KARSZT *és* BARLANG

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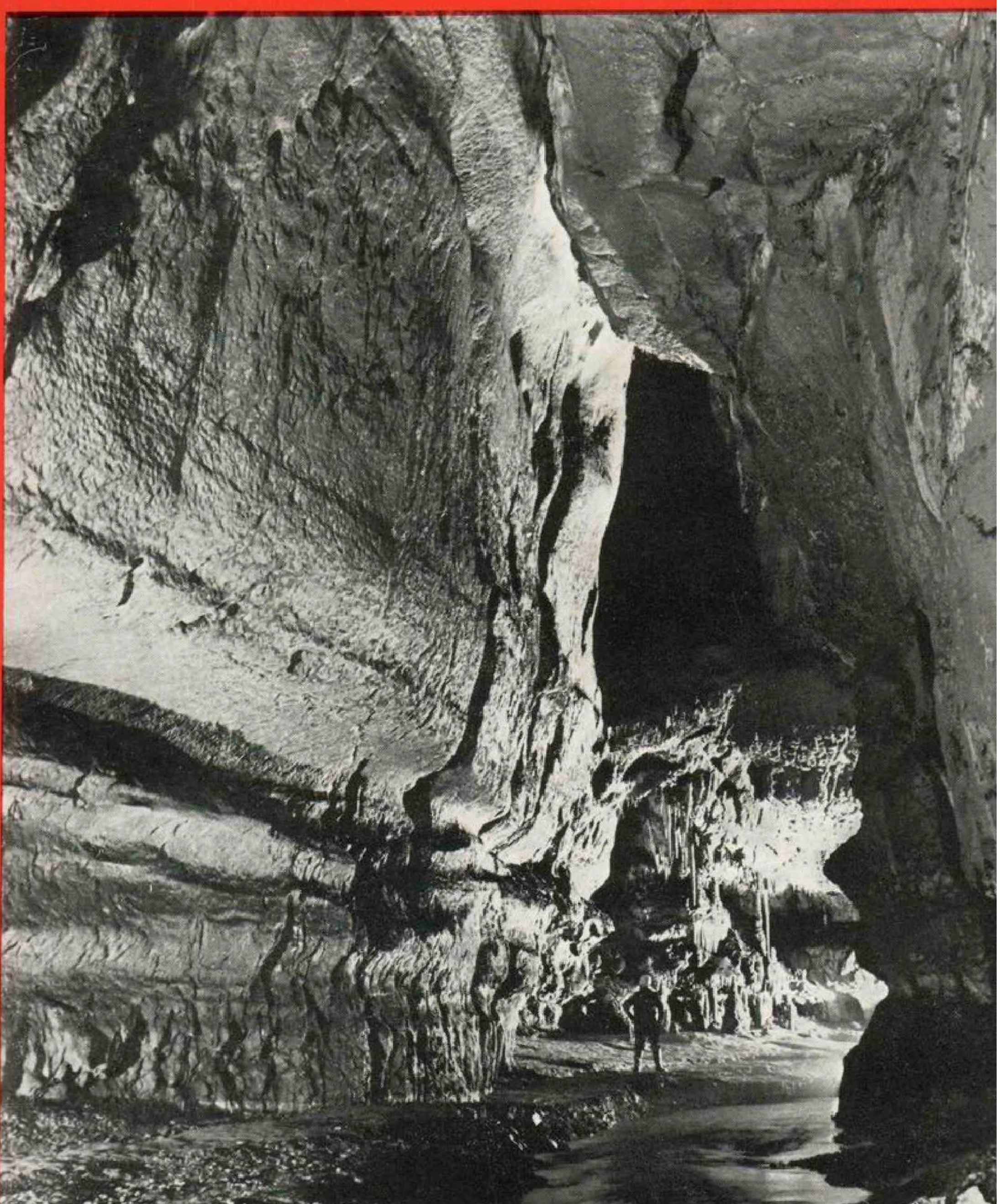

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on the occasion of 7th International Speleological Congress held in England 1977

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MAGYAR OLVASÓINKHOZ

A Karszt és Barlang jelen száma angol nyelven jelenik meg a 7. Nemzetközi Szpeleológiai Kongresszus alkalmából. E kiadványunkban a magyar karszt- és barlangkutatás legújabb eredményeiről tájékoztatjuk a külföldi szakembereket. A cikkek egy részét magyar nyelven a Karszt és Barlang 1977. I-II. füzete tartalmazza. Az MKBT tagjai csak az utóbbi számot kapják meg térítés nélkül, tagdíjfizetésük fejében.

Szerkesztőség

First cover photo: The main passage of the Baradla Cave, Aggtelek (by P. Borzsák and A. Prágai)

KARST and CAVE

BULLETIN OF THE HUNGARIAN SPELEOLOGICAL SOCIETY

SPECIAL ISSUE

ON THE OCCASION OF 7TH INTERNATIONAL SPELEOLOGICAL CONGRESS HELD IN ENGLAND 1977

Landmarks in the history of Hungarian karst and speleological research

Dr. Sándor LÁNG

Chairman of the Hungarian Speleological Society

Ties between man and karst in Hungary go back to very early times as in the instance of settlements established 1,500 to 2,000 years ago in what is now Budapest. These owe their birth and survival to the presence of karst springs. Karst and speleological research in the modern sense developed about 200 years ago when individuals began to explore the caves of the Carpathians and other mountains and then to survey and map them and analyse data by scientific methods. Pre-eminent amongst early workers was the engineer, Imre Vass, who in 1825 discovered the extension of the Baradla Cave, surveyed it very correctly and published a brilliant bilingual monograph about it.

Later on, cave surveying and mapping was extended over greater areas, both geographically and thematically. During the past 100 years or so an inventory of Hungarian karst areas and caves was built up and scientific and practical research gradually developed. Much early data and analysis e.g., in the fields of archeology and geomorphology, etc., remain valid today. Notable contributions include the start of paleo-anthropological research in Hungary as a consequence of cave excavations by Ottó Herman, a Hungarian polymath who made very remarkable progress in various scientific fields; Jenő Cholnoky's explanation of the relationship between caves and rivers in his synthesis on karst morphology; Ottokár Kadic's contribution to the classification and systematization of caves; and the outstanding results obtained by Lajos Steiner in speleoclimatology—the first research work of these kinds to be undertaken in Hungary.

Speleobiology was highly advanced as early as 50 years ago, due to research work carried out by Endre Dudich in the Baradla Cave. Published as a monograph, the results obtained by this outstanding scientist have been fundamental achievements.

All in all the representatives of the five or six early generations of Hungarian speleologists are to be praised for their hard work and achievement of lasting results of an inestimable value, despite working with very modest facilities. Their legacy in a number of fields, in part mentioned above, has been fundamental and is still used.

Because karst and cave research requires much collective work, cave discovery and exploration gradually became the object of organised effort as early as 100 to 150 years ago. Following the War of Independence of 1848, the first organisers of Hungarian speleology were various scientific societies operating informally, such as the Society of Hungarian Physicians and Nature-Lovers, the Hungarian Geological Society, the Hungarian Geographical Society and, later and locally, the Hungarian Association for the Carpathians and the Transylvanian Association for the Carpathians. By the turn of the century the time was ripe to establish a special Commission on Speleology within the Hungarian Geological Society which in 1926 became an independent Speleological Society. The new society published a periodical of high scientific standing as well as other occasional scientific publications.

Since the Second World War, Hungarian karst studies and speleology has developed by leaps and bounds. Significant publications of this period are several times greater in number than those published during the preceding 150 years. Hungarian State organisations have become increasingly interested in using the research results. The last three decades of Hungarian speleology have been characterised by the initiation of interdisciplinary research projects aimed at, amongst other things, discovery of concealed caves from geomorphological, geological and hydrological evidences above ground. One consequence of this development was the discovery by László Jakucs in 1952 of Béke Cave, the second lengthiest decorated cave in Hungary. Funds invested in karst and speleological work, as in any other kind of scientific research, depend upon growth of the gross national product and standard of living. Because national income and living standard have tripled or quadrupled during the last thirty years financial support from governmental and non-governmental sources for exploration and development is now much higher than ever before.

Objectives of karst research today are related to general trends of economic development. On the one hand, a major principle adopted is that the science of today is the practise of tomorrow; on the other hand given the regrettable fact that Hungary is poorly supplied with mineral and energy resources and industrial raw materials, even the karst regions may represent important raw mineral resources. Consider the bauxite mining of Hungary, which is second in output in Europe and requires comprehensive karst scientific input to geological reconnaisance, prospecting and mining because the deposits occur in highly karstified areas. Another up-to-the-moment field is that of karst water prospecting which has developed in its modern complexity only during the past thirty years. A few enthusiasts initiated work during the late 1930s. Now there are more than fifty research specialists occupying full-time positions in various scientific institutions.

To prospect for karst water is a much more complex task than the investigation of surface karsts because of the intricate and complex vertical pattern of subsurface karst aquifer distribution in Hungary. Karsted rocks at 0—3,000 meters depth underly about 1/3 of the national territory. However, only 6—7% of this occurrence is represented in outcrop, the remainder being concealed by younger rocks ("deep karst"). On the "surface" of hidden karst rocks or between them there may be accumulations of bauxite or possibly of coals or other sedimentary rocks of industrial value. Because the deep karst rocks tend to be more fractured than adjacent strata they tend as a rule to have twice to three times the yield of thermal water commonly expected from other sediments, as has been established by drilled wells.

The above example has been just one small instance picked at random from the enormous mass of information on Hungarian karst hydrology that is now available both to theoreticians and to practical scientists, promoters of the development of the people's economy.

With increase of scientific knowledge of the karsts of Hungary, it has become possible to carry out practical projects of increasing sophistication. Examples include the control of karst water draining into mines and the utilisation of this waste water by industrial plants, power stations and municipal water authorities, etc. Here there is collaboration between two entirely different interests: on the one hand, the wish of miners to dispose of unwanted water and, on the other hand, the wish of industrial managers etc., to obtain reliable and economical water supplies. A good instance of this collaboration is the water supply system of the northern and western shores of Lake Balaton.

Excessive karst water withdrawal, however, may upset the equilibrium of the natural environment. Hungarian karst scientists are now seeking to persuade miners that rates of karst water withdrawal must not exceed average annual rates of infiltration, which are approximately 500 cubic meters per minute in the Transdanubian Mountain Range and about 750 cubic meters per minute on the national average. Two special meetings of Hungarian karst researchers recently have been devoted to the problem of drastically waning recharge to the country's famous spa, Lake Hévíz, due to uncontrolled water pumping from mines. Here karst research is becoming associated with nature conservancy and environment control. There is plenty of work to do, for in Hungary quarrying has reached the point of devouring the nation's most scenic limestone hills e.g., the Nagyharsány, the Nagyszál, the Esztramos, the Bélkő and others. Hungarian researchers have developed and submitted proposals for long-term, economical limestone quarrying operations without spoiling the scenic beauty of the mountains and hills.

The recognition that a cave's atmosphere may favourably influence the recovery of persons suffering from illnesses of the respiratory tract has enhanced development of a new branch of knowledge—speleotherapeutics. This new branch is an off-shoot of speleoclimatology. To be able to cure people in a cave it is necessary to be familiar with meteorological conditions of its atmosphere and their variations, particularly if the cave is visited frequently by patients or tourists. Speleotherapeutics, like karst hydrology and cave tourism, is one of the new developing areas of practical use of caves.

Both the classical and new areas of cave and karst research are pursued by large numbers of Hungarian workers. As a rule, research is co-ordinated by the Hungarian Academy of Sciences, the Federation of Hungarian Scientific and Technical Societies or the government ministries or other relevant State organisations. The ranks of the Hungarian Speleological Society include more than half a dozen Ph.D's, more than ten Ph.D. candidates and an even larger number of M.Sc.'s. Their exemplary activities stimulate new generations.

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Dr. László JAKUCS

GENETIC TYPES OF THE HUNGARIAN KARST

SUMMARY

The diversified landforms of the Hungarian karst regions are discussed in a phenomenological grouping. The major phases of karstification (Early Cretaceous, Latest Tertiary, Pleistocene) are characterized and their morphological features are listed.

The author emphasizes the particular importance of the tectonic control in some karst regions of this country, pointing out that hydrothermal activities accompanying tectonism have brought about one of the most interesting form-assemblages of surface and subsurface hydrothermal karstification in Hungary. A particularly striking phenomenon is the karstification of the dolomite area of the Buda Hills under the effect of hydrothermae (dolomite pulverulence, formation of thermal caves, etc.). The different form-groups connected with changes in the temperature and chemical composition of the thermal caves of the area are analyzed.

The problems of water control in coal mines situated in a karstic environment and the karstic hydrocarbon reservoirs are also dealt with in detail. Two main types of Hungarian karst forms are distinguished: the Aggtelek type, reflecting the effects of all three phases of karstification and the Transdanubian type showing just a partial karstic effect owing to a post-Cretaceous burial. With their ground-plan resembling to surface river valleys, the erosion karst caves have their most beautiful representatives in the Aggtelek Karst Region.

Hungary is one of the small countries of central Europe with an area of 93,000 kilometres square, i.e. 0.9% of the area of the continent. The country is located in the centre of the middle Danube Basin and surrounded by the mountain chains of the Alps, Carpathians and Dinarides. This geographic situation has determined geologic and geomorphologic patterns. 68% of the landscapes consists of plains resulting from basin infill by younger sediments and 29% of low rolling hills, or plateaus covered by young, mostly unconsolidated sediments attaining altitudes of 200—400 m. Only 2% of the area of Hungary is higher than 400 m a.s.l. Therefore, there are no high mountains, and highland landscapes (500—1,000 m) are confined to minor, isolated patches.

From the above summary it would appear probable that the karst regions of Hungary will be insignificant in extent and importance when compared to the rest of Europe and that there may be few noteworthy karstic phenomena. Karst areas *are* small. The total area of exposed karst amounts to 1350 km square, or only 1,45% of the nation's territory *(Fig. 1)*. This is certainly small particularly compared to neighbouring Yugoslavia where the combined area of karst landscapes is about 67 times greater (90,000 km square in round figures). So it may appear really surprising or paradoxical that in such an apparently "karst-poor" country as Hungary there is an astonishing diversity of karst phenomena of great scenic beauty.

To illustrate this claim it would perhaps be sufficient to mention the more than 40 km of richly decorated cave galleries and chambers that are known in the Aggtelek karst area; or the very large, hydrothermal dolomite karst features of Transdanubia which display a breathtaking variety of form; or to the many large hotsprings caves of Hungary with their rich secondary mineral deposits of barytes, gypsum and aragonite. Another rarity and curiosity amongst European caverns are the Calc-tufa caves such as Anna Cave at Lillafüred: this is an example of syngenetic karstification within the country rock. Finally, it might be mentioned

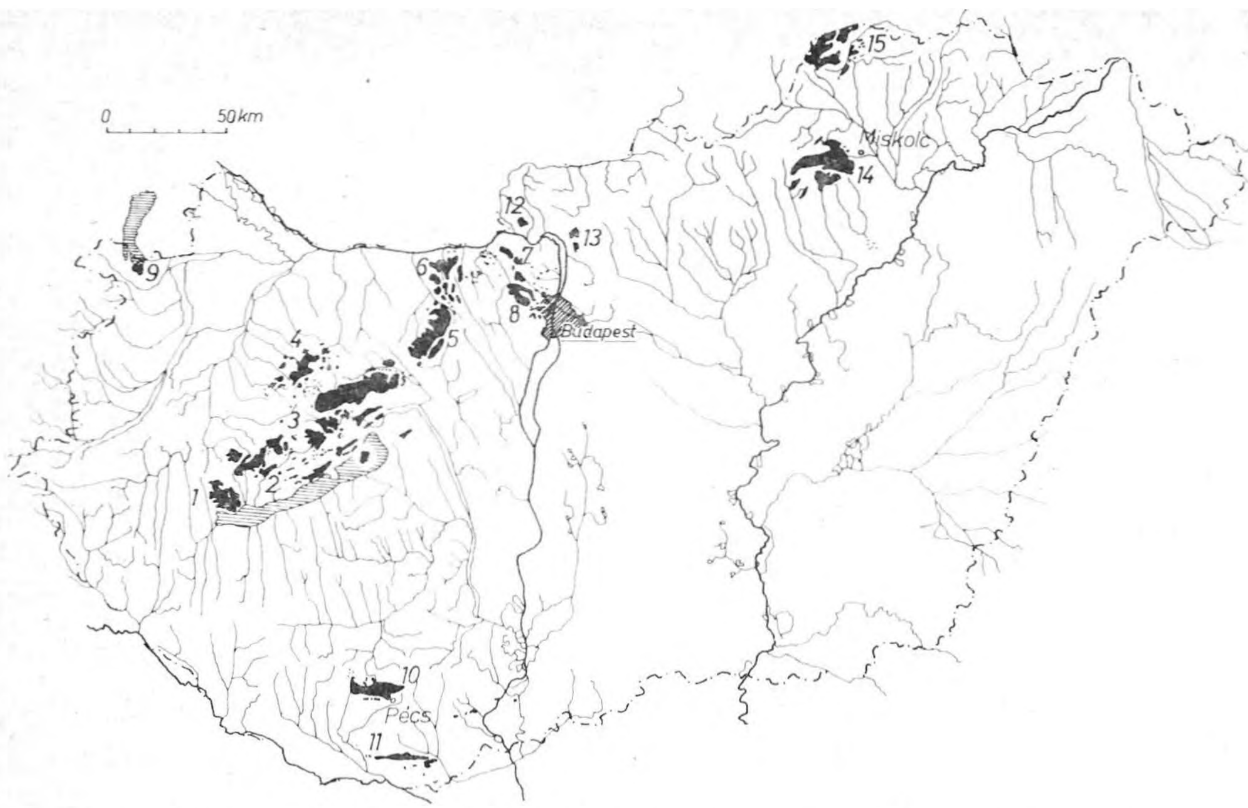


Fig. 1. Surface karst lands of Hungary. For the names of the karst regions indicated with numerals, see text

that a considerable portion of the petroleum production of Hungary is recovered from karstic channels, in this instance a network of deeply buried, ancient caves.

