springs (like the Imó, Vöröskő and Feketelen springs). From the partly red-clay mantled ridge of the Berva-Cseres crest, uplifted above a non-karstic environment, blind valleys ending in ponors and valleys with swallow dolines start.

The Carboniferous-Permian-Triassic limestone surface of the *N-Bükk* are of smaller area than those of the SW-Bükk. These karstic areas at 400—600 m altitude are isolated exhumed open independent karsts (Table 1, 1.1.2.) rising as klippen formed by selective erosion above their non-karstic environs (Carboniferous-Permian-Triassic shales, sandstones, Miocene marine sediments and tuffs). Disregarding the two dolines of the Kemesnye-hegy, only some caves and rock niches are known. The most typical karst process today is continuous travertine deposition. A third of the 36 travertine occurrences of the mountains (11) are located here. Deposition takes place from either karst springs or from confined groundwater springs of non-karstic rocks, in communication with karst water. The travertine steps of the Szalajka valley are the finest in Hungary.

The neighbouring *Uppony Mountains* contains smaller Triassic and semicrystalline Carboniferous limestone outcrops. In addition to small caves, the spectacular antecedent gorge of the Csermely stream, carved into Carboniferous limestone is worth mentioning. The Paleozoic rocks are overlain by Middle Miocene (Badenian) marine sediments and Sarmatian andesite agglomerate in the E. Agglomerate blocks of the size of houses have slumped down on sandy-clayey Badenian series and as a result of slumping have produced zig-zag cavity systems closed at the top and dilated at the bottom. The most extensive non-karstic pseudocave of the country developed between the agglomerate blocks of the Damasa gorge of Bánhorváti, as a result of similar slumping only 300 years ago.

Mecsek Mountains

This mountain region lies a long distance away from both the Transdanubian and the North-Hungarian Mountain Range. The karstifying rocks (Middle Triassic, Middle Jurassic and Middle Miocene limestones) only occur in quantities sufficient for the evolution of a major karst region in the W part.

On the Middle Triassic limestone of the W-Mecsek a 38 km² karst area has developed. It continues under Pleistocene loess to the NW and N and under Middle Miocene marine deposits to the NE, while on the STriassic slate and sandstone zone trancates it down. By position it is a two level marginal karst plateau of 300—500 m altitude. The paleokarst features of the Cretaceous-Eocene peneplain, fundamentally reshaped during the Oligocene-Lower Miocene were destroyed by the Middle Miocene marine transgression, which carved a wide abrasional platform into the mountain slopes. After regression, the Triassic limestone body of the W-Mecsek became land as covered karst and was exhuming through the Sarmation down to the Pannonian. In the northern lower part the Pannonian sea abraded a new beach and laiddown deposits where they were missing from the Middle Miocene cover.

The karst region, open from the Jurassic to the mid-Miocene, buried in the Miocene and partially covered today, is a mixed non-independent karst (Table 1, 2.3.1.). It is situated on two raised beaches above each other. Karstification has been continuous on the higher and older level since the Sarmatian and on the lower and younger one since the Pliocene.

The exhumation of the W-Mecsek karst which is much lower than the ones mentioned above, could only have been much less rapid. This explains why the rows of swallow dolines in the antecedent valleys are much younger (although mostly dry for long periods), their slopes are steeper and their diameter is smaller than their counterparts in the Aggtelek karst or Bükk Mountains. The NW and N margin of the W-Mecsek is a typical non-independent cryptokarst (Table 1, 2.2.1.), where the doline like depressions of the loess surface are also present in the Triassic limestone. On the other hand, the S margin of the karst is slowly exhuming, open mixed non-independent (Table 1, 2.1.2.), where minor intermittent and permanent resurgent streams have blind valleys ending in ponors (Büdös-kút and Szuadó valleys). The ponors of the higher-lying S margin and the spring caves of the lower N margin communicate through more-or-less passable passages. Most of them are active through caves.

Lower elevation means that fewer cave levels, multistoreyed caves, abandoned caves, subsummit avens and hanging dolines are found here.

The most picturesque limestone gorge in this karst area is the Nagy-Mély valley and the Melegmány stream flowing through is famous for its travertine steps.

2. Bakony-type karsts

Transdanubian Mountains

Although 65 per cent of the rocks forming this mountain range are non-karstic, 21 per cent are poorly karstifying dolomite, and limestones of all age only make up 9 per cent, all the members of the range are rich in caves. This paradox situation can be explained by the presence of easily karstifying rocks (Dachstein Limestone 5 per cent, with average length of cavities: 25 m/km²; Eocene limestone 4 per cent; 36 m/km²) almost everywhere and the solution capacity of ascending thermal waters.

The karsts are found on the Mesozoic limestones and dolomites of the horsts of the cretaceous-Paleocene peneplain at different elevations and consequently exhumed to various degrees (Fig. 7). A smaller part was formed on late Tertiary-Quaternary raised beaches on these peneplain remnants,

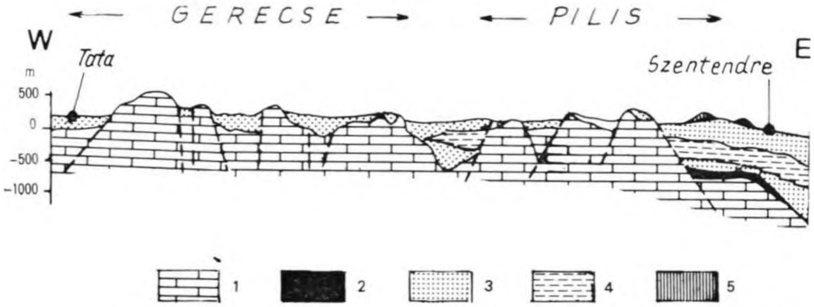

Fig. 7. Geological section of Gerecse and Pilis Mountains (after L. Korpás, 1980). — 1 = Mesozoic and Eocene limestone and dolomite, 2 = Oligocene sandstone, 3 = Oligocene sand with coal desposits, 4 = Oligocene clay, 5 = Neogene rocks

Eocene limestones and marls, Miocene limestone as well as on pediments and river terraces.

Bakony

The 350—700 m high Bakony form the most extensive mountains with one of the most diverse lithologies in Hungary. From Silurian porphiroids and slates to the Holocene, each period (with the exception of the Carboniferous) and from the late Tertiary each epoch are represented by (usually sedimentary) rocks.

Among the three regions the most uniform is the plateau-like *Keszthely Mountains* built up predominantly of Triassic dolomite with Pannonian sand and sandstone cover on its margins. As a consequence of its lithological composition, the mountains is relatively poor in karst phenomena. Some sinkholes and swallow caves (the Szél-lik of Ederics, 50.2 m deep) formed on the Triassic limestone zone above Balatonederics. The short rock niches in dolomite open on the cliffs of narrow gorges (Kígyós, Csider and Szentmiklóssy valleys) or on the steep scarp above the Pannonian raised beach. A true abrasional cave is the Vadlán-lik of Gyenesdiás. Among the thermal solution caves of Upper Pannonian age along the W marginal faults of the mountains the Cserszegtomaj well cave is worth mentioning. The successors of these thermal springs — mixed with lukewarm karst water — issue today much to the S and at lower levels, at Héviz.

The other two regions of the Bakony, the N- and S-Bakony are much more diverse in lithology and more fractured. The covered and partially exhumed planated horsts make it the microregion richest in paleokarst features in the country and even in the Carpathian Basin. The Cretaceous-Paleocene tropical karst features exposed by open-cast bauxite and manganese mining are equally common in Triassic-Jurassic limestones and Triassic dolomite (Halimba, Nyirád, Szőc, Iharkút and Urkút) (see Fig. 2). The relative uplift of horsts and grabens also produced younger, Oligocene to Miocene dolines. They are filled by red clay mixed with Miocene gravels instead of bauxite.

The conditions of more recent, Upper Miocene-Pliocene-Quaternary karstification and the forms produced in the N- and S-Bakony are not always the same. Most of the caves in the 350—700 m high *N-Bakony* were dissolved by cold waters in Triassic. Jurassic and Eocene limestones and Triassic dolomite. The elevated, totally or almost totally exhumed limestone and dolomite planated horsts contain short abandoned caves and some truncated shafts (Odvas-kő cave, Nagy-Pénz-lik, Hálóvető-völgyi-átjáró, Gombás cave, Likas-kő of Tönkölös and the Kőris-hegy Ördög-lik). Over the mostly covered broader ridges less elevated and mantled by loess and slope loess with red clay intermittent swallow caves have been and are being produced by short intermittent water-courses cutting into the cover layers. The short blind valleys in loess terminating in ponors and the related caves are characteristic of the partially covered plateau blocks encircled by higher horsts of the N-Bakony (the Tés Plateau, Mellás Plateau of Isztimér and Hárskút half-basin). These are also the most extensive karst features of the whole mountains. The 400—450 m surface of the Tés Plateau is densely spotted by ponors (17 in number).