The explanation of the wealth of karst in Hungary is as follows:

1. The Hungarian karsts are small and isolated enclaves within mountain masses composed of other rocks e.g. volcanics, sandstones etc. Because tectonic and hydrological environments are varied the contained karsts have diversified and peculiar morphostructures. Environmental control of processes of karstification and their reflection in resulting morphostructure are more striking in the small karst islands of Hungary than in most other regions of Europe.

2. Karsts exposed at the surface in Hungary may be described as "residual karsts" because they represent only a very small fraction of the hidden karst masses contiguous with them. In early geological eras (primarily in the Cretaceous and early Tertiary) the hidden karst rocks were exposed and already in an advanced state of karst denudation. Subsequently they subsided and were buried as a consequence of basinal tectonism (Tertiary and Quaternary) and cover sediments have confined aquifer bodies within them. Readers are referred to *Fig. 2*, a litho-facies map of the pre-tertiary basement based on deep drilling information, which indicates that almost half of the country was once a limestone karst region. Degree of karstification of the old mountains that are now buried in the basement can be assessed by examining core samples (degree of corrosion) as well as inferred from the number and depth of sudden drops of drill pipes which indicate something of the degree of cavernosity *(Photo 1)*. These means of analysis have indicated that the concealed karst masses of Hungary are very similar in their state of denudation to the karst rocks presently exposed. Hence, it is concluded that the exposed karsts possess deep and widely ramifying systems of roots (termed *root-karst*) associated with synchronous karst development. In other words, present surface karst areas contain unusual features which cannot be interpreted as the products of recent or modern surficial processes but which must be reflections of ancient, underground agents of denudation. The author believes that recognition of such relationships may provide a key to interpretation of the hydrothermal karst phenomena characteristic of the Transdanubian Mountain Range.

3. Finally, it should be pointed out that the Hungarian karsts have been particularly intensively explored. There are few other nations, even in Europe, where fossil and active underground karst networks have been so exhaustively investigated.

This unusual situtation is to be attributed to the fact that because of the association of karst and buried bedrock, karst research is bound up with many everyday problems of development of the nation's industry, energy supply, mining, urbanization and water supply. Exploration of karst phenomena has for a long time been part of the plan of the people's economic development, carried out by established geological, civil engineering, mining

Fig. 2. Basement karst facies map of Hungary. The huge carbonate mountain chains or rock belts extending deep underground were in earlier geological history mountains exposed to karstic denudation at the surface

engineering or hydrological services. One consequence of the carefully scheduled research programmes has been the location since the early 1950s of a number of large new caves; following location, special exploration adits were opened at specific points to gain access to these caves.

In the following discussion, the author first reviews the regional systems of limestone and dolomite karsts in Hungary and then expounds the fundamental principles of a comparative typology of the individual karst districts.

Hungary's karsted limestone and dolomite outcrops are primarily found in the Highland Range which traverses the country from southwest to northeast. Away from the Range there are only two other minor karst outcrops, in the Mecsek Mountains and along the shore of Lake Fertő, *(Fig. 1.)*.

With the exception of some late Tertiary and Quaternary strata, carbonate rocks of Hungary display considerable tectonic disturbance, being abundantly fractured and considerably folded in some areas e.g. Mecsek. The karst rocks are enclaves incorporated within older or younger rocks. In several cases limestones are intruded (e.g. by andesites) or covered by volcanics as in the Dunazug Mountains and Mátra Region. All these circumstances are due to the fact that, because of the northward drift of the Tisia massif forming the substratum of the middle Danube Basin, the respective rock sequences have been piled up on the southern margin of the Transdanubian Mountains and this motion has produced in the foreland a fault block range of diversified geology and densely dissected structure with highly localized folding.

On the basis of topography the following karst regions are popularly distinguished in Hungary (numbers are keyed to *Fig. 1*):

1. Karstic solution cavities in a bore plug from upper Cretaceous limestone in Nagylengyel, at a depth of 1600 m. In the section of walls of the solution cavities the depth of oil infiltration can also be seen. The pores of rock are not oily.

I. *Transdanubian Mountain Range*

1. Dolomite karst of Keszthely Mountains
2. Mesosoic karsts of the Balaton Highland, including the Sarmatian limestone landscape of the northern half of the Tapolca Basin.
3. Karst of the southern Bakony Mountains.
4. Kárst of the northern Bakony Mountains.
5. The mainly Triassic dolomite karst of the Vértes Mountains.
6. Mesozoic karst of the Gerecse Region, (including the Sarmatian limestone zone of the Zsámbék Basin).
7. Triassic limestone karst of the Pilis Mountains with the Pomáz Calc-tufa plateau.
8. The mainly hydrothermal karst features of the Buda Hills, including the Sarmatian limestone of the Tétény Plateau and minor Lajta Limestone patches on the Pest Plain.

II. *Karstic Inselbergs of Transdanubia*

9. The Lajta Limestone karst of the shore of Lake Fertő, Northwest Hungary.
10. Karst features of the Mecsek Mountains.
11. Karst of the Villány Mountains and the Beremend block.

III. *Karst landscapes of the North Hungarian Highland*

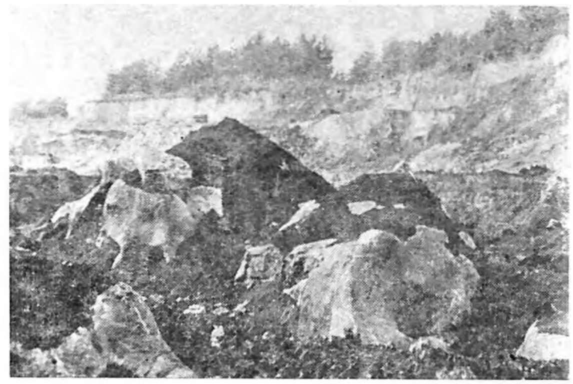
12. Lajta Limestone karst in the southern Börzsöny Mountains (Szokolya Basin, Törökmező).
13. Limestone blocks of the Cserhát Region (Naszály, Mt. Romhány, Mt. Csővár).
14. Karst features of the Bükk Mountains with the Uppony block.
15. The Aggtelek Karst Region with limestone areas of the adjacent Rudabánya, Szalonna and Szendrő blocks.

The karst landscapes differ from each other in size, in geological-tectonic structure and in time-range and degree of karstification, i.e. in geomorphology, as well. Since lithification the Paleozoic and Mezosoic (mainly Triassic) limestones and dolomites have undergone several intensive phases of karstification so that they have preserved very large karst solution forms of most complex genesis. The best preserved morphological features were generated under tropical denudation conditions during the first half of the Cretaceous, then by sub-tropical-mediterranean denudation phases of the upper Tertiary and finally by erosion cycles of the Quaternary.

Rock surfaces which were characterised by typically tropical forms during the Cretaceous e.g. haystack, minor karst towers etc., would be overlain by younger sediments including bauxites and manganese ore which more or less perfectly preserved the ancient karst forms. These paleokarsts were later partially exhumed by repeated phases of erosion (Aggtelek Karst, *Photo 2*) or have been revealed by mining for manganese and bauxite. An example of exposure by mining are the karst cones of the Csárda-hegy deposit at Úrkút or the features underlying the Iszkaszentgyörgy and Gánt bauxite *(Photo 3)*.

In addition to the heavily dissected palaeokarst landscapes are karst peneplain plateaus of which portions at different altitudes in the Aggtelek Karst, the Alsó-hegy, the Nagyoldal, the Haragistya-tető, etc., as well as the Nagy and Kis plateaus of the Bükk Mountains best preserve the ancient forms.

The different Hungarian caves formed at different periods. Genetic asynchrony is recognized on the one hand between different caverns formed in different ways (e.g. stream caves controlled by local base levels, tectogenetic caves, hydrothermal caverns, etc.); on the other hand by asynchronous features which occur within one single genetic type or even within a single cave. For instance studies at Solymár Cave in the Buda Hills confirm that part of the system formed during the main denudation phase of the Cretaceous ("First Excavation Phase"). In the Eocene and Oligocene this part was largely filled with alluvial gravels which became cemented and are preserved in the cave walls. Later, hydrothermal activities associated with Miocene volcanism partially reexcavated the old caves and created new extensions. This "Second Excavation Phase" produced large vents, spherical concentric niches and blind pockets in the passages as well as providing gypsum deposits that are still preserved in the Fehér-terem Passage. There followed a "Third Excavation Phase" of ordinary erosion and solution by running waters, manifested locally by icely eroded river channel forms with terrace remnants. This phase is either pre-Pleistocene or not later than the Mindel-Riss Interglacial because non-potamogenic sediments of later, humid denudation phases (Riss-Wurm Interglacial) remain undisturbed. It should be noted that above Solymár Cave the surface karst forms of today are not associated i.e. indicating that the "Third Excavation Phase" terminated a long while ago.



3. Lower Cretaceous primary karstic terrains at Iszkaszentgyörgy. These tropical karren had been covered from the upper Cretaceous up to recent and have been excavated by bauxite-mining.

Such heterogenity is characteristic of Hungarian karst. Almost every landscape has specific features of its own. Therefore it is difficult to generalize and to identify global morphologic features. Detailed accounts of individual areas have been given by Láng, Leél-Őssy, and others. An attempt is made below to outline the most typical and the most unusual features of Hungarian karst, grouped phenomenologically.

1. Relationship between karst formations and tectonics

In the Transdanubian Mountain Range karsts are tectonically controlled. Powerful and renewed movements have divided the mountains into minor blocks. Dilatation fault-fissures occur in dense swarms, especially in Triassic dolomite and limestone features but locally in Eocene limestones as well. Strike of the fissure systems corresponds to two principal tectonic axes, the northeast-southwest axis of the mountains and transverse faults normal to it. The fracture planes, which are frequently vertical, have offered channels for groundwaters

2. Recent denudation phases in the uvala of the Vörös Lake at Jósvafő. Lower Cretaceous limestone pinnacles like tropic cone-karst, were excavated from beneath Cretaceous terra rossa. Thus their karst-denudation continues (Bear Rocks).

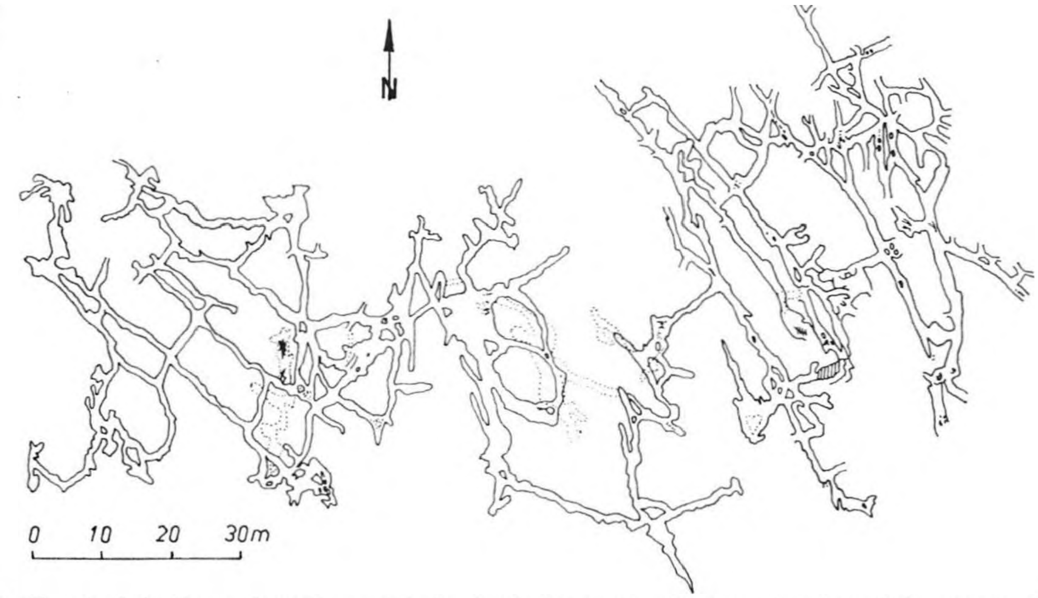


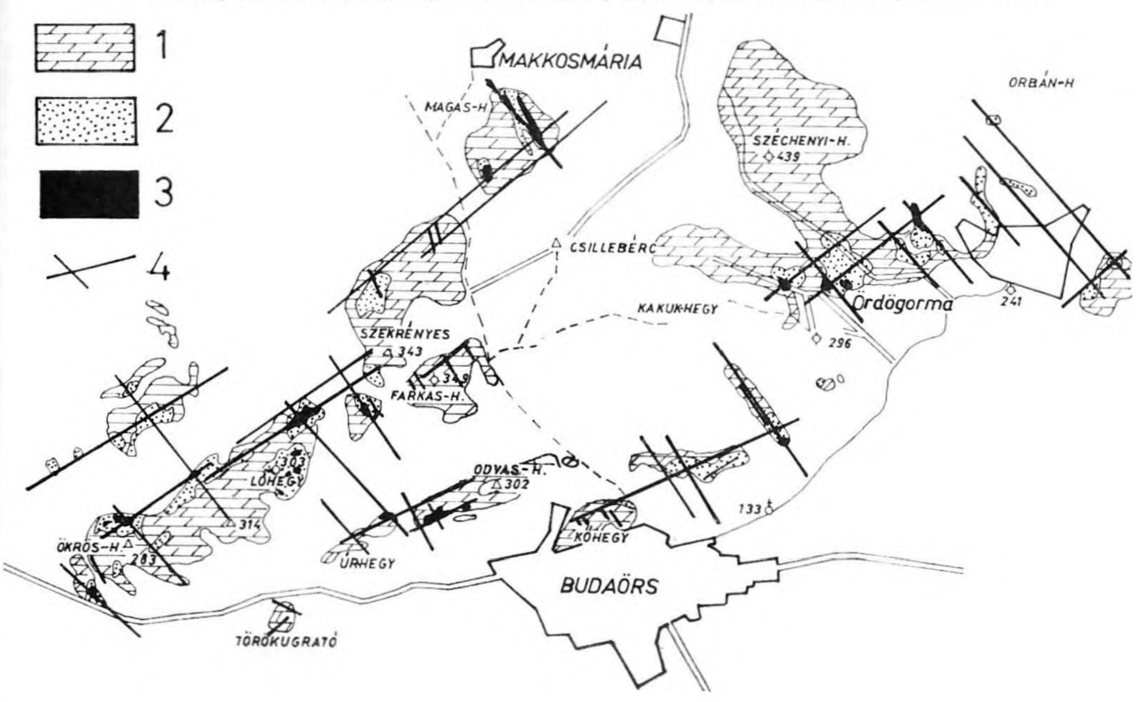
Fig. 3. Sketch of the Ferenc-hegy Cave of Buda, clearly illustrating the tectonic origin of the system of caverns concerned

and thus control their direction of flow and hydrodynamic characteristics. Because of the fractures, horizontal evacuation of waters at actual water-tables could rarely take place, whilst vertical flow was little impeded. Therefore flow paths descended far below local base levels, developing caverns along their routes.

By this means a maze of tectonic cave systems has developed, particularly in the Buda Hills. The caves comprise intersecting, narrow galleries with high, parallel and precipitous walls and the rock masses delimited by them are disintegrated into chessboards of cube-like slabs. The Ferenc-hegy Cave of the Buda Hills is the prototype of such a mode of cave formation *(Fig. 3)*. Similar examples are Mátyás-hegy Cave, Szemlőhegy Cave, Solymár Cave, Legény Cave in Pilis, Tavas Cave at Tapolca etc.

In addition, tectonic movements have served as locating agents for several classes of phenomena. For example, it can be shown that Hungary's natural hotsprings, recent and fossil, are localised along Piedmont tectonic fracture lines or at fracture intersections. This has resulted in a peculiar linear system of development of hydrothermal karst phenomena *(Fig. 4)*.

Fig. 4. Dolomite karst features of the Budaörs Hills with indication of the pulverulent dolomite karst facies. The occurrences of changes in rock quality (including dolomite pulverulence) correspond to those points of intersection of tectonic lines characterized by earlier hot water emergences. Legend: 1. fresh Hauptdolomit, 2. crumbling Hauptdolomit, 3. pulverulent Hauptdolomit, 4. lithoclases or fracture lines.

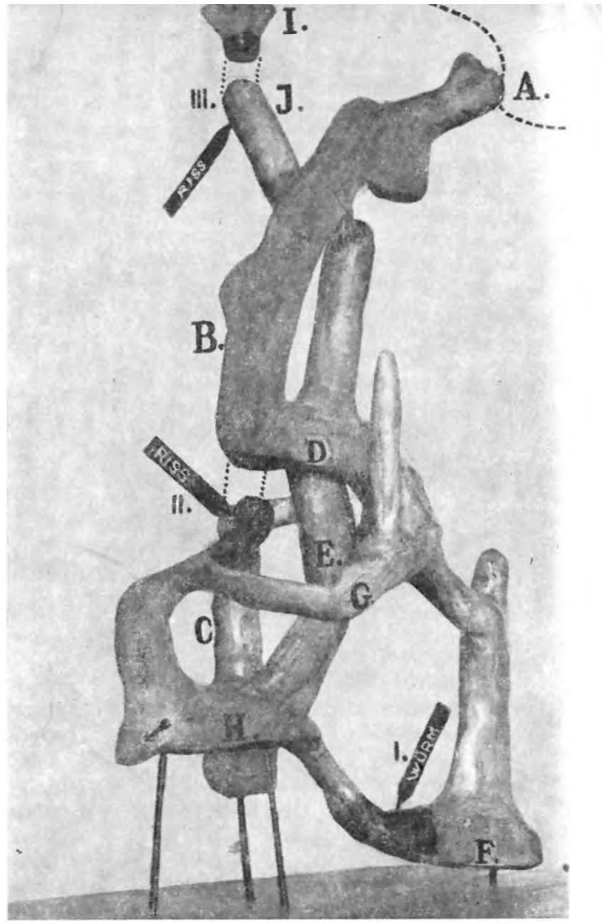


Tectonic control is involved either directly or indirectly in determining the strike directions and other morphological features of certain karst plateaus (the Bükk Mountains, the seven minor plateaus of the Aggtelek Karst Region and the Karst Plateau of western Mecsek Mountains) and of karst valleys, river caves, chains of dolines or even individual dolines and uvalas etc.