Compared to its richness in caves, disregarding the lapiés fields and ponors, the N-Bakony is poor in surface karst forms. Well-developed dolines are only found on the Jurassic limestone of the Nagy-Som-hegy (650 m) and on the Eocene limestone of the area SE of Bakonybél. The red-clay flats of the Tés Plateau are only shallow embrionic dolines. Spectacular features are the gorge sections, perhaps collapsed caves, of the antecedent valleys cutting through the limestone-dolomite crests. Their steep, locally subvertical cliffs or even overhangs are spotted by a lot of rock niches, shelters, cave and chimney remnants (Cuha, Gaja, Burok, Vár, Sötét-horog valleys, Ördög-árok and Kő-árok). The most abundant marginal karst spring, the Tapolca-fő, once feeding the Tapolca stream of Pápa, mixed with ascending hot waters, supplied Ajka in the late sixties and it dried out when the karst water niveau was reduced for mining.

The 300—600 m high S-Bakony is much poorer in elevated caves, avens and spectacular gorges than the N-Bakony. The dry hollows (the Baglyas-hegy, Biked-tető, Dobogó-tető and Mecsek-hegy caves and the Somos-kő spring cave) are short niches and cave fragments. Only the Eocene limestone outcrop adjoining the Pliocene basalt mantle of the Kab-hegy to the SW between Padrag, Csékút, Ajka and Urkút is a typical karst region. The blind

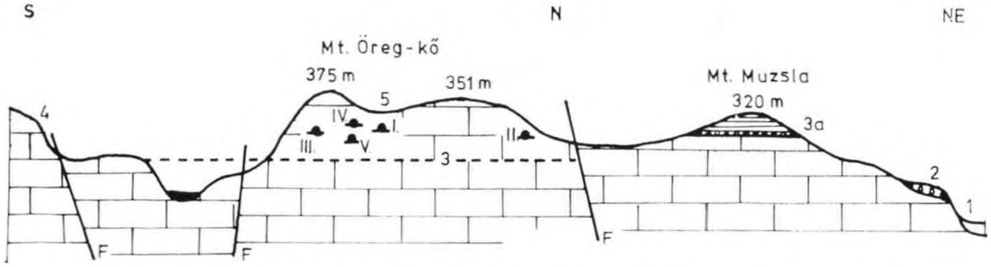

Fig. 8. Geological section of the Mount Öreg-kő (N—Gerecse Mountains)

valleys of the intermittent water-courses coming from the lava terrain and continued in resurgent streams end partly in ponors (Bújó-lik) of open, mixed, non-independent karsts (Table 1, 2.1.) and partly in those (e.g. Macska-lik) beginning in non-karstic rock (here basalt) and continuing in Eocene limestone characteristic of non-independent crypto-karsts (Table 1, 2.2.1.).

The S-Bakony is richer in thermal cavities and those of other extraordinary development. To the S the Balaton Uplands the Lóczy Cave is a system of passages solved by thermal water in folded Triassic limestone, while the largest and most picturesque is the Tapolca lake cave in Sarmatian limestone.

The geysers accompanying Pliocene basalt volcanism and also surviving to the Pleistocene produced several spring hollows (the Forrás cave of Tihany and the Csúcs-hegy spring hollow). Vent chambers of geyserite cones are similar (Aranyház, Cser-hegy and Koloska-völgy geyserite cone hollows).

In other respects Pliocene volcanic activity also contributed to the karst features of the S-Bakony karst: the basalt mantles show doline-like depressions with ponds and irregular passages have formed along the fractures of the lava mantle (Kab-hegy, Loncsos-tető and Fekete-hegy of Monostorapáti and Láz-hegy of Zsid).

Vértes

The 300—480 m high Vértes is the most uniform member of the Transdanubian Mountains. To the extensive Triassic dolomite plates only smaller Triassic limestone areas and insignificant patches of Jurassic, Cretaceous and Eocene limestones are added. Therefore, of the Bakony-type karsts it is the poorest in karst features. Although in the neighbourhood of Gánt Cretaceous-Paleocene paleodolines have been preserved, outcrops with lapiés fields are only common on faulted marginal slopes and gorge walls (Fáni, Kőlik, Ugró and Csákberény Meszes valleys).

The formation of the Csókakő spring vent is due to the action of ascending hot waters and their calcareous silica cemented the material of some of the marginal cliff towers. In the central part of the mountains — disregarding the head-waters of gorges — only minor caves occur (e.g. the Nagy-tiszta swallow cave).

Gerecse

The 300—630 m high, exhumed and partially covered planated horsts are mainly built up of Triassic limestone and dolomite as well as Jurassic and Cretaceous limestones. The partially exhumed limestone blocks are locally covered by Eocene-Oligocene sediments, Pliocene travertines or Pleistocene loesses. The highest elevated and totally exhumed horsts are classified as exhumed open mixed non-independent karsts (Table 1, 2.1.2. or 1.1.2.). As the isolated limestone patches of the latter were also part of the Cretaceous-Paleocene peneplain with much larger open mixed non-independent karsts and then during the exhumation after burial became partially covered non-independent karsts, they are also rich in *swallow and spring caves*.

The most extensive karst plateau fragments after the Bakony are found here. Besides lapiés fields, there are some dolines (Nagy-Gerecse and Lukas-kő) and on the Nagy-Som-hegy even some doline rows. At the terminal point of a small water-course, in a small sinkhole the Arany-lyuk of Szőlős opens. The Vértestolna Basin is a loess-filled graben between planated horst series, resembling a tectonic polje. Towards the N the Bitva stream leaves it through a splendid gorge and and to the S the Tuskó-rét-szurdok stream carved its counterpart.

The Gerecse is also next to the Bakony as regards the abundance of karst cavities in the Transdanubian Mountains. The number of avens and spring caves in summit or subsummit positions is even higher. The precision of cave dating is the highest in the Gerecse as it relies on the paleontological finds of travertines deposited from thermal springs.

Some exhumed horsts are densely spotted by hollows of various dimensions (Fábián-kő, Nagy-Somlyó, Nagy-Pisznice, the Turul-hegy of Alsó-galla, Öreg-kő of Bajót, and others). Among the uplifted spring caves the Pisznice cave and the Szelim and Jankovich caves, famous for their paleontological-archaeological finds, are worth mentioning. Both have huge, caved-in entrance chambers and that of the Szelim Cave now resembles a collapse doline.

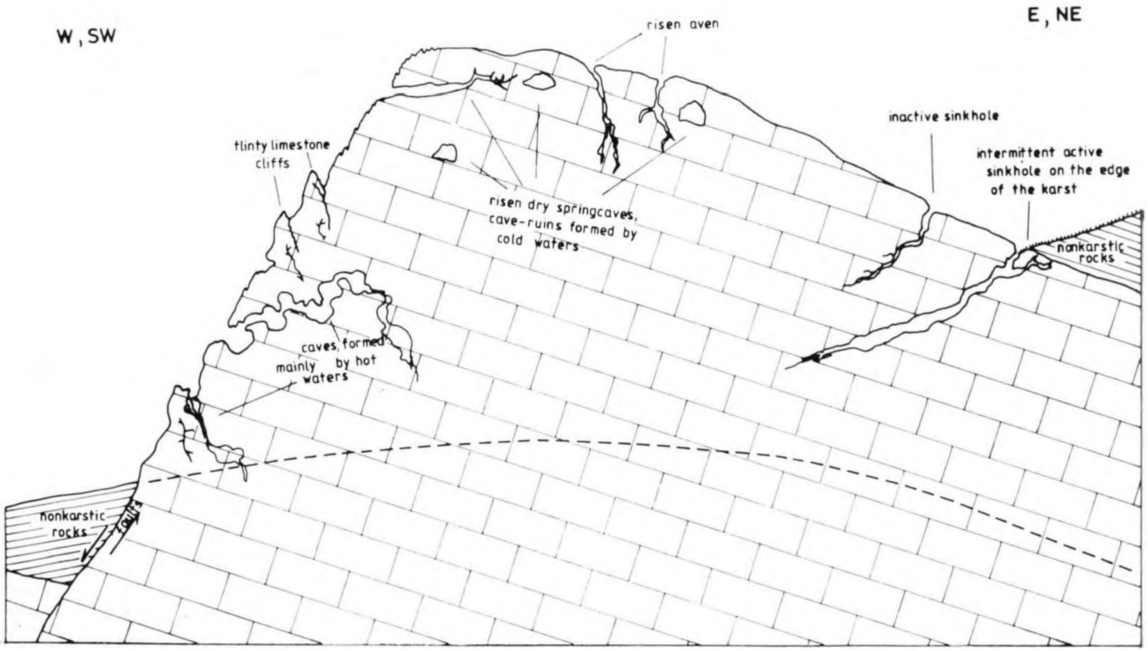

Fig. 9. General distribution of the karst features on the horst of Pilis Mountains

The distribution of intermittent swallow caves, mostly active for only some days, is substantially more sporadic. The deepest is the Nagy-Kaverna Cave of Dorog (Tokod-altáró Cave no 1) of hot water origin.