2. Hydrothermal karst phenomena (thermal waters, hydrothermal caves, dolomite pulverulence, siliceous rock towers, pinnacles, travertine accumulations)

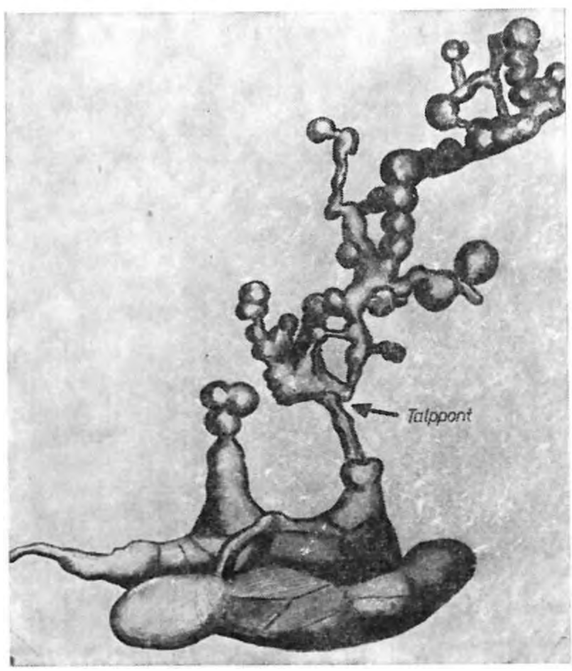
Past and present, Hungary has been the scene or large-scale hotspring activity associated primarily with the faulted southern margin of the Transdanubian Mountain Range. Today thermal waters along the Danubian margin of the Buda Hills (Gellért Bath, Rudas Bath, Lukács Bath etc.) and in the Keszthely Mountains (Hévíz) induce local changes in the rocks by corrosion, mineralogical transformations and sedimentation. In the geological past the thermal waters appear to have had wider distribution, higher temperature and greater chemical aggressivity at certain periods of time. Consequently, hydrothermal activity was a considerable, locally dominant, factor modelling the geomorphology of rather large areas. Because thermal springs emerge primarily in dolomites and limestones, the hydrothermal effects created peculiar karst phenomena. The most typical hydrothermal karst formation of central Hungary is the Triassic Hauptdolomit and Dachsteinkalk of Buda Hills.

Hydrothermal karst features may be both surface and subsurface. However it should be recognized that because hydrothermal karstification is a process of subsurface origin it always produces three-dimensional spatial features which may be contrasted with the mainly two-dimensional surficial forms created by other karst processes e. g. karren, solution dolines etc. Hydrothermal karst features observed at the surface always extend to depth e.g. silicified vents, pulverized dolomites etc.

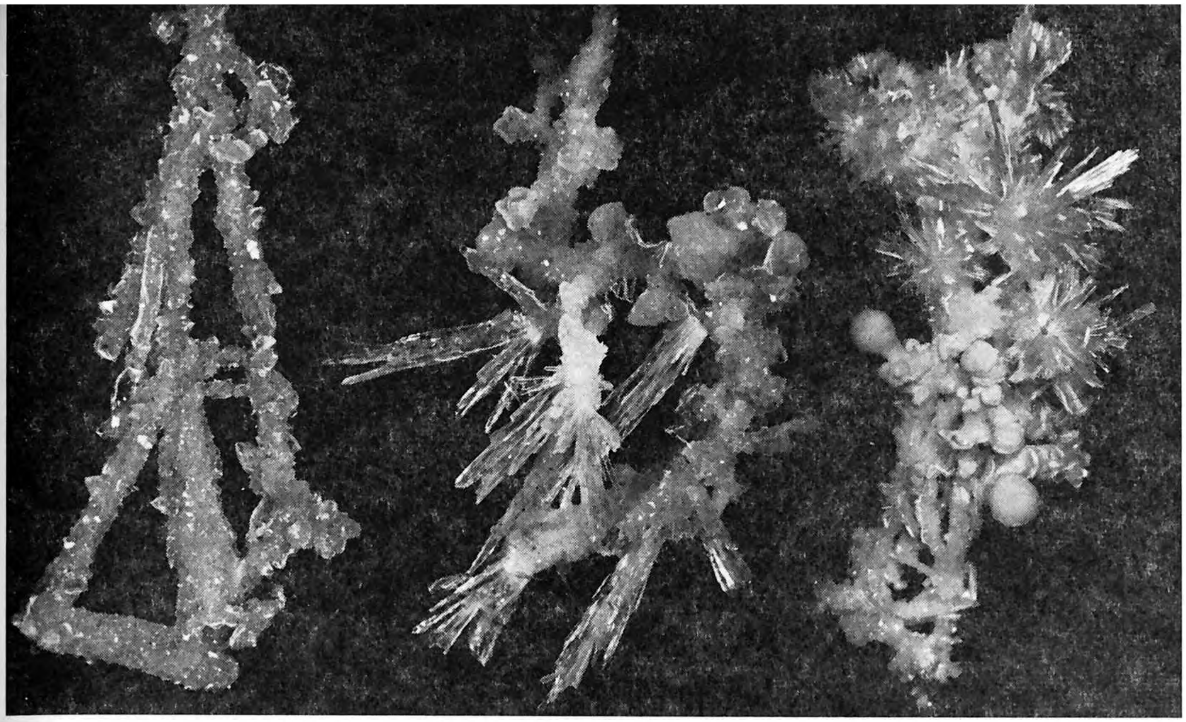


4. A gypsum stereo-model of the sections at the main entrance showing hydrothermal evacuation in the Solymár Devil's Hole.

Thermal caves are one of the most remarkable forms. Hungary contains active examples (e.g. Görömbölytapolca Cave) and inactive. The caves have been created by waters or by vapors rising from great depths, partly by direct dissolution, partly by chemical alteration of the permeated rock which permitted its ready destruction by more common weathering processes. Morphology of such caves is quite different from that of common karst caves because development is not dependent upon gravity-controlled water flow. Thermal caves may develop with almost equal facility in all spatial directions i.e. unlike the case of stream caves developed by entrenchment or lateral action, thermal galleries develop from the bottom upwards and may distribute radially towards the surface, developing more and more intricate ramifications



5. A gypsum stereo-model with scale relations and characteristic shape showing the Sátorkőpuszta Cave at Dorog, a prototype for hydrothermal cave. The base point in the cave, where the slots with spherical recesses and the passages fork from, is at the top-chimney of the lower Large-Chamber (at the point signed with the finger).

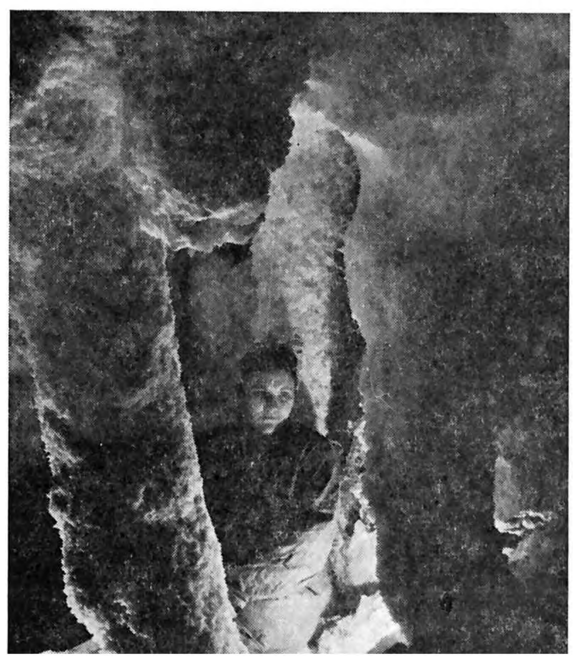


6. Groups of druse of different crystal-types of aragonite and gypsum of hydrothermal origin from the Sátorkőpuszta Cave.

as they approach it. Most branchways do not reach the surface but terminate in blind vents or pockets quite abruptly without any transition. Such pockets usually have a regular spherical or hemispherical form (Pávai—Vajna, 1930; Jakucs, 1948). Accordingly, galleries are arranged within the rock like boughs and twigs of a bush. Forming something like a string of beads, a maze of concentric cavities of regular spherical form may interconnect to create further passageways. These caves are usually so complicated spatially that their cartographic representation by the common planimetric projections may prove to be practically useless. Therefore it is advisable to construct threedimensional, true-scale models in gypsum *(Photos 4 and 5)*.

Hungarian speleologists consider as a rule that Sátorkőpuszta Cave near Dorog represents the purest monogenetic prototype of hydrothermal cavern development. Other hydrothermal caves in Hungary display rather more complex genesis with a number of factors interacting. The hydrothermal excavation process is usually guided by tectonic controls (Solymár Cave, Szemlő-hegy Cave, Mátyás-hegy Cave etc.) but thermal-morphology may be re-arranged occasionally by post-genetic effects such as stream erosion as well (portions of Mátyás-hegy and Solymár systems, Pál-völgy Caves etc.) Moreover, several instances are known to the author where a hydrothermal plume penetrated briefly into an existing cavern of different origin. In these cases the thermal waters did not erode the cave but produced mineral encrustations on the walls (Ferenc-hegy Cave.)

The thermal caves contain various paragenetic mineral overgrowths on walls and roofs. Most common are Aragonite, crystalline gypsum *(Photo 6)* and large individual gypsum crystals; there are some instances of gypsum stalactites and stalagmites *(Photo 7)* scalenohedral, rombohedral calcite crystals, limonite pseudomorphs of pyrite, platy baryte and fluorite crystals. Presence of baryte and fluorite causes one to ponder the origin of the hydrothermal plumes. The question is much debated today. It can hardly be doubted that, even when hot, karst waters do not contain barium

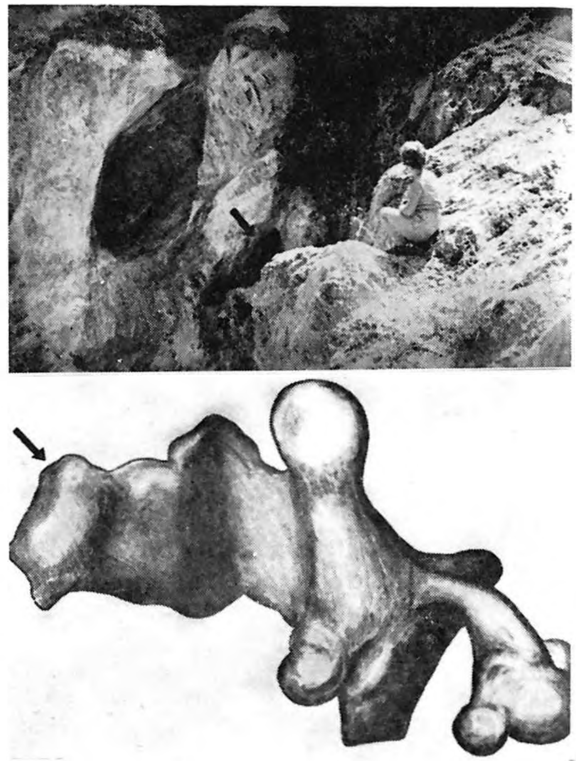


7. Cavernous gypsum stalactites from the Large Chamber of the Sátorkőpuszta Cave. Their thicknesses are larger than a human trunk, and their genetics has not yet been unanimously cleared up (Photo: I. Markó.)

of fluoride compounds. Consequently, it is most probable that the origin of the Hungarian thermal waters is associated with post volcanic effects. The common occurrence and abundance of gypsum deposits in the caves testify to the fact that the waters involved in cave formation must have contained some free sulphuric acid and this would not be the case if the plumes were composed simply of meteoric karst waters that were warmed up as a consequence of circulation to considerable depth.

The most conspicuous hydrothermal karst phenomenon that is most widely distributed at the surface is pulverulence and susceptibility to disintegration of the Hauptdolomite. This phenomenon is seen principally in the Buda Hills but can also be observed in places in the Dachstein limestone on Fazekas Hill. Consequently, pulverulence is not specifically restricted to dolomites. But examples from dolomite include totally pulverized beds which retain the original position and same macroscopic texture as do fresh, intact dolomites, although the microstructure has been completely disintegrated *in situ*. In many places the Hauptdolomit is exposed as a dust that is very fine-grained. Because the soil if any develops very poorly it supports little vegetation and thus appears as white, shining surfaces resembling desert sand *(Photo 8)*. Rainwaters rapidly scour gulleys in the pulverulent dolomite which are quickly destroyed and replaced by others. Deflation of the powdery surfaces is common.

In former times, entrepreneurs mined the dolomite dust by hand, creating caverns and galleries of strange configuration that illustrate most excellently the relationship between zones of pulverization and remaining unaltered rock *(Photo 9)*. As evidenced by the distribution, pulverulence occurs only along tectonic fracture lines or about the zones of their intersection and is related in every case of places of past hotspring efflux. Dolomite pulverulence was shown to have been caused by hydrothermal water by Scherf (1922) and Jakucs (1950). The mechanism is thought to be deposition of aragonite or anhydrite from interstitial waters which alter, with an increase in volume, to calcite or gypsum that is stable at normal temperatures when hydrothermal volumes decay. Volume expansion pulverizes the microscopic texture.



9. The entrance hole of a peculiar cavity system freed from dolomite powder mined out from unbroken rocks (upper picture) and its gypsum model with scale relations and characteristic shape (lower picture.) The entrance holes in the pictures, signed with fingers are the same.

Free sulphuric acid and iron sulphate are very often present in hydrothermal waters and may also have intruded the calcitic interstitial matrix of the dolomites, thus exchanging their products of decomposition. If the matrix is converted to gypsum or even to siderite, crystalline structure is immediately disintegrated. Accordingly, dolomites display in a disintegrated texture and dusty habit may be interpreted as equi-final products of various chemical processes associated with aqueous hydrothermal invasion.

It is also true that solution by cool waters promotes pulverulence of the rock. In the Hungarian climate, the calcite matrix cementing twinned crystal grains is relatively rapidly exsolved from dolomite and a crumbled, pulverulent rock may be the product. However, the dolomite dust occurrences of the Buda Hills are always located upon sites of extinct hydrothermal springs indicating that the pulverization is to be attributed mainly to thermal waters *(Fig. 4)*.

8. A characteristic phenomenon of hydrothermal dolomite karst: the karst of desert-like, powdered dolomite (Fehér Hills at Pilisvörösvár.)

In the dolomite karst lands a special hydrothermal origin is attributed to towers and pinnacles which project high above surrounding land because the rock is more resistent to karst denudation. Such features have formed where waters of past hotsprings deposited hydroquartzite i.e. silica. The silica-rich solutions penetrated a few metres into the walls of the ancient spring vents and deposited hydroquartzite there reinforcing the rock. Formations of this kind are found principally in the Csiki Hills near Budaörs, on the southern slope of the Huszonnégyökrös Hills and a similar mechanism was responsible for formation of the Ördögtorony ("Devils Tower") at Pilisszentiván *(Photo 10)*. There is no pulverulence in the southernmost range of the Budaörs Hills, from the Törökugrató to the Kőhegy. All that is found there is heavy silicification indicating that hotsprings here must have been silica-depositing from their beginning, whereas in the Csiki Hills there was simultaneous discharge of silica-free thermal waters at lower temperatures.

There are other evidences of changes of temperature and chemical composition in the Hungarian hotsprings. Thermal waters emerging along the river bed of the Danube in Pleistocene time did not carry silica and their capacity to excavate caves had markedly declined. These waters developed a strictly lime-depositing characteristic. This was the time when Hungary's vast accumulation of freshwater calc-tufa were laid down. The greatest is the plateau of Castle Hill in Buda. Its mode of occurrence and texture can be studied in caves on the Hill.

10. The Devil's Tower at Pilisszentivány: one of the characteristic shapes of hydrothermal dolomite karst. It was primarily a slot of a thermal spring.

3. Concealed or deep karst phenomena in Hungary (mine waters, hydrocarbon accumulations in karstic reservoirs)

As has been mentioned above, a consequence of the multiple fault tectonic history of the Transdanubian Mountain Range is that karst water tables (i.e. horizons of preferential solution at depth) have occupied differing positions with reference to the actual land surface at differing times. Consequently there are dissolution horizons at several different levels in most fault blocks of the Triassic basement. Uplift and subsidence was so dynamic that vertical displacement of horizons may exceed 1,000 m.

Karst water channels were plunged to great depth in deep-sunken blocks and remained as huge reservoirs after the advent of the inactive tectonic phase. A peculiar feature of these sunken reservoirs is the fact that they are in hydrological contact with one another laterally, by way of fractures. This is the reason why, when a cone of depression is introduced artificially by pumping one of the deep-sunken cavern systems, the karst water masses (hitherto static) are able to flow towards the point of withdrawal and so assure recharge. Due to these patterns of interconnected karst channel systems at great depth, prolonged withdrawal of water may induce a fall of karst water levels throughout an entire mountain range or even in several contiguous mountain ranges. This has been illustrated by numerous instances in the Transdanubian Mountain Range. Unfortunately, coal and bauxite mines operated in these areas below the water table very often breach karst channels and, unless the points of breaching are very rapidly sealed off by cementing, the mines can only be preserved in operation by continuous pumping of the intruding karst waters. The rate of water withdrawal in some districts has become so high that natural karst springs have dried up (Fényes Spring at Tata), indicating that the karst watertable has fallen considerably throughout the Mountains.