The successors of the Pliocene-Pleistocene hot springs of the Gerecse, issue mixed with cold karst water in the area of Szomód, Dunaalmás and Tata.

In addition to Mesozoic limestones, some smaller karst features also occur in the travertines and loesses of the Gerecse. A major joint cave deepens into the travertine of the Mogyorós-hegy Kő-hegy and into the loesses of Neszmély, wells and gorges are being cut even today. On the loess surface of the cryptokarst of the Sörház-dülő, Tokod, doline-like negative forms can be detected.

Pilis

A single, 5-tier NW to SE strike horst series with two adjoining N to S blocks at the middle and the SE end. The Triassic limestone and subordinate dolomite tilted planated horsts 230—750 m altitude are elevated above their surroundings by precipitous-fault scarps further emphasised by erosion. The NW margin is less steep, although mostly not gently sloping, and covered by Eocene limestone and marl and Oligocene sandstone. The highest and broadest member, the Fekete-hegy of the Pilis-tető group is divided from its E and NE (Miocene andesite and andesite tuff) neighbourhood by precipices.

The asymmetry of horst ranges is reflected in the spatial distribution of their karst features. The long SW and W edges and N front are ornamented by white lapiés fields on outcrops of beds, cliffs preserved between caved-in chimneys and abandoned through caves and stone arches (Fehér Cliff, Öreg Cliff, Klastrom and Csév Cliffs, Oszoly, Kis- and Nagy-Kevély, Solymár Cliff). Most of the cavities opening at the foot of the SW and S fault scarp are spheroidal caves of thermal or partly thermal origin, adorned with extraordinary minerals and clusters of minerals (Csév, Sátorkő-puszta, Leány, and Legény Caves, Ezüst-hegy Caves; Fig. 9).

Ascending thermal waters were prominent in the formation of the Fekete-hegy of Piliscsaba, the Solymár Cliff and the Teve Cliffs of Pilisborosjenő. The not waters penetrated into the capillary joints of dolomite and decomposed the rock, the walls of their spring vent were made more resistent by depositing calcareous and siliceous cement. Subsequently erosion controlled by to rock quality removed the loose dolomite debris from between the chimneys now solidified into 'towers'.

Since the horst range of the Pilis rises high above its neighbourhood, numerous shafts open on their ridges and many spring caves below their summits and on their walls.

The asymmetry of the tilted horsts and sediment cover on the NE and E, the seasonally active spring caves are concentrated along the NE and E margins (Pilis-nyereg, Pomáz and Harapovács swallow caves and Üröm swallow cave, Arany-lyuk). Also the finest limestone gorges carved by water-courses arriving from non-karstic terrain are located on this margin (the Pilisszentkereszt Szurdok of the Dera stream).

Buda Mountains

These form the *densest fractured, most heavily dismembered* representative of Bakony-type karsts, *richest in caves of hot water origin.* The small Triassic limestone and dolomite karsts at 250—550 m altitude are the best examples of horsts and due to their tilted position their gentler slopes are often mantled by Eocene limestone and marl, Oligocene clay, sandstone and Pliocene-Quaternary travertine or loess.

The majority of caves were dissolved by thermal waters ascending along faults and descending cold waters only played a modifying role. Their plan is zigzag; the spheroidal niches and labyrinths (equally in limestone, dolomite, marl and sandstone are controlled by faults and joints. The overwhelming majority of cavities are enclosed by Eocene limestone.

The four longest cave system of thermal water origin are found here. The Pál-völgy Cave, in Eocene limestone, rich in dripstones, is the third longest cave of the country, while the Szemlő-hegy, Ferenc-hegy and particularly the recently explored József-hegy Caves excel with their rare minerals and clusters of crystals.

The remainder of the hot springs issue along the E marginal fault, parallel with the Danube, some through spacious spring caves. In the passages hot waters mix with descending cold karst waters. Particularly on dolomite crests, the same mechanism of tower formation is also common in the Buda Mountains (Tündér Rock, Kő-hegy of Budaörs, Odvas-hegy).

It is characteristic of the Buda Mountains that most of the caves open in areas not at all resembling a karst. The main reason is the density of buildings. Barren karst terrain only occurs on steep fault scarps. The Nagy-Kopasz group and neighbouring Remete-hegy where large and broad blocks show a karstic face. Dolines of various size have developed on their flat surfaces (Vöröspocsolyás-hát and Remete-hegy) and the gorge of the Ördög-árok stream is a splendid antecedent one between Remete-hegy and Hosszúerdő-hegy. In the walls of the gorge and along its upper edge most of the cavities of cold water origin are found.

W-Cserhát

The Mesozoic limestone blocks of the Transdanubian Mountains reappear in the three horsts (Naszály, Csővár and Romhány Blocks) NE of the Danube in the North-Hungarian Mountains. With the Nézsa bauxite locality, they constitute the only karst region of Bakony-type in the North-Hungarian Mountains.

The most important karst is found on the Naszály plateau (652 m), mostly exhumed from below Oligocene sandstone. Due to its large limestone mass, twelve 2—5 m deep dolines 20—50 m across have formed. Hot waters — as attested by aragonite in the Sárkány-lyuk and the spheroidal niche of the Zsömlye-lyuk — also contirbuted to the formation of shafts double entrance chimneys, swallow and spring caves, rock niches and shelters. The Naszály sinkhole cave of 407 m length and 171 m depth is the fourth deepest in the country. Some small shelters are found in the Csővár-hegy. The Oligocene sandstone cover of the Romhány Block is hardly interrupted.

Villány Mountains

The 442 m high Villány Mountains lies S of the Mecsek, isolated in the SE corner of Transdanubia. Heavily imbricated Triassic limestone and dolomite and Jurassic-Cretaceous limestone (Fig. 1) are separated by sharp faults from their surroundings. The small extent explains why only bright white lapiés fields adorn its surface, but in the inside relatively major cavities mostly of hot water origin have been revealed by stone quarrying. The most famous is the Beremend crystal cave with rich calcite and aragonite formations. The chimneys filled with red clay and truncated hollows are famous for extraordinarily abundant Upper Pliocene — early Pleistocene animal finds.

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REFERENCES

BALÁZS D. (1963): Karsztgenetikai problémák. – *Földr. Ért. XII. 4.*

BALOGH K. (1964): A Bükkhegység földtani képződményei. – *MÁFI Évkönyve, XLVIII. 2. p. 719.*

BÁRÁNY I.–JAKUCS L. (1984): Szempontok a karsztok felszínformáinak rendszerezéséhez. – *Földr. Ért., 33. 3. p. 259–265.*

BIRÓ B. (1969): A halimbai és nyirádi bauxitelőfordulások karsztos feküje. – *Földt. Közl., 99. p. 98–104.*

BULLA B. (1964): Magyarország természeti földrajza. – *Tankönyvkiadó, Bp.*

CHOLNOKY J. (1932): A mészkőhegységek földrajzi jellemvonása. – *Földgömb.*

CHOLNOKY J. (1939): A mészkővidék arculata. – *Barlangvilág, 3. p. 41–53.*

DÉNES GY. (1971): A fokozatosan lepusztuló vízzáró takaró szerepe az exhumálódó karszt morfológiai fejlődésében. – *Karszt és Barlang, I. p. 5–8.*

DUDICH E.–KOMLÓSSY GY. (1969): Ősföldrajzi szerkezeti szempontok a magyar bauxit korkérdéséhez. – *Földtani Közlöny, 99. p. 155–165.*

ESZTERHÁS I. (1986): Barlangkeletkezés lúgos oldódással. – *Nehézipari Műszaki Egyetem Közleményei, Miskolc, I. Bányászat, 33. 1–4. p. 139–148.*