Buried in the Hungarian deep karsts are solutional galleries of considerable size which if intercepted by mining may supply catastrophic floods of water that can scarcely be halted because of their enormous size; sometimes an entire mine is flooded and devastated (e.g. Dorog, Tatabánya, etc.) Where pumping has made such hidden caverns accessible to Man it is apparent that hydrothermal agencies have played a part in their enlargement.

For example, cavern systems entered at 500–600 m depth in Dorog coalmine display walls covered by aragonite, gypsum, etc., crystalline deposits similar in development, habit and beauty to those known in the Sátorkőpuszta Cave, which is situated much above the modern watertable.

There is cavernous deep karst in areas where the overburden consists of thick formations of non-karst rock. As determined mainly by petroleum drilling experience, carbonate basement rocks of the Hungarian Basin substratum contain open solution caverns as deep as 1,000–2,000 m below ground. In these caverns beneath Nagylengyel in Transdanubia and Szeged in the Great Hungarian Plain a remarkable quantity of hydrocarbon has accumulated.

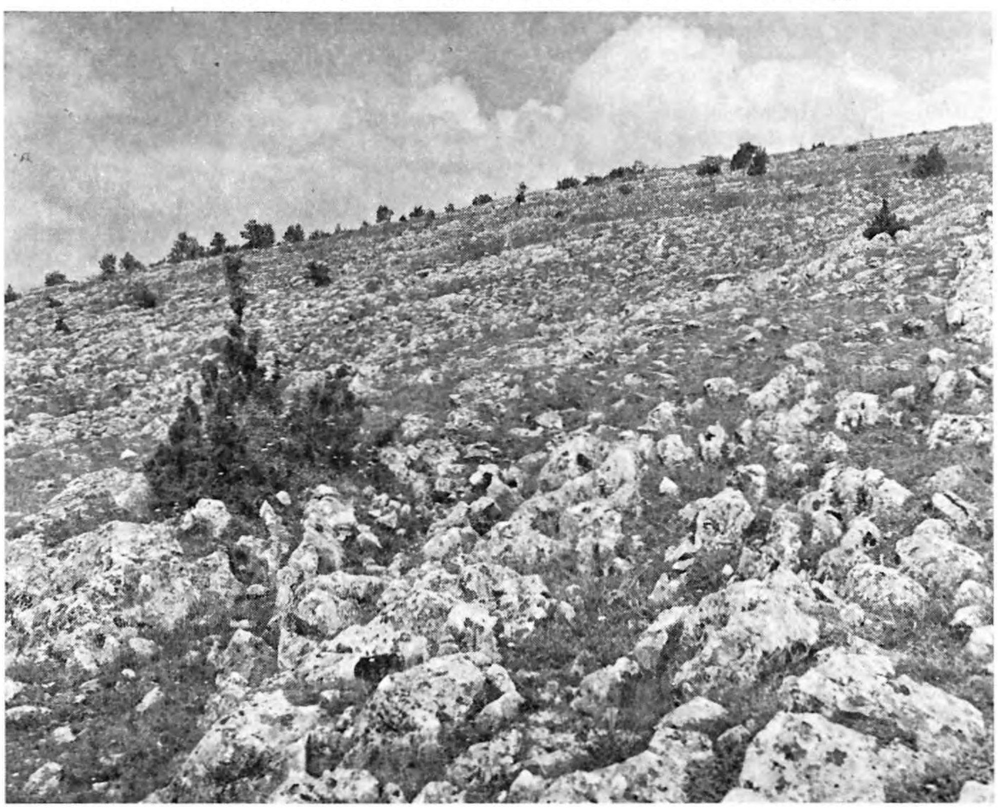
Karstification that produced the Hungarian deep-karst hydrocarbon reservoirs occurred in two main phases, late Jurassic – early Cretaceous and late Eocene-Helvetian. In the former phase karstification of Triassic rocks occurred and in the latter, of Cretaceous limestones. It is evident, too, that in the second phase there was renewed karstification of Triassic strata. Accordingly karstic development of the Triassics presently situated at great depths in the basement should be considered to have been more complex than that of the Cretaceous reservoir horizons.

11. A rock shape showing different karst-genetic phases in the Aggtelek Karst.

4. Surface karst solution phenomena (Karren and dolines)

Surface solution phenomena attain varying degrees of development in Hungary's karst areas. On the limestone and dolomite surfaces of the Transdanubian Montain Range there are comparatively few forms, despite the range of ages of strata. Although certain karren forms, mainly rounded types do occur in some places, development

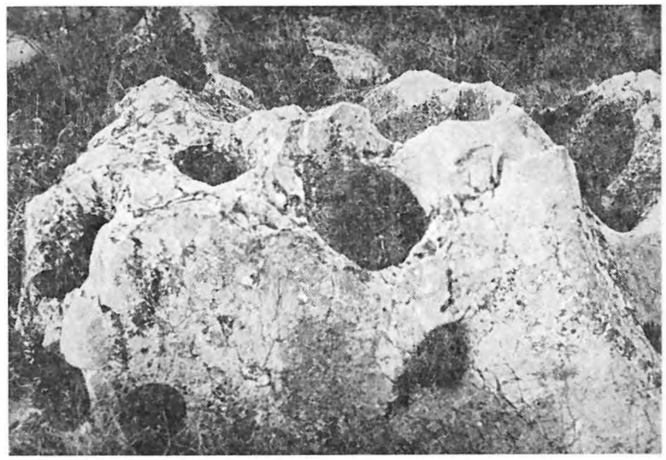
12. A section of the large karren-field called Devil's Ploughing at Aggtelek.



of dolines is quite insignificant = "Transdanubian karst type". This absence is particularly striking when it is remembered that these karstic blocks abound in hydrothermal karst phenomena and tectonic caves; the more so when compared with the very dissected karren fields and doline pitted surfaces of the Aggtelek Region, the Bükk Mountains and Mecsek and Villány Mountains = "Aggtelek type". This is particularly surprising for there is no basic difference, either in lithology or climate, between these two morphologically contrasted types of karst regions. Moreover, the number and time spans of their periods of karstification during geological history are very similar. So, explanation of the difference must rest primarily upon different tectonism and temporal differences in the thickness and consistency of overburden.

It appears that because of strong tectonism and consequent frequent marine transgressions with deposition of sedimentary rocks followed by their partial erosion, the solutional attack during successive phases of karstification in the Transdanubian-type areas impinged upon different karst surfaces each time. In other words, there was no cumulative superimposition of the individual karstic forms created during succeeding, widely spaced intervals of time. As a result the modern topography does not exhibit in any integrated manner cumulative effects of phases of karstification of the geologic past.

In karst areas of Aggtelek the converse is true. Successive phases of karstification impinged upon the selfsame surfaces which are exposed today. Thus, in the Bakony and Vértes Mountains paleo-

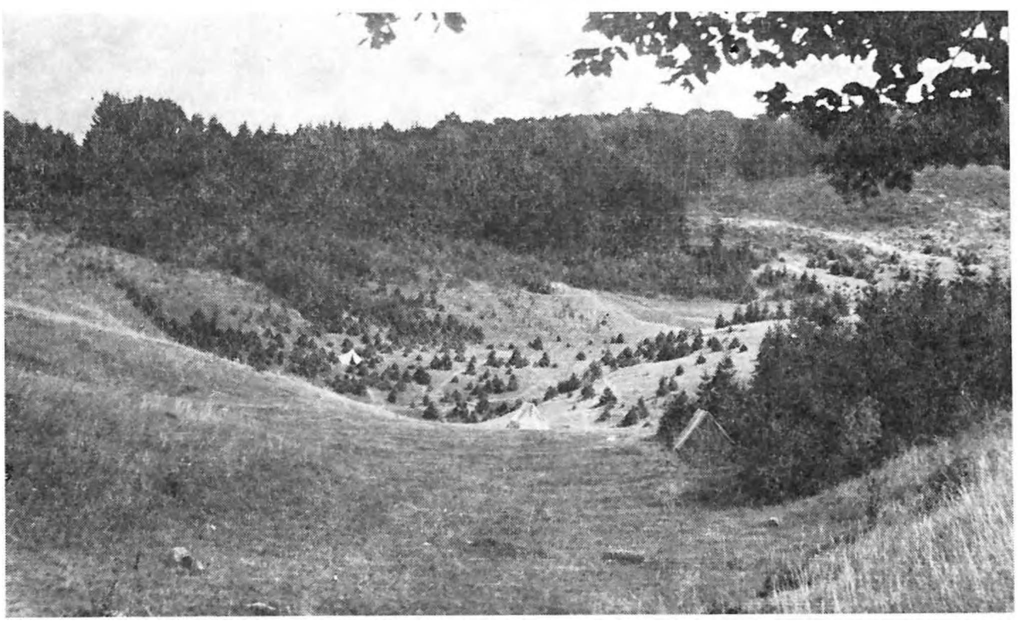


13. Finely developed root-karren of temperate zone type in Triassic limestone at the side of the Aggtelek Lake.

karst surfaces of Cretaceous age are buried by great thicknesses of Tertiary sediments and will not be revealed until these plus bauxites underneath are stripped away by Man (see *Photo 3*). At Aggtelek the same Cretaceous paleokarst terrains remain exposed at the surface today *(Photo 11)* and are undergoing normal karstification. This phenomenon Hungarian speleologists term "permanence of karstification" of Aggtelek-type karst lands.

The very complex form assemblages that may arise where there is "permanence of karstification" can be studied on the slopes of the uvala of Lake

14. Dolines with relatively small depth but large in diametre in the Great Plateau of the Bükk Mountains.



15. A row of dolines in the Aggtelek Karst, along the road between Aggtelek and Jósvafő.

Vörös at Jósvafő, particularly in a cluster of cliffs called the Medve-sziklák ("Bear Rocks"). It occurs in many other places in karstlands of Aggtelek-type e.g. in the Villány Mountains. Wherever present these forms are associated with accumulations of dark red terra rossa i.e. with a tropical red karst soil that implies denudation under climatic conditions considerably warmer and more humid than at present.

The most beautiful bare karren fields of Hungary occur at Aggtelek *(Photo 12)* and on the southern slopes of the Villány Mountains. Similar fields occur in great numbers in the Transdanubian Mountain Range, where the dolomite karren of Veszprém, Hajmáskér and Budaörs deserve special mention because of their rock-desert barrenness.

The limestone karren are generally of the subsoil kind with mazes of nicely developed root-channels. Free karren (gravitational forms such as rillenkarren or rinnenkarren) are not common. The frequency of root-karren *(Photo 13)* indicate that the slopes upon which they occur must have been covered

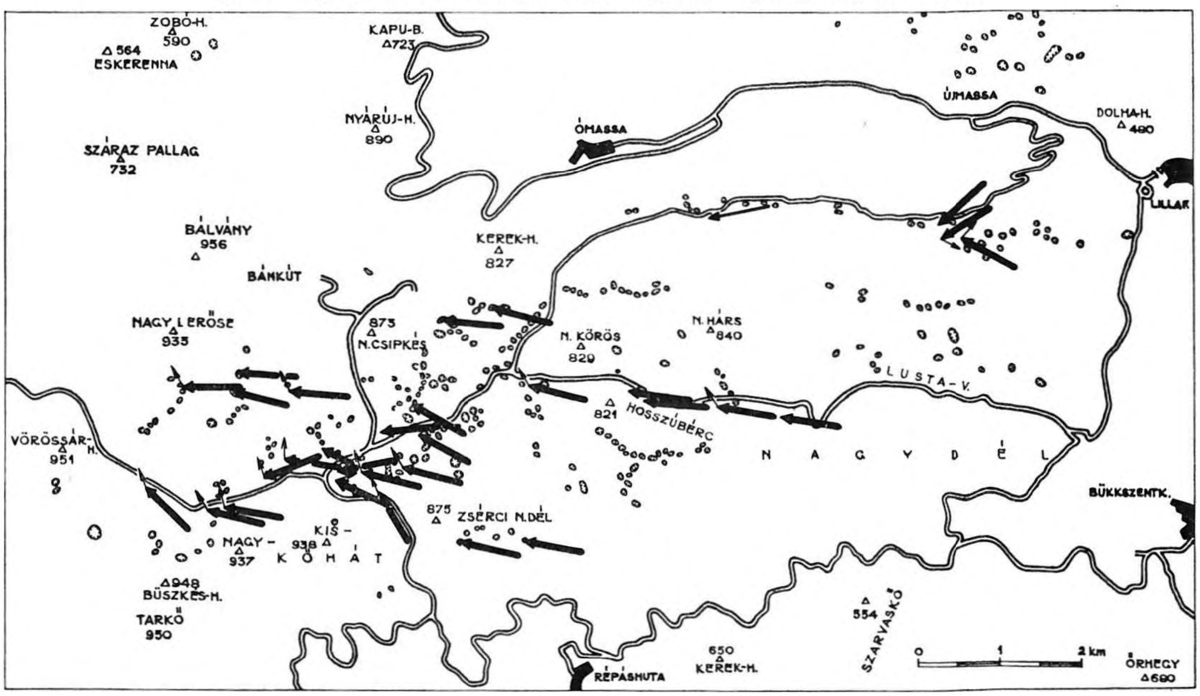


Fig. 5. Comparison of the orientations of asymmetric dolines in the Bükk Mountains with the rock dip directions observable at the dolines. Heavy arrows are pointed towards the steepest, opposite sides of the dolines. Small arrows indicate rock dip directions. Divergencies in the orientation of the arrows prove that the disproportions of the dolines are due to the specific microclimatic effects corresponding to exposure to different quarters of the heavens and not to the different dip angles of the strata.

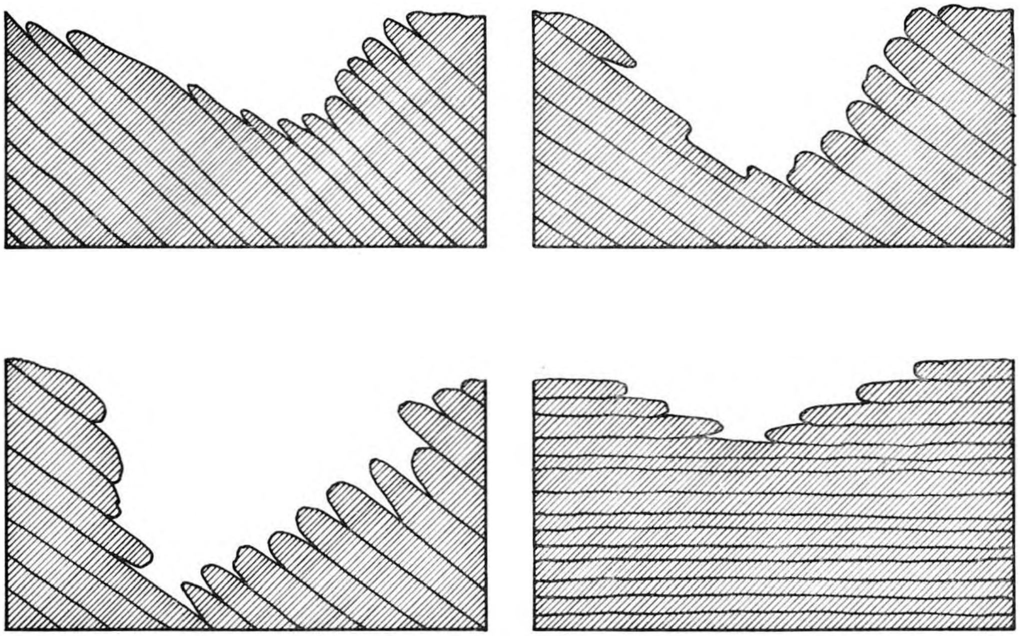


Fig. 6. As evidenced by the geological sections of karst dolines with the topsoil and the various disintegration products removed and thus cleared down to the bedrock surface, the so-called "collapse dolines" are virtually due to corrosion of the limestone bedrock under the soil cover rather than a subsidence or collapse of the bedrock itself. Independently of the original dip angle of the rock, dip direction and angle will remain constant during the entire doline formation process and only the foresets of beds largely reduced in thickness in the course of corrosion will collapse.

not long ago by rich topsoil and lush vegetation, neither of which is present today. Oak-dominated forests and karst bush which used to cover the surfaces were eradicated in historical times, presumably by Man's activities as in the karstlands of Dalmatia.

Dolines occur in three karst areas only, the Aggtelek karst, Bükk Mountains and western Mecsek Mountains. However, there are a great many of them at these localities and some are of considerable size *(Photo 14)*. The smallest dolines are 5—10 m in diameter and 1—3 m deep. The largest are 100—300 m in diameter, 20—40 m in depth. Sometimes, several dolines are combined in a uvala (Aggtelek Karst).

As a first approximation, the dolines appear to possess circular form in plan view. In reality, however, most are assymetric, certain of the side slopes (East-facing slopes in a majority of instances) being steeper *(Fig. 5)*. A great many dolines are known where, as a consequence, length of west-facing slopes is several times greater than that of east-facing slopes. This phenomenon is attributed to the different soil climates and consequent biological and vegetational characteristics of slopes of different exposure. The amount of dissolution of slopes of differing exposure varies also.