GÓCZÁN L.—MAROSI S.—PÉCSI M.—SOMOGYI S.—SZILÁRD J. (1959): Budapest természeti földrajza. — *Akadémiai Kiadó, p. 416.*
HEVESI A. (1972): Forrásmészkő-képződés a Bükkben. — *Földr. Ért., 21. 2—3. p. 187—205.*
(1977): A Bükki-vidék természeti földrajza, Bükk útikalauz. — *Sport, p. 9—48.*
(1978): A Bükk szerkezet- és felszínfejlődésének vázlata. — *Földr. Ért., 27. 2. p. 169—203.*
(1980): Adatok a Bükk hegység negyedidőszaki ősföldrajzi képéhez. — *Földr. Közl., 110. 3—4. p. 540—550.*
(1986): A Bükk hegység felszínfejlődése és karsztja. — *Kézirat, Kandidátusi értekezés.*
(1984): On the Dating of Karst Formations and their Significance on the Late Tertiary-Pleistocene of Hungarian Limestone Mountains the Bükk Mountains. — *Geographical Essays in Hungary, Bp., Geographycal Research Institute of the Hungarian Academy of Sciences.*
(1986): Hidegvizek létrehozta karsztok osztályozása. — *Földr. Ért., 35. 3—4. p. 231—254.*
(1986): Gondolatok dr. Tóth Géza „A Központi-Bükk és geomorfológiai körzetei" c. tanulmányáról. — *Földr. Ért., 35. 3—4. p. 375—386.*
(1986): A Déli-Bükk karsztja I. Délkeleti-Bükk. — *Karszt és Barlang, I. p. 3—14.*
(1986): A Déli-Bükk II. Délnyugati-Bükk. — *Karszt és Barlang,* II. p. *87—94.*
JASKÓ S. (1959): A földtani felépítés és a karsztvíz elterjedésének kapcsolata a Dunántúli-középhegységben. — *Hidr. Közl. 39. 4. p. 289—297.*
JUHÁSZ Á. (1988): A Bakonyvidék domborzatminősítése és tájtípusai. — *Kézirat, Kandidátusi értekezés.*
KASSAI F. (1953): A karsztvíznívó jelentősége és ezzel kapcsolatos problémák. — *MTA Műszaki Tudományos Osztályának Közleményei, I.*
KEREKES J. (1938): Az Eger környéki barlangvidék kialakulása. — *Barlangkutatás, XVI. 1. p. 90—139.*
KEVEINÉ BÁRÁNY I. (1986): Újabb adatok a karsztdolinák képződéséhez. — *Nehézipari Műszaki Egyetem Közleményei, Miskolc, I. Bányászat, 33. 1—4. p. 149—155.*
KÉZ A. (1959): A mészkőfelszín pusztulása.
KORDOS L. (1984): Magyarország barlangjai. — *Gondolat Kiadó.*
KORPÁS E. (1933): A Gerecse hegység morfológiája. — *Földr. Közl. LXI. 1—3. p. 1—17.*
KRETZOI M. (1954): Befejező jelentés a Csákvári-barlang őslénytani feltárásáról. — *MÁFI Évi jelentése az 1953. évről, p. 37—69.*
LÁNG S. (1948): Karszttanulmányok a Dunántúli-Középhegységben. — *Hidr. Közl. 28. 1—4. p. 49—52.*
(1952): A Cserhát morfológiája. — *Földr. Ért. 1. 4. p. 738—804.*
(1952): Geomorfológiai-karsztmorfológiai kérdések. — *Földr. Ért. 1.*
(1953): A Pilis morfológiája. — *Földr. Ért. 2. 3. p. 336—369.*
(1954): Hidrológiai és morfológiai megfigyelések a Bükkben. — *Hidr. Közl. 34. 1—2.*
(1955): Geomorfológiai tanulmányok az Aggteleki karsztvidéken. — *Földr. Ért. 4. 1. p. 1—20.*
(1955): A Gerecse peremhegységi részeinek geomorfológiája. — *Földr. Ért. 4. 1. p. 157—194.*
(1956): A Központi Gerecse geomorfológiája. — *Földr. Ért. 5. 3. p. 265—282.*
(1958): A Bakony geomorfológiai képe. — *Földr. Közl. VI. (LXXXII.) 4. p. 325.*
(1971): A hazai karsztok és környékük lepusztulásának egyes kérdései. — *Karszt és Barlang I. p. 1—4.*
LÁNG S.—MIHÁLTZ I.-né—VITÁLIS GY. (1970): A miskolctapolcai Nagykőmázsa dolináinak morfológiai és földtani vizsgálata. — *Földr. Ért. 19. 1. p. 77—85.*
LEÉL-ÖSSY S. (1953): Geomorfológiai és hidrológiai vizsgálatok a Szalonnai-karszton. — *Földr. Ért. 2. 3—4. p. 323—335.*
(1953): Karszt- és barlangkutatás a Szalonnai-karszton. — *Hidr. Közl. 33. 1—2. p. 67—70.*
(1954): A Magas Bükk geomorfológiája. — *Földr. Ért. 3. 3. p. 323—355.*
(1955): Magyarország karsztmorfológiája. — *Kézirat, Kandidátusi értekezés.*
(1957): A Budai-hegység barlangjai. — *Földr. Ért. 6. p. 155—169.*
(1958): A Kevély-hegycsoport — karsztmorfológiája. *Földr. Ért. 7. 1. p. 17—32.*
(1960): Magyarország karsztvidékei. — *Karszt- és Barlangkutatás, I. p. 79—88.*
(1987): Karsztformák és karsztjelenségek, Dunántúli-középhegység, Természeti adottságok és erőforrások. — *Akadémiai Kiadó, p. 188—195.*
LOVÁSZ GY. (1971): Adatok az Abaligeti-karszt geomorfológiai és hidrológiai jellemzéséhez. — *Földr. Ért. 20. p. 283—296.*
(1977): Baranya megye természetföldrajza. — *Pécs, p. 62—68.*
MÁRTON E.—MÁRTON P. (1984): Tectonic and paleoclimatic aspectes of paleomagnetism studies in the Transdanubian Central Mountains. — *Acta Geologica.*
OZORAY GY. (1960): Nemkarsztos üregek genetikája magyarországi példák alapján. — *Karszt- és Barlangkutatási Tájékoztató, jan.—febr.*
PÉCSI M. (1964): A magyar középhegységek geomorfológiai kutatásának újabb kérdései. — *Földr. Ért.*
PÉCSI M. (1987): A Dunántúli-középhegység domborzata. A Dunántúli-középhegység. Természeti adottságok és erőforrások. — *Akadémiai Kiadó, p. 140.*
RÓNAKI L. (1971): A karsztformák irányítottságának vizsgálata a mecseki triászban. — *Karszt és Barlang, II. p. 65—68.*
SÁG L. (1987): A hegységet alkotó képződmények kialakulásának története és szerkezeti fölépítése. Dunántúli-középhegység, Természeti adottságok és erőforrások. — *Akadémiai Kiadó, p. 122—131.*
SCHERF E. (1922): Hévforrások okozta kőzetelváltozások a Buda—pilisi-hegységben. — *Hidr. Közl. 2. p. 19—88.*
STRÖMPL G. (1914): A borsodi Bükk karsztja. — *Földr. Közl. XLII. p. 79—98.*
SZABÓ PÁL Z. (1931): A Mecsek hegység formáinak ismerete. — *LIX. 9—10. p. 165—180.*
(1953): A Mecsek karsztvízrendszere. — *Hidr. Közl. 33. 7—8. p. 241—251.*
(1956): Magyarországi karsztformák klímatörténeti vonatkozásai. — *Dunántúli Tudományos Gyűjtemény, 14.*
(1957): A karszt, mint klímatikus morfológiai probléma. — *Dunántúli Tudományos Gyűjtemény, 15.*
(1961): A pécsi Mecsek karsztvizének hidrodinamikai sajátosságai. — *Dunántúli Tudományos Gyűjtemény, Értekezések 1960 c. kötete, p. 5—49.*
(1963): A hidrodinamika és a karsztalaktan néhány összefüggése Magyarországon. — *Dunántúli Tudományos Gyűjtemény.*
(1966): Újabb adatok és megfigyelések a magyarországi őskarsztjelenségek ismeretéhez. — *Dunántúli Tudományos Gyűjtemény.*
(1968): A magyarországi karsztosodás fejlődéstörténeti vázlata. — *MTA Dunántúli Intézete, Értekezések, p. 13—26.*
VADÁSZ E. (1940): A Dunántúl karsztvizei. — *Hidr. Közl. 20. p. 120—135.*
(1949): Termális „karsztvíz" Délbaranyában. — *Hidr. Közl. 20. 3—4. p. 81—83.*
VENKOVITS I. (1947): Abaliget környéki barlangok — *MÁFI Évi jelentése, 1945—47. II. p. 311—315.*
VITÁLIS GY. (1970): Földtani és vízföldtani megfigyelések a miskolctapolcai Nagykőmázsán. — *Hidr. Közl. 50. 2. p. 49—55.*
WEIN GY. (1952): A Mecsek hegység hidrogeológiája. — *Földr. Ért. I. 2. p. 237—250.*
(1959): A mecsekhegységbeli kisújbányai medence karszthidrogeológiája. — *Hidr. Közl. 39. 4. p. 298—302.*
ZÁMBÓ L. (1970): A vörösagyagok és a felszíni karsztosodás kapcsolata az Aggteleki-karszt délnyugati részén. — *Földr. Közl. XVIII. (XCIV), 4. p. 281—293.*
(1986): Karsztvörösagyagok CO_2 termelése és a karsztkorrózió összefüggése. — *Nehézipari Műszaki Egyetem Közleményei, Miskolc, I. Bányászat, 33. 1—4. p. 125—238.*

Top: Retek passage in the Baradla Cave (by Pr. Borzsák)

Bottom: Meander (left) and botryoid formations (right) in the Szabadság Cave, Aggtelek Karst (by L. Gazdag)