Except in one or two cases Hungarian dolines are of subsoil solution origin rather than being due to collapse. There is no close genetic interdependence of dolines and large solutional cave systems. In modern times there have been instances of minor collapses of soil at the bottoms or on the side slopes of the dolines but these can be interpreted as confined to the soil and represent its adaptation to changes in the bedrock surface underneath that are a consequence of subsoil solution. Investigations by the author have shown that bedrock strata preserve the original directions and degrees of dip in dolines, which would not be the case if these features were of collapse or subsidence origin *(Fig. 6)*.

Chains of aligned dolines are readily observed in all three karst areas of Aggtelek type *(Photo 15)*. Earlier workers attributed alignment to collapse of underlying caves but this has not been supported. Such aligned dolines are solutional macroforms of the limestone bedrock surface when subjected to subsoil solution, exactly as is the case with individual dolines. Development of lines of dolines is attributed to directional control by pre-existing denudation forms, primarily river valleys, which during karst denudation phases determine geographical location of microregions of enhanced solution intensity. A particular factor is the accumulation in paleo-valley bottoms of soils eroded from side slopes; thicker valley-bottom soils inducing enrichment of carbon dioxide in the filtering waters.

In areas containing both aligned dolines and scattered individuals, the aligned features are larger, better developed and at lower altitude.

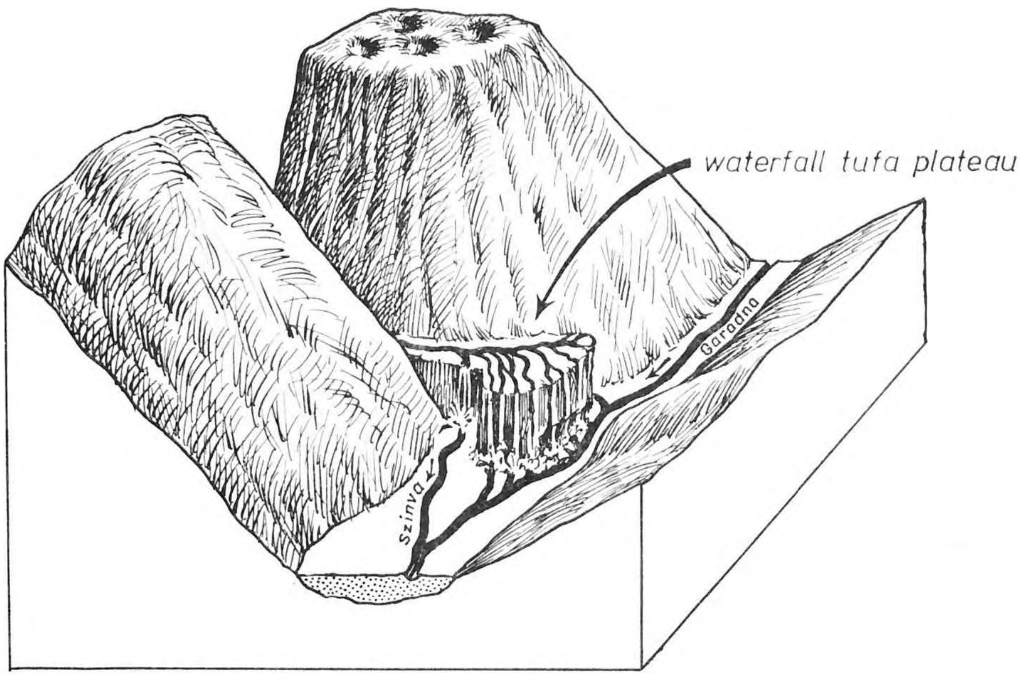
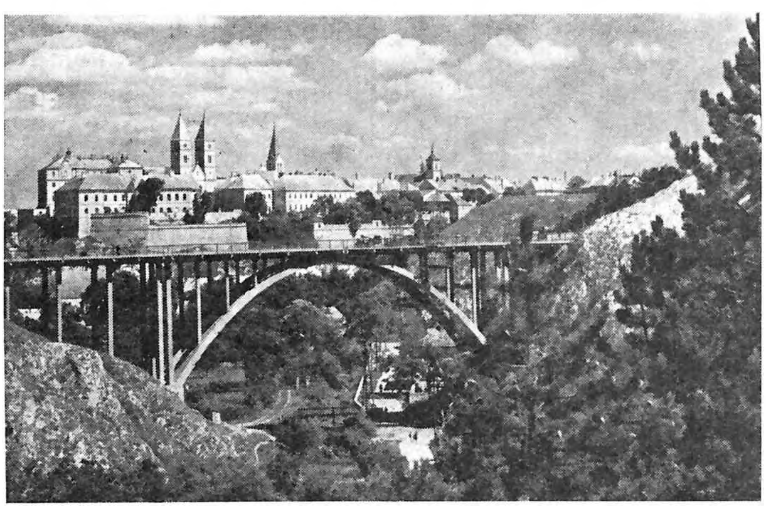


Fig. 7. Block-diagram of the calc-tufa hillock of Lillafüred hiding the syngenetic Forrás (Anna, Petőfi) Cave in its body. The hillock with its frontal edge protruding was built up by karstic cataracts of the River Szinva whilst its frontal base was constantly undercut by Garadna brook.

5. Karst sediments

The Hungarian karstlands are rich in karstic sediments, primarily various types of travertine. In frequency and volume per unit karst area abundancies exceed even those of the Alps or the Dinaric karst. Although surprising upon first reflection, this follows from natural laws. It is due to two effects. First, the Hungarian karstlands are at relatively low altitudes and their soil and air temperatures are higher than those of the Alpine karst regions. Second, unlike Mediterranean karsts, Hungarian karstlands are humid throughout the summer or, more precisely, throughout the period of vegetation growth. Combined, these circumstances are very favourable for deciduous forest growth (oak woodland) and in their natural state the Hungarian karsts were characterised by dense forest cover and the concommitant bioactive soil formation upon the rock. As a result, meteoric waters passing through the soils carry a very high carbonic acid content. The simultaneous availability of both warmth and moisture renders solution in the Hungarian karst more efficient than in the Alps (where, as a rule precipitation occurs only at the peak of the growing period) or the Mediterranean where rainfall is often inadequate during growth periods.



16. The Séd Creek is digged at a depth of 80 m into the dolomite plateau at Veszprém. The town was built on the edge of the plateau along the clough.

That massive accumulation of travertines (tufa) about springs is unambiguously correlated with the quality of vegetation covering spring catchments is most eloquently indicated by those travertine sites where the springs *stopped depositing* calcite following degradation of plant and soil cover by Man. An example is the Inota Spring where the catchment has become completely barren and the Garadna Spring of the Bükk Mountains or Jósva Spring at the village of Jósvafő. Before clearance, all these waters were strongly travertine-depositing in character and built huge calc-tufa mounds.

At those springs where the natural vegetation and soil cover are preserved on the catchment, such changes have not occurred. Examples are Monosbél Spring in the forested western Bükk Mountains and the nearby Szalajka Spring, Szinva Spring etc.

Amongst the cold water calc-tufa accumulations of Hungary the hillock of Lillafüred is certainly the most interesting because it contains a primary cave, Mésztufa (Calc-tufa) Cave, earlier known as Anna Cave, today called also Petőfi Cave. This cave is a typical example of syngenetic karst development; it formed during building of the enclosing rock. Its galleries and chambers have been locally widened and interconnected by artificial adits. Naturally, caverns of varying size are known in other travertine mounds as well but because of a peculiar configuration of relief and hydrography, calc-tufa deposition at Lillafüred was associated with a cavern — forming process of above-average efficiency. The calcite-depositing Szinva stream discharges from a hanging valley (i.e. as a waterfall of substantial height) into the Garadna stream and calc-tufa deposited by the Szinva at the base of the falls was continuously undercut by the erosive waters of the Garadna. Because of this, Lillafüred Mound could not grow in the normal way with a convex slope but developed as a plateau with an overhanging face. *(Fig. 7)*. Roots of aquatic plants suspended from the overhangs were calcified and reinforced by grasses, mosses, leaves etc., which accreted to them and were calcified in their turn. New curtains of calcified vegetation grew progressively outwards, enclosing new cavernous spaces. This process of "eave-building" can still be studied at Szinva waterfall and older calcified draperies of vegetation still hang down like lace from the vaulted roofs of Mésztufa Cave.

6. Erosional karst valleys and cave systems

Surficial karst valleys of an interesting linear erosion origin are abundant in Hungary though they do not attain the scale of karst canyons. Even the so-called "Remete-hegyi-szurdok" (Remete Hill Canyon) is really just a rocky valley head with an open, V-shaped cross-section. Although minor stretches of some karst valleys contain sub-vertical cliffs (Mária Cliff in the Vértes Mountains, Kerteskői Canyon and Gaja Canyon at Bodajk in the Bakony Mountains, Csúnya Valley, Felsőtárkány Pass, Csondró Valley and Szinva Valley in the Bükk Mountains and Séd Valley at Veszprém *(Photo 16)*, these are far from being imposing karst canyons even on the European scale. In Hungary, karstic erosion could manifest itself only underground where it has produced a maze of hidden valleys of considerable size.

17. Stream erosion forms in the Retek passage (Baradla Cave) as underground continuation of valley terraces.

The modern stream caves have been produced, not by local seepage waters from the karst basin but by allogenic rivers draining adjacent non-karst rocks. Genetically the classic cave systems of Hungary are not truly products of limestone dissolution but represent the sub-surface extension of river valley incisions. All the large caves are vaulted erosional valleys (active or inactive) which head in normal surface valleys and return to them. The sinkholes (swallow holes) and springs associated with such caves are no more than the points at which stretches of surface valleys become subsurface valleys and vice versa *(Photo 17)*.

Of the river-channel erosional caves of Hungary, the giants of the Aggtelek Karst Region such as Baradla, Béke Cave, Szabadság Cave at Égerszög and Vass Imre Cave at Jósvafő, are the foremost. In addition Kecskekút Cave in the Bükk Mountains and Abaliget Cave in the Mecsek Mountains deserve mention. This list does not exhaust the inventory of Hungarian caves for a substantial number of other sinkhole and spring caves, partly or completely explored, are known in the Aggtelek Karst and Bükk Mountains. However, these are the subject of a special paper and so are not discussed further here.

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Dr. György DÉNES

THE CAVES OF HUNGARY

SUMMARY

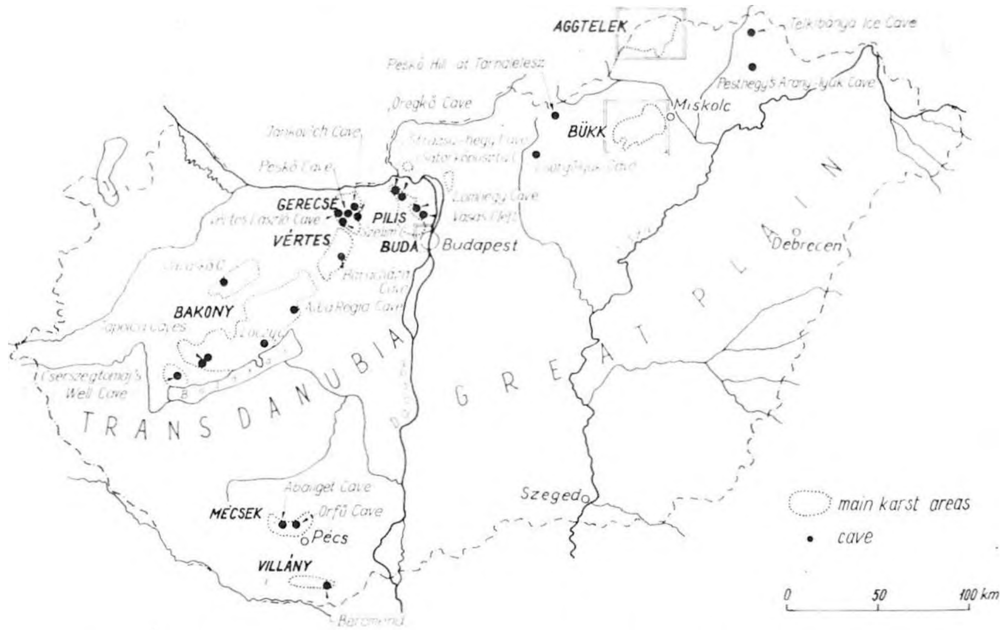
More than a thousand caves are on record in Hungary. Most of these occur in the major karst regions: the Aggtelek Karst, the Bükk Mountains, the Transdanubian Mountain Range and the Mecsek Mountains. The largest of them is the Baradla-Domica Cave System at Aggtelek, totalling more than 25 km in length, a part of which is in the service of regular tourism. In its vicinity there are other cave systems of kilometre order of magnitude: the Béke Cave, the Szabadság Cave, the Vass Imre Cave, the Kossuth Cave and the Meteor Cave. The Aggtelek Karst Region includes the karst plateau of the Alsó-hegy, in which speleologists have explored more than a hundred vertical shafts, among others, the Vecsembükk Shaft, the deepest cave of Hungary (245 m). The caverns of the Esztramos Hill are noted for their fossils, the caves of the Bükk Mountains, for their archaeological finds of Paleolithic and Neolithic age; the István Cave and the Forrás (Petőfi) Calc-Tufa Cave of Lillafüred are touristic attractions. In the municipal area of Budapest, the country's capital, scores of thermal caves are hidden underground. These are the kilometre-size labyrinths of the Mátyás-hegy Cave, the Ferenc-hegy Cave, the Szemlő-hegy Cave und the Pál-völgy Cave. Several cave systems of kilometre order of magnitude are hidden under the calc-tufa mantle of the Castle Hill carrying the ancient royal palace on its top. Most famous of the caves of the Transdanubian Mountain Range are the Tavas Cave, visited by masses of tourists, in the town of Tapolca and the Kórház (Hospital) Cave installed for therapeutical purposes, in its neighbourhood. In the Mecsek Mountains the Abaliget Cave is visited by many tourists.

In Hungary there are more than one thousand caves on record. Of these, nearly twenty caves are longer than one kilometre and about the same number are deeper than 100 m. The number of caves that are significant from the archaeological and palaeontological point of view is also large. Eight caves are open as show caves, three are used by doctors for regular speleotherapeutic treatments and one thermal cave is being operated as a public spa.

The vast majority of Hungarian caves are karst caves, though there are a few interesting non-karst caverns. In the following discussion the caves will be reviewed across the country from the north-east to the south-west.

Most karst caves have developed in the major, continuous karst areas of the country; the *Aggtelek Karst Region* and the *Bükk Mountains* in the north-east, in the *Transdanubian Mountain Range* extending from Budapest up to the southwestern corner of the country and in the *Mecsek Mountains* in the south.

The largest caves contaning underground rivers occur near Aggtelek village in the northeast of the country, along the Czechoslovak border. The author suggests that the formation of these caves was connected with the erosion of the impermeable overburden Even today these deposits of quartz gravels, sands and clays of mostly Pliocene alluvial origin, including remnants of Miocene tuff still cover part of the area. It should be noted that erosion has removed the impervious mantle from an ever increasing area of previously covered limestone. Thus the boundary line between the impervious cover and the denuded karst has shifted with time. The surface area of the hidden karst was gradually reduced and the size of the exposed limestone surface became ever larger. Surface water-courses running off the impervious cover produced sinkholes at the contact between the two rock surfaces. Penetrating deep underground through the sinkholes, they produced karstic water ducts and caves which lead to karst springs welling up in the valleys representing the local base level of erosion. With the gradual denudation of the impervious cover this boundary has gradually receded farther away from the springs and newer sinkholes have developed at the changing karst boundary, giving rise to additional cave passages, thus increasing the total length of the caves. This



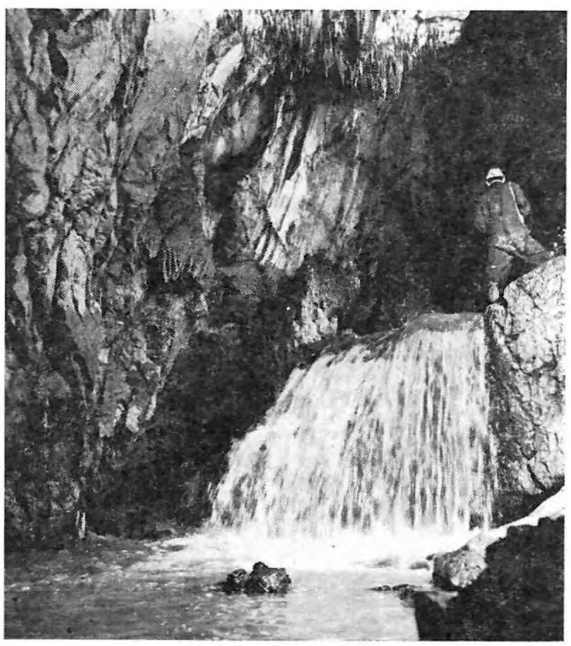
The geographical distribution of Hungarian caves mentioned in this article.

process is still continuing today. The erosive action of quartz grains introduced from the surface through the sinkholes has largely contributed to the widening of the galleries of the cave system. Thus the length of the underground rivers gradually increased at the expense of the surface stretches of the existing watercourses. The author believes the large cave systems of the country to have developed this way. The majority of the ancient sinkholes, once abandoned by running water, would with the passing of time be plugged and thus be transformed into karst dolines, some of them even into doline-lakes. Some of the vertical shaft caves of the region seem to have been ancient sinkholes, but, as a result of the considerable morphological changes of their environment, it is rather difficult to recognize their one-time role.

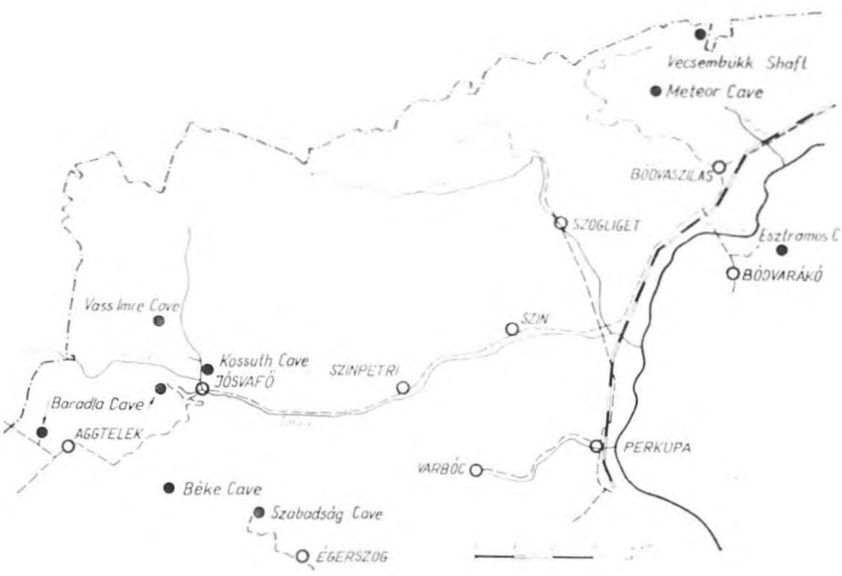
The largest cave of the Aggtelek Karst Region is the *Baradla-Domica Cave System*. Its two ancient entrances open respectively at the foot of the Baradla-tető, in Hungary, and of the Domica-tető, in Slovakia. Both entrances were known to, and made use of by, early man, as evidenced by the wide range of Neolithic and Iron Age artifacts recovered from the cave.

The Baradla Cave has been investigated and surveyed since the 1700's, the Domica Cave since the 1800's. The survey of 1794 prepared by János Farkas and József Sartory illustrates little more than one kilometre of the Baradla. Keresztély Raisz recorded three kilometres on his detailed survey made in 1801. Imre Vass, in turn, with the discovery of the cave passages beyond the Vaskapu (Iron Gate) mapped, after 1825, a total length of more than 8 km of the Baradla. By the late 1920's, the known length of the Baradla exceeded 10 km.

In the meantime, in 1927, Jan Majko and his companions explored new passages in the Domica Cave, thus increasing its total length to 7 km. The connection between the Baradla and the Domica was assumed to exist in the early 1800's, but it was not until the intervention of Hubert Kessler and his companions in 1932 that the water-filled passages and closed siphons, could be drained and thus rendered passable by man. According to Kessler's calculations, the total length of the explored continuous cave system attained 21 km in 1938, including those parts explored by members of the Tourist Club of the Budapest University.



Waterfall below the Mount Morea in the Baradla Cave (by P. Borzsák and A. Prágai)



The biggest caves of Aggtelek Karst Region.

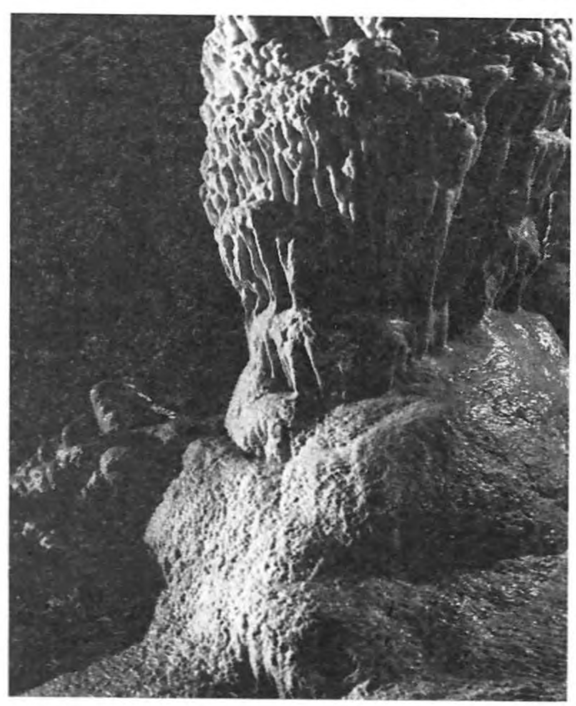
Following some minor explorations by several contributors, this figure subsequently increased to 22 km or so by 1960. During the decade and a half that has elapsed since that time, the speleologists of the Vörös Meteor Club, led by György Dénes, have explored and mapped a total of 3 km more. Thus the presently known length of the Baradla-Domica Cave System now totals about 25 km.

The huge system of the Baradla has encouraged people not only to exploratory activities, but also to undertake most diversified forms of special investigations. Archaeological research began in the last century and numerous brilliant archaeologists have since that time recovered a wealth of artifacts of the Bükk culture of Neolithic man from this cave site. Excavations have brought to light countless remains of the culture of the group of people who were dwelling in the cave at the turn of the Bronze and Iron Ages.

In the early 1930's Endre Dudich investigated and produced a paper on the animal world of thé Baradla, and thereafter he organized an underground speleo-biological laboratory set up in one of the side passages of the cave. That laboratory is now functioning as a research station for Budapest University. The algae and lamp flora have been investigated, as also have the hydrological conditions and the problems of speleogenesis of the cave system.

As well as being the subject of interdisciplinary research, the cave system is of great significance for its stalagmites of worldwide fame. In the Hungarian sector of the cave system more than four kilometres are illuminated. Every year more than a quarter of a million visitors descend to the cave, via its natural entrance at Aggtelek and its artificial one at Jósvafő, to admire its beauties. They can traverse part of the cave by paddling in boats. A huge chamber with breath-taking acoustics has been developed into a hall in which organized public concerts are held regularly.

Hotels and restaurants have been built near the Aggtelek and Jósvafő entrances to the cave. Camping facilities with wooden bungalows and sites for tents have also been provided, in order to help accomodate visitors to Aggtelek. There is a high-standard museum exhibiting information on the



Flowstone column in the Baradla Cave (by P. Borzsák) genesis of the Baradla; its archaeological and palaeontological treasures; the history of its exploration and the interdisciplinary research carried out in the cave.

It is worth mentioning that the Baradla-Domica is a typical, multilevel cave system including underground streams. The main passage of the cave is joined by side passages originating from sinkholes. The topmost level exists only in some parts of the cave. At the middle level, the one where tourists enter, runs the River Styx. This originates in the Domica and is traceable over a large stretch of the main passage of the Baradla, before it penetrates through underground sinkholes down into the passages of the base level leading to the prolific Jósva spring.

The resurgence cave of the Baradla-Domica Cave System, the *Alsó Cave* (Lower Cave), has for the moment no passable communication with the higher levels of the cave system. Overcoming the difficulties imposed by a series of vertical siphons, speleologists have so far explored for a total length of 400 m.

The *Béke Cave* (Peace Cave), close to the Baradla, is similarly between Aggtelek and Jósvafő. László Jakucs, leader of the exploration, has found cave passage of more than 8 km in total length and thus the Béke Cave is the second longest cave in Hungary. The Béke Cave has wide chambers at its Jósvafő entrance, where the speleotherapeutical stations of a cave-sanatorium have been set up. For this reason, the Béke Cave has been left free from tourism, in order to prevent eventual pollution of its health-giving atmosphere.

Just a few kilometres farther away, in the vicinity of Égerszög, in 1954, Dénes Balázs and his companions discovered a system nearly 3 km long, the *Szabadság Cave* (Freedom Cave), again with stalactites, stalagmites and a stream.

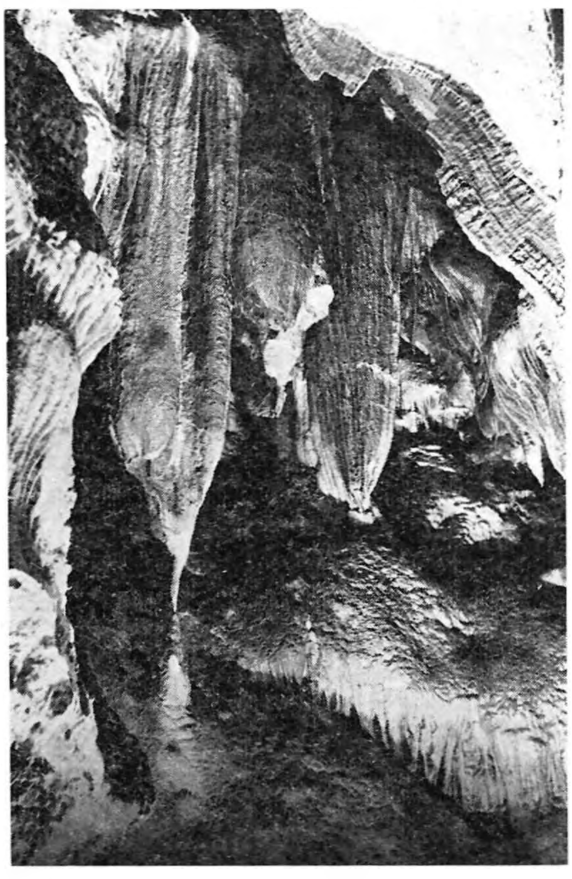
In the neighbourhood of Jósvafő, an enthusiastic group of speleologists, László Maucha and his companions, explored nearly 1 km of well decorated passage in the *Vass Imre Cave*. Upon Professor Ferenc Papp's initiative a speleological and karst hydrological research station was established close to the cave. This station is equipped with instruments suitable for recording a wide range of measurements. The equipment is capable of continuous monitoring of the results measured by the instruments installed in the cave. At present, the station is being run by the Research Institute of Water Resources Development.

Again on the edges of Jósvafő, near a large karst spring, entry was made into the passages of the *Kossuth Cave* which has been explored for more than 500 m, further progress having been stopped by deep siphons.

On the Alsó-hegy Plateau, rising above Bódvaszilas, 20 km north-east of Aggtelek, speleologists of the Vörös Meteor Club, led by György Dénes, have so far explored 500 m of the so-called *Meteor Cave*, which contains formations and a stream. This cave includes one of the largest underground chambers found in Hungary, the Hall of Titans, containing an extraordinary wealth of helictites, stalactites and stalagmites.

Above the Meteor Cave lies the large, karst plateau of the Alsó-hegy, which is crossed by the Hungarian—Czechoslovakian border. Between the karst dolines of the plateau there are numerous deep vertical shafts. As a result of the hard work and stubborn efforts made during the last two decades by Vörös Meteor's speleologists, the number of vertical shafts explored on the Alsó-hegy Plateau now exceeds one hundred. The most significant of these is the 245 m deep *Vecsembükk Shaft* which is the deepest karst shaft ever found in Hungary. On the Alsó-hegy Plateau there are also several vertical shafts exceeding 100 m in depth.

Mining activities on *Mt. Esztramos* facing the Alsó-hegy Plateau on the other side of the River Bódva have led to the discovery of numerous caves with an unparalleled profusion of crystals. In the natural caverns uncovered or rendered accessible, and in the materials partly or completely filling them, a very diversified and abundant palaeontological fauna has been found. This material, which includes remnants of numerous animal species of



A portion of Orange Waterfall in the Vass Imre Cave in Jósvafő (by P. Borzsák) different Pliocene and Pleistocene horizons, hitherto unknown to science, is worthy of consideration even on the international scale.

Another significant Hungarian karst area lies in the Bükk Mountains to the south of Aggtelek. In this area, hundreds of caves are known, some of them over a kilometre long. However, even many of the minor ones are of great scientific value, with diverse and valuable anthropological, archaeological and palaeontological research sites.

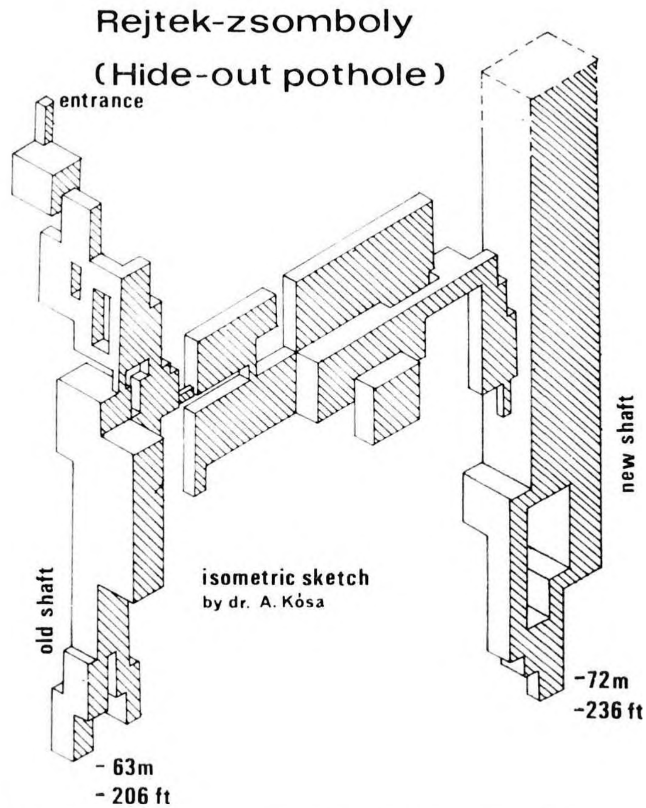
The largest known cave system of the Bükk Mountains is in the mountain range above the recreation resort of Lillafüred in the vicinity of the city of Miskolc. Speleologists from Miskolc have so far explored four sections of the *Lillafüred Cave System*. The first is the *Létrási-Vizes Cave*, explored for approximately 2 km, secondly the *Létrás-tető Cave* which has been explored for more than 1.6 km. Thirdly the *István-lápa Cave* which is nearly 3 km long and at 240 m is the second deepest cave in Hungary. Finally, on the base level of the system, in the centre of the resort, speleologists have explored the *István Cave* for 350 m. This cave attracts many visitors who come to see its well-illuminated stalactites. A total of nearly 7 km of passages have been explored so far in the Lillafüred Cave System, but the explored sections of cave are separated from one another by considerable stretches of unexplored passages.

Also at Lillafüred, there is the *Forrás (Anna, Petőfi) Cave*. This is a nicely illuminated calc-tufa cave of particular scientific value whose caverns contain calc-tufa concretions of extraordinary beauty and are well worth seeing.

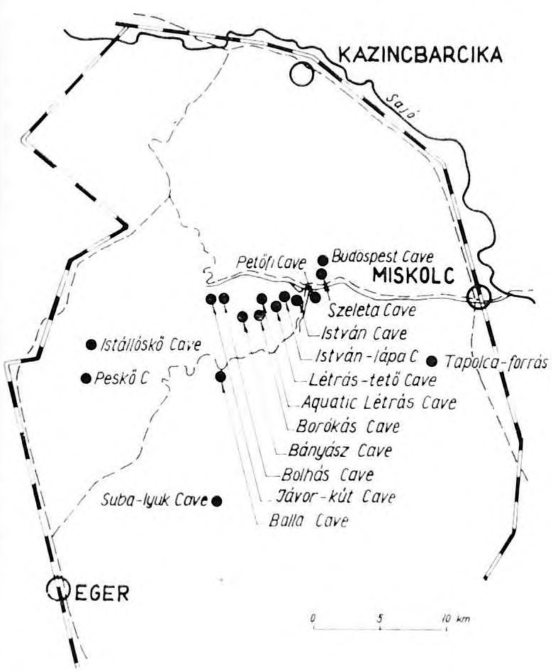
By much hard digging to open both active and fossil sinkholes, speleologits from Miskolc have explored the *Jávor-kút, Bolhás, Bányász* and *Borókás Caves* as well as many others in the large karst area of the Bükk Mountains. The *Spring Cave of Miskolc-Tapolca* has spacious chambers with nicely corroded walls overlain by lofty avens and splendid limestone vaults. The subthermal waters of this wonderful spring cave have been used as a popular cave-bath.

Of all the caves of the Bükk Mountains famous for palaeoanthropological, archaeological and palaeontological finds, the following may be quoted as random examples. The *Suba-lyuk* and the *Balla Cave* from which bones of early man have been recovered; the *Szeleta Cave* known for its Palaeolithic implements which have become known under the name of the Seletian culture; as well as the *Büdös-pest, Peskő* and *Istállóskő Caves* abounding in both archaeological remnants and fossils.

In the Aggtelek Karst Region and the Bükk Mountains the cave systems result from either percolation water or drainage from surrounding impervious rock surfaces. On reaching the limestone boundary, these waters sink deep underground by way of sinkholes and have carved out gently sloping passages along their underground paths towards the springs. Essentially these caves are horizontal



A characteristic example of vertical shafts in the Alsó-hegy Plateau, North East Hungary

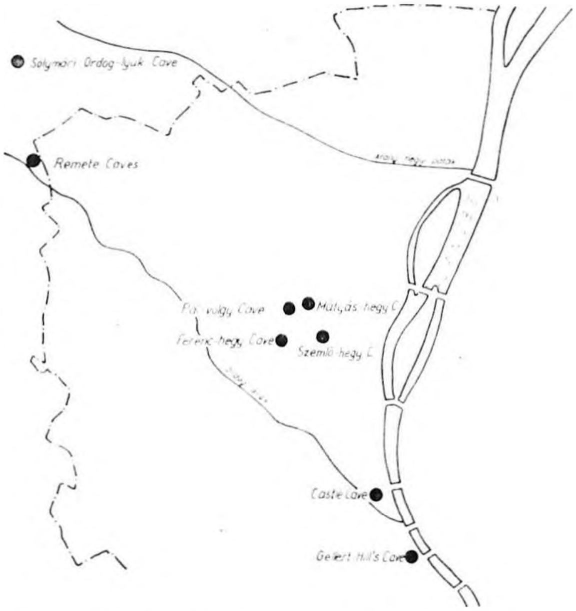


Caves of the Bükk Mountains mentioned by the author.

systems in which the only vertical elements are the sinkholes and shafts which have drained the waters deep underground. However, the caves of Budapest and its vicinity are different in character. In the majority of these caves there are no underground streams or subhorizontal passages; instead, there is a labyrinth of complex underground passages. Most of the caves result from thermal waters travelling at great depths from remote mountain areas. These waters then well up to the surface along fracture lines running at past or present levels of the Danube representing the local base level of erosion. C-14 dating has shown that the bulk of these waters fell as precipitation between 10,000 and 20,000 years ago and soaked deep under the surface, far away from the springs. The thermal waters have ascended simultaneously through several adjacent fractures in the karst fracture zone up to the surface, resulting in the formation of a maze-like network of vents alternately converging and diverging on their paths towards the surface. Overall they demonstrate a vertical trend as would be expected by waters progressing towards the surface but closer scrutiny shows that some passages within this labyrinth must have been controlled by the dip of the strata and intersecting fault lines.

In Budapest, Hungary's capital, on the bank of the river Danube, rises the Gellért Hill which used to be called the Pest Hill in the Middle Ages. It had been given that name because there was a noticeable large cave on the escarpment overlooking the Danube and medieval Hungarians used the Old Bulgarian word *pest* for caves. This word meant both a cave and an oven, just as the German word Ofen did. The ferry which had been installed at the foot of the Pest Hill would be called the *Pest ferry*, while the settlements that had sprouted on the two sides of the ferry would be named *Pest* by the Hungarians and *Ofen* by the Germans. The entrance of the cave, which had given the nation's capital its name, was walled up in the 1940's. The cave now houses a karst-hydrological observation station of the Research Institute of Water Resources Development.

The plateau of the Castle Hill, the site of the ancient Hungarian royal palace, is covered by a travertine sheet. The thermal karst waters that used to well up there have carved out caverns and vents under the travertine accumulations. These cavities were discovered by medieval well-diggers. Thereafter they were connected artifically with one another, resulting in the development of a complex branching system of cave tunnels extending over a total length of about 10 km. The inhabitants of the castle would use the tunnel system as casemates and shelters during wartime blockades and as cellars in peace time. At present much of the *Castle Cave* is open to tourists who are shown round the nicely illuminated catacombs and tunnels. These abound with interesting solutional sculptures on their roof and underground wells in their floor. The cave is operated by the Hungarian Speleological Society.



Approximate locations of the most important caves in Budapest and its surroundings.

In 1904 a kilometre of cave labyrinth was discovered in the Pál-völgy quarry in Budapest. Beside its stalactites and stalagmites, this cave is notable for the occurrence of unusual thermal dissolution forms known as spherical niches. The *Pál-völgy Cave* is operated by the National Nature Conservancy Office and is provided with good lighting and tourist facilities.

In the early 1930's, two other caves of similar thermal origin were explored close to the Pál-völgy Cave. One of them, the *Szemlő-hegy Cave*, was discovered during housing foundation works, the other one, the *Ferenc-hegy Cave*, during digging for a canal. The Szemlő-hegy Cave has been explored for over two kilometres. It contains many spectacular crystal masses of thermal origin, resembling grapes or a mass of rounded coral. The National Nature Conservancy Office is now developing it as a show cave. The passages of the neighbouring Ferenc-hegy Cave, explored for nearly 4 km, are also rich in similar formations. However, since its passages are not wide enough for tourist purposes, the cave has been completely closed except to speleologists.

On the hillside opposite the Pál-völgy Cave, quarrymen initially uncovered a minor group of caverns, part of the *Mátyás-hegy Cave*. In 1948, speleologists of the Tourist Club of the Budapest University explored nearly 2 km of the cave. In the 1960's a further 2 km were explored and surveyed by speleologists of the Vörös Meteor Club. Now totalling 4.2 km in length, this cave system is the third longest, and at the same time the largest, cave of thermal water origin in this country. Although rather poor in formations, with its intricate labyrinth of chambers and passages, its deep rifts, vents and shafts, it is a favourite training ground for Budapest speleologists.

The nearly 2 km long labyrinth of passages of the *Solymári-ördöglyuk* (Devil's Hole of Solymár) opens on the side of the Zsíros-hegy Hill which rises near the capital. It is notable both for its rare fossils and for its unusual thermal water dissolution forms, and is another old training ground of the capital's speleologists.

On the boundary of Budapest's metropolitan area is the spacious *Remete Cave*, famous for its archaeological remains. Archaeologists have recovered artifacts and relicts of twelve different cultures from the thick sediment filling the chambers of the cave. The fill from the narrower chambers of the adjacent *Remete-Felső* (Remete-Upper) *Cave* has yielded both Paleolithic implements and three coherent teeth of Neanderthal man, while the top layer of the fill was found to hide a rich hoard of Bronze Age treasure.

On the side of the Hárs-hegy Hill, one of the favourite places for outings from the capital, is the *Bátori Cave*. Here traces of ancient mining activities can be seen in a ferruginous vein within the limestone. Recently, speleologists have explored new, untouched parts of the cave.

To the northwest of Budapest, on the edges of Esztergom, the ancient capital, explorers discovered two adjacent caves. In 1946, they found the *Sátorkőpuszta Cave* consisting of a series of spherical niches of thermal water origin and showing an extraordinary wealth of gypsum crystal accumulations. In 1960, they discovered the *Strázsa-hegy Cave* covered with similar crystal formations.

In the adjacent mountain region of the Transdanubian Mountain Range, the Gerecse, no major cave is known, though the *Jankovich Cave* and the *Szelim Cave* are well-known for their archaeological relicts and artifacts. The *Peskő Cave* of Tatabánya and the *Öregkő Cave* (which used to be called *Kőpest* in the Middle Ages) of Bajna have been known and kept on record by local people from time immemorial. Of the caves explored by speleologists in this mountain mass, the 82 m deep *Vértes László Cave* is worth mention.

The karst of the Vértes Mountains, the next area to the southwest, consists predominantly of dolomites, which explains the lack of major caves in that area. One minor cavern, the so-called *Báracháza Cave*, is well-known for its rich Hypparion fauna.

To the southwest the next karst area is in the Bakony Mountains, where the most significant cave is the *Alba Regia*. This has recently been explored by speleologists from Székesfehérvár to a length in excess of 800 m and a depth of 170 m, and is at present the third deepest cave in Hungary.

A hill in the Bakony, called *Odvaskő* (cavernous hill), noted for its small cave, is mentioned in a royal document of 1037, and thus is the oldest known cave-name recorded in Hungary.

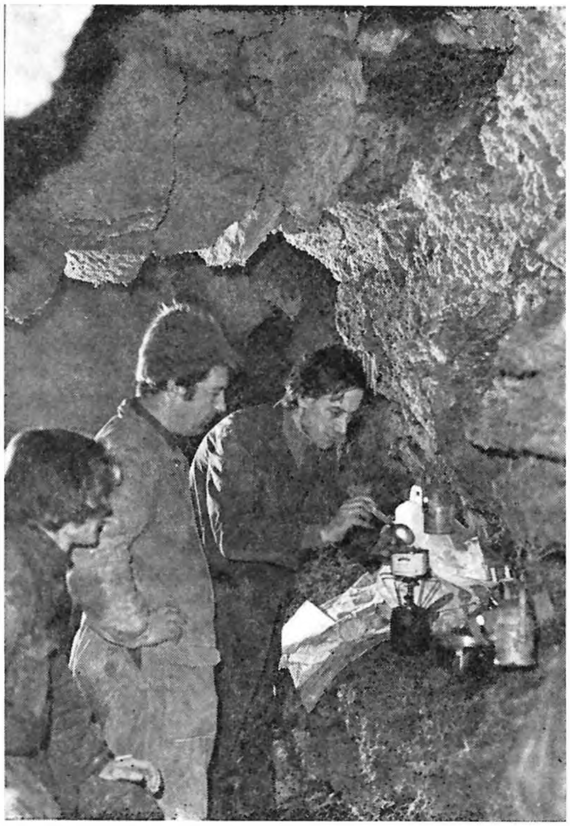
To the south of the Bakony Mountains, the partially karst Balaton Highland extends along the northern shore of Lake Balaton. In the vicinity of Balatonfüred spa, quarry-men discovered a minor cave which was named the *Lóczy Cave* after Lajos Lóczy, the prominent Hungarian earth scientist. Though of modest size, this cave shows interesting solution forms which are illuminated by electric light for visitors.

In the central part of the town of Tapolca, on the boundary of the Bakony and the Balaton Highland there are two caves of much greater significance which may form part of one system. In 1902, well-diggers discovered a cave which was named the *Tapolca's Tavas Cave* and is characterized by the alternation of dry and water-filled passages. Its water belongs to the hydrological system of a high yield karst spring which wells up at the centre of the town. The cave was supplied with electricity as early as 1928 and since then has become one of the tourist highlights of the town. Particularly attractive are the organized boat tours round the partially water-filled passages of the cave. As a result of cave diving in recent years, the length of the cave is now about 1 km.

Close by, in the basement of the town's municipal hospital, cellar-bilders discovered another cave which was called the *Kórház* (Hospital) *Cave* and which certainly belongs to the same cave system as the Tapolca's Tavas Cave. As it is in the basement of a hospital it is reasonable to use it for speleotherapeutic purposes. On the basis of a careful preliminary examination of the cave's climatic elements and the favourable results of subsequent experimental cures, the physicians of the hospital are now carrying on regular speleotherapeutic treatments there. Patients are transported by lift from the wards down to the cave so that they need not walk to reach their destination.

On the margin of the Keszthely Mountains, rising by the southwest corner of Lake Balaton, is the spa resort of Hévíz. Here, in the cemetery of Cserszegtomaj-Szőlőhegy, well-diggers discovered Hungary's largest cave developed in dolomites. Along the contact between sandstones and dolomites, thermal waters which used to well up from great depths have generated a labyrinth of intercommunicating caverns so far explored for a total length of approximately 800 m. This cave, which is still accessible via that well, is called the *Cserszegtomaji-kútbarlang* (Cserszegtomaj's Well-cave).

In south Hungary, the Mecsek Mountains occur in the southeast corner of Transdanubia. South of them is the smaller range of the Villány Mountains. The longest cave found in the Mecsek, the *Abaliget Cave*, was discovered by a local miller in 1768 while opening the entrance of a large karst spring. Speleologists have so far explored the cave for approximately 1,200 m. A typical stream cave, fed by several sinkholes, it has been provided with electric lighting



Underground camp in the Szabadság Cave of Égerszög (Aggtelek Karst Region) (by T. Seregélyes)

in its fascinating chambers and attracts a considerable number of tourists. Around its entrance a popular excursion and recreation site has been developed.

The *spring-cave* hidden behind the *Orfű* spring, the largest karst spring in the Mecsek has so far been explored for only a short distance. The speleologists of the city of Pécs (South Hungary) are making considerable efforts to explore the supposed large cave system which includes several siphons and is fed by a large catchment area.

The karst caverns and fissures of the Villány Mountains situated south of the Mecsek are famous for fossiliferous localities. The *Beremend Cave* which was uncovered in the course of mining activities is rich in formations.

In Hungary no cave of significance has formed in non-karst rocks. For the sake of completeness, mention may be made of the *Telkibánya Ice-cave* and the *Pesthegy's Arany-lyuk* (Golden Hole) *Cave*, both occurring in the volcanic rocks of the Zemplén Mountains in the northeast part of the country. Having originally been natural cavities, both seem to have been widened by man. In the Ózd Hill country, minor caves have formed in the sandy clay-marls on the slope of the *Peskő Hill at Tarnalelesz*. In the Mátra Mountains there occurs the largest cave found in volcanic rocks in Hungary. This is the *Csörgőlyuk* opening on the side of the Ágasvár and exceeds 100 m in length. Out of the numerous minor caverns occurring in the andesite mountains of the Danube Bend, the *Lomhegy Cave* and the fissure-cave of the *Vasas Cleft* are worthy of mention.

For lack of space, the author has quoted above little more than fifty of more than one thousand caves in Hungary. It would not be an exaggeration to point out, however, that many others deserve to be mentioned. In the small karst area of this country there are hundreds of extremely interesting caves that offer scientists engaged in any special field of speleology many possibilities for carrying out observations and collecting new information.

English translation revised by R. A. Halliwell.

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Dr. Tivadar BÖCKER

ECONOMIC SIGNIFICANCE OF KARST WATER RESEARCH IN HUNGARY

SUMMARY

Scientific research works on karst water are based upon the National Karst Water Observation Network in Hungary. It consists of about 700 karst springs and about 450 observation wells. The report presents the percentage distribution of karst water resources, its utilization, and the most significant results of scientific research on karst water, e.g. the determination of porosity, permeability, water age determination and the influence of dewatering in mines on karst water.

1. Introduction

Harnessing of karst waters such as springs in the region comprising modern Hungary can be traced back for several thousands of years, as it can in numerous other countries. Celtic people knew of a major spring in the vicinity of Budapest as early as 2,000 years ago and named it "Ak Ink" for its high yield. Later, the Romans founded a military camp and town here (Aquincum) and built an aqueduct to draw water from the spring. In the one hundred and fifty years of Turkish rule during the Middle Ages, the Turks developed a magnificent bathing culture. They constructed one bath after another, especially at Buda, tapping and harnessing karst springs with temperatures of about 40° C that well up along the Danube. Some of these spas remain in service today.

In the 1860s a brilliant Hungarian mining engineer, Vilmos Zsigmondy, put down the first deep bore hole on the Pest side of the river. His bore uncovered a confined karst water system and tapped artesian water warmer than 70° C. The discovery marked the beginning of a process of thermal water exploration and exploitation that is still going on.

In the final decades of the last century mining for brown coal began in Transdanubia. This and other mining activities in the region (bauxite, manganese, oil) have from their beginnings experienced hazards from karst groundwater and these difficulties will continue in the future. For safe mining it is necessary to pump enormous quantities of karst water to the surface. For example in 1975 mine waters amounted to more than 40% of total karst water discharge in the region.

Excellent in quality, karst waters are being used for municipal water supply at a gradually increasing rate.

2. Observation systems

Practical karst water projects and relevant scientific research works are based upon data files of the National Karst Water Observation Network. This system was begun as a cadastral register of karst springs (H. Kessler); a project aimed at collecting data for all springs with a water yield greater than 20 litres per minute. A total of 1,600 springs were registered, approximately 700 of them being karstic. Discharge, temperature and electrical resistivity were measured regularly at an average of 200 springs each year. The data set spans 25 years.

Because of losses of water pumped from mines the karst watertable sank over an area of more than 1,000 sq. kilometers. Since the 1950s special observation wells have been developed to register changes in water level. The staff of the Karst Water Research Department of the Research Institute for Water Resources Development ("VITUKI") designed a plan for a system of observation wells to be developed in the Transdanubian Mountain Range, under my direction. These wells vary 50—1,200 metres in depth. Their cost totalled 1.4 million dollars and the project took three years to complete. At present, some 450 observation wells are checked at 4-day intervals to provide water level data.

Specially located meteorological stations have been established to investigate elements of the water budget in the particular karst regions of Hungary. This permits hydrologists to trace and assess atmospheric precipitation in karst areas with an accuracy considerably higher than that offered by the National Meteorological Observation System. In 1955 another special system was developed to measure rate of water dripping in caves.

The karst Water Research Department of VITUKI compiles annual registers of rates of withdrawal from the karst aquifer system and particularly, water production from mines.

3. Karst water reserves of Hungary

Four groups of karst areas can be distinguished in Hungary (Figure 1):

a) Western Highland Range (Transdanubian Mountain Range)
b) Northern Highland Range
c) Southern Karst Region
d) Minor subsurface blocks

The Western and Northern Highland Ranges are thought to be separated underground by a belt of volcanics. The presence or absence of this hypothetical belt has still to be verified.

Water temperatures from wells and streams have been used to plot the thermal distribution of karst waters *(Figure 1)*. In the figure only three temperature ranges have been indicated ($<15°$ C; $15-60°$ C; $>60°$ C). Waters hotter than 60° C are found in three distinct areas, two of which are located in the vicinity of the supposed belt of volcanics. *Table 1* cites percentage output of different categories of karst waters of five thermal ranges. The total mean annual discharge of karst water in Hungary is estimated to be 25 cubic metres per second.

Table 2 indicates karst water reserves by region and tripartite thermal range for an assumed mean stratal thickness of 500 metres and a void volume of 1%. The Table indicates that the proportion of cold and thermal water reserves are approximately equal. The great bulk of reserves are contained within the intermediate temperature range, $15-60°$ C. It is worth mentioning that the available reserves of thermal water ($>60°$ C) will last for more than 1,000 years at the present rate of exploitation even if there is no recharge by infiltration.

Of the total mean annual precipitation falling upon Hungary, 34% enters the karst water regimes.

Table 1

Water temperature °C	Production of wells	Cased springs	Mine waters	Uncased springs	Total output
<15	34	58	100	90	88
15–25	33	6	—	10	7
25–35	10	36	—	—	3
35–60	11	—	—	—	1
>60	12	—	—	—	1
	100%	100%	100%	100%	100%
	6%	8%	41%	45%	100%

Table 2

Karst region	Water temperature °C <15	15–60	>60	Total
Western	24	49	27	100%
Northern	9	72	19	100%
Southern	9	91	—	100%
Blocks	—	100	—	100%
Total Hungary	17	63	20	100%

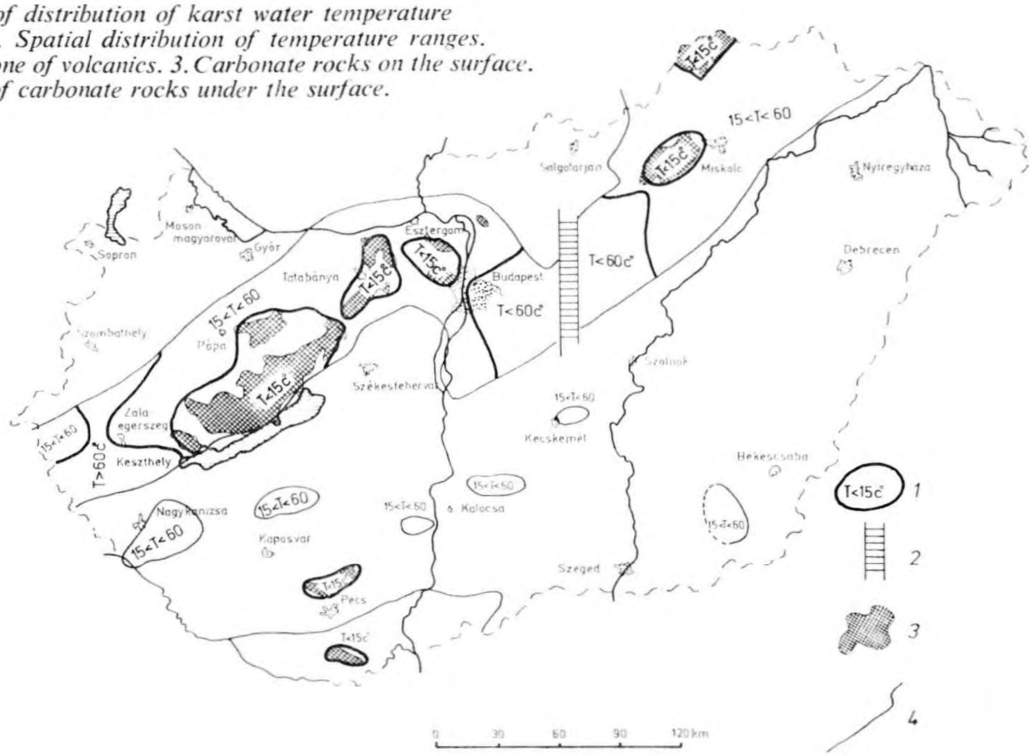
Apart from a few examples of small cased springs of low yield used for local supply, utilization of karst groundwaters for drinking water is centered upon high yield springs and wells plus mine waters of potable grade. These represent the regional water supply systems summarized in *Figure 2*.

In 1975 the proportion of the total meteoric groundwater reserves of Hungary obtained from karst sources had risen to 55%.

4. Scientific research on karst waters

In Hungary there has been intensive study of petrophysical parameters such as porosity and permeability. Observations, e.g. by the author, indicate that the porosity of karst masses depends, up to a given limit, on the size of the rock mass considered. Beyond that limit porosity can be considered to be constant in a statistical sense. Locally, porosity varies between 0.5 and 30%; as a national average, taking into consideration the extensive

Fig. 1. Map of distribution of karst water temperature in Hungary 1. Spatial distribution of temperature ranges. 2. Supposed zone of volcanics. 3. Carbonate rocks on the surface. 4. Boundary of carbonate rocks under the surface.



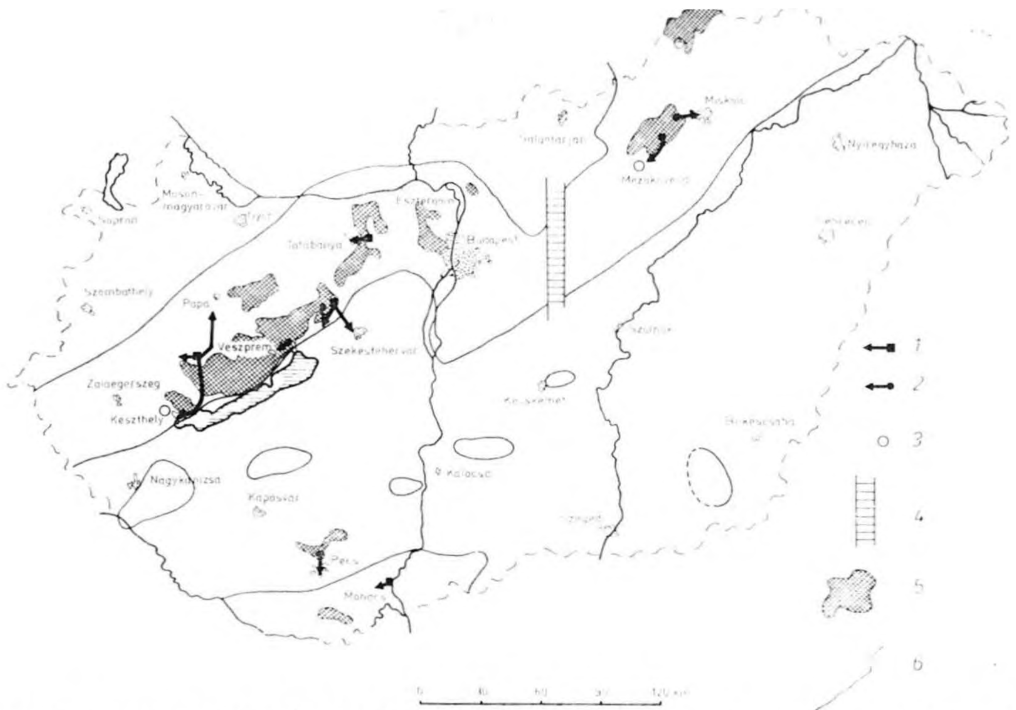


Fig. 2. Map of more important karst waterworks in Hungary. 1. Mine waterworks. 2. Spring waterworks. 3. Springs, yield more than 10×10^6 m³/year. 4. Supposed zone of volcanics. 5. Carbonate rocks on the surface. 6. Boundary of carbonate rocks under the surface.

varied karstic masses, it is close to 0.5%. In the Western Karst Region the hydraulically critical dimension of a water-conducting void ("slot width") *is below one millimeter.*

Both field and model experiments have determined that, taken as average in the larger karst areas, the coefficient of intrinsic permeability of krastic rock varies in the range

$$10^{-6} < k\left(\frac{m}{s}\right) < 10^{-3}$$

Hungarian specialists carried out a major analysis of the karst water budget and regime at an experimental research station at Jósvafő, Northern Hungary. It was established in an area undisturbed by human activity and therefore suited for examination of natural elements of the water budget. The first "karst runoff plot" has been developed at this VITUKI station, to study relationships of surface runoff, infiltration, rainfall, rock temperature etc.

Fig. 3. Map of supposed flow system of karst water. 1. Supposed horizontal flow lines. B/1 Supposed water age between 15,000 and 25,000 years. B/2 Supposed water age between 8,000 and 10,000 years. B/3. Supposed water age between 6,000 and 8,000 years. C Supposed zone of volcanics. D Carbonate rocks on the surface. E Boundary of carbonate rocks under the surface.

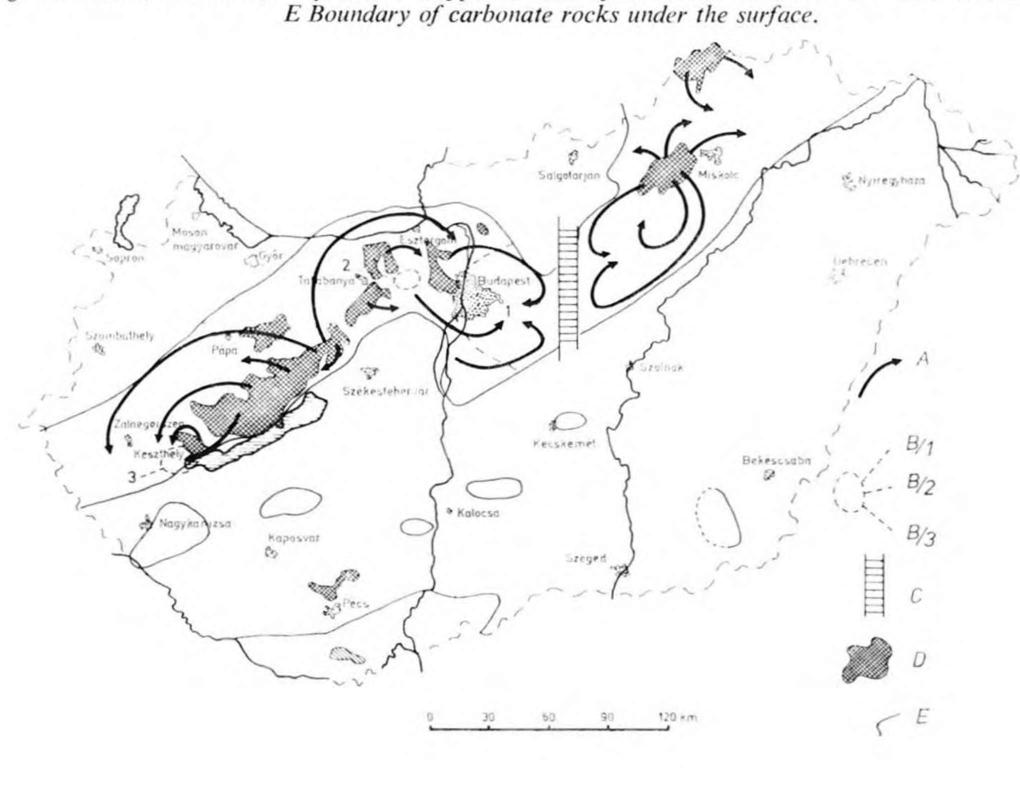


Fig. 4. Map of difference of karst water level. 1. Difference of water level. 2 Impermeable zones.

Study of the spatial flow pattern in a karst system was started in 1974, based on observation well data (Böcker, Lorberer). *Figure 3* shows the deduced pattern of horizontal flow of groundwater in the Western and Northern Highland Ranges. The hypothetical volcanic belt represents a point of inversion of horizontal flow for both systems. The temperature of the karst water and, consequently, its pressure are greatest in the vicinity of this belt.

The best means of study of the flow systems are determinations of ages of waters. Therefore the tritium and 14-C isotopic content of karst water is being regularly examined. 14-C content has been determined for 20 cases to date and the spatial distribution of water ages obtained is indicated in *Figure 3.* Continuation of these investigations is expected to eliminate doubts concerning interpretation of sampling results.

The karst Water Research Department of VITUKI monitors effects of mining upon the karst water regime each year. Between 1970 and 1975 a considerable drop in the karst water level occurred as a consequence of withdrawal of water from mines. This is illustrated in *Figure 4,* plotted from data obtained from the observation wells. *Table 3* shows percentage distribution of karst water output for 1975 in the Western Highland Range, referred to 1970 as statistical base year (100%). Mine water output increased by 18%. As a result, a considerable proportion of cased springs have dried up and their total output diminished by 77%. To compensate for this deficiency new wells were drilled that increased total output of wells by 24%. In the final analysis, aggregate groundwater output changed only in the proportions of its respective constituents because the proportion of output from uncased springs fell only 4% short of yield in 1970; this is within the limits of one standard deviation.

In the years to come we shall continue our researches into the hydrology and hydraulics of karst waters and relevant studies of environmental controls and management. So we hope to attain results in this latter field as well.

Table 3

Water temperature °C	Yield of wells	Cased springs	Mine water	Uncased springs	Total
<15	121	25	118	80	96
15–25	257	—	—	83	102
25–35	58	—	—	—	58
35–60	109	—	—	—	109
>60	80	—	—	—	80
Total	124	23	118	80	96

English translation revised by D.C. Ford.

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SPELEOCLIMATOLOGICAL RESEARCH IN HUNGARY: RESULTS AND SPELEOTHERAPEUTIC APPLICATIONS

SUMMARY

Speleoclimatological research recently undertaken in Hungary has included the following major works: 1. the meteorological modelling of caves, 2. anthropo-bioclimatological research in caves, with special emphasis on their natural health resort function, 3. meteorological observations as a part of biospeleological research, 4. sporadical meteorological observations in caves in the service of other scientific fields (hydrology, geology, etc.) 5. improvement of instruments used in speleoclimatological research.
The concluding part of the paper deals with the application of speleotherapy which has found a wide use in Hungary in the last decade and a half. At present, three cave-sanatoria are in service in Hungary, where patients suffering from asthma bronchiale and cronicus bronchitis are cured.

Extensive speleoclimatological research began in Hungary in the 1920's and 1930's where it was associated with L. Steiner, D. Berényi, E. Dudich and A. Gebhardt. For example, Berényi investigated the thermal regime of Zichy Cave and environs at Rév village and compared the cave to the famous Baradla Cave at Aggtelek (Berényi, 1943).

A different approach was introduced in the same years by biospeleologists who measured many parameters of cave climate as a part of their investigations of the particularities of the cave biotope. They were principally concerned with the effects of cave climate stability or instability upon cave fauna. For example, in 1928—29 Dudich made detailed measurements of temperature, atmospheric moisture, airflow, limit of light penetration and hydrological and soil conditions at Baradla. Inside of the immediate entrance zone he found maximum and minimum temperatures were 4.5° C and 11.5° C, with a mean value of 9.5° C. He considered this variation to be comparatively low and did not find, either in the principal passage or secondary passages of the cave, any places of strikingly different and peculiar thermal characteristics. Consequently, the cave represents an oligothermous and stenothermous biotope, i.e. a biotope favourable for psychrothermous fauna (Dudich, 1932). Dudich also determined that relative humidity of the Baradla was high and displayed little fluctuation, making the cave a biotope suitable for polyhygrous animals. He established the limits of daylight penetration at 60 metres from entrance No. 1, at 95—100 metres from entrance No. 2, and at 70 metres from entrance No. 3.

Cave ecology and the behaviour of cave organisms were also investigated by A. Gebhardt at Abaliget Cave (Gebhardt, 1934). In a valuable study, he describes 287 species and groups of animals collected by himself and collaborators between 1900 and 1930. In addition to systematic description of these fauna, the paper reports on the particular living conditions prevailing in the cave, so furnishing a good deal of valuable information on its climate; for example, from year-round observations he established a mean annual temperature of 12.6° C, a minimum of 10° C and a maximum of 13.6° C. He also evaluated absolute and relative humidity conditions and the nature of air circulation in the cave.

Since the 1950's researchers have made many new contributions to the national and international literature on cave climate. The increased activities of recent years may be ascribed to two factors:
1. the development of many new meteorological instruments with the consequent increase in the range of topics that may be investigated,
2. new concepts for the practical utilisation of caves.

Considering the first factor, a common problem in speleoclimate research is that the daily and annual variability of external climatic parameters is considerably higher than that of corresponding parameters underground. There is a need for instruments of high resolution, including electronic recorders. However, if such instruments are introduced without an increase in the accuracy of specific measurements, the reliability of the results is decreased due to superimposed secondary phenomena. With new developments in instrumentation, speleoclimatic research will embrace continuous recording of air temperature, humidity, airflow, atmospheric pressure, atmospheric pollution, ionisation, radioactivity and measurement of airborne bacteria content etc., etc.

The second factor is a consequence of the accidental discovery in the post-war years by physicians and other specialists working at Klutert Cave in the Federal Republic of Germany, that cave atmospheres have special and helpful physiological effects upon human respiratory organs. This discovery has underlined the need for very detailed instrumental measurements based upon the new generation of instruments.

A new approach to climatological research in natural and artifical underground voids has been proposed by B. Béll. He was the first to discuss an energy-based approach to the subject. In a paper discussing air circulation in mines he develops a set of theoretical statements which also apply to caves but he indicates as well the differences that stem from the artificial energy sources operating in the mining situation (Béll, 1945).

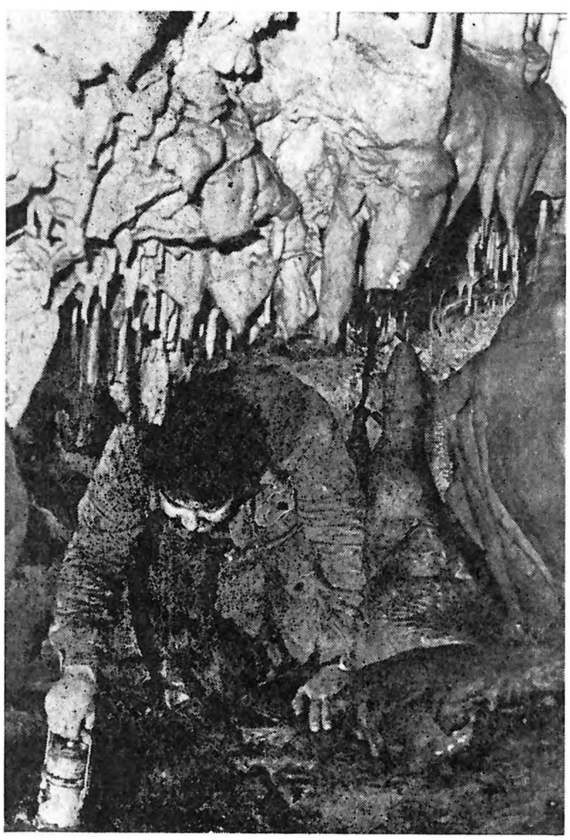
Our comprehension of air circulation conditions in caves has been expanded by L. Jakucs (1953) and Jakucs and L. Markó (1956) who explain physical circumstances responsible for the generation of air currents, tracing the pressure differences that provoke air currents back to differences of air temperature in most instances. D. Balázs, from his own work and that of earlier researchers attributed the generation of air currents in caves to differences between external and internal air density (Balázs, 1969).

D. Berényi and J. Justyák (1960) examined the climate close to the entrance of Baradla Cave in detail. They are the first to show that in addition to horizontal temperature gradings, vertical temperature gradients also occur in the cave. They make an interesting comparison with the climate of a wine cellar. "The temperature differences as a rule are smaller than the values measured in the entrances of wine cellars. Whereas in cellar entrances differences in temperature over the ten to two hundred centimetre extent of the entrance are higher than 1° C, at grottoes with actively growing stalactites or stalagmites in the caves, this figure is 0.5° C or less" (Berényi—Justyák, 1960).

L. Kordos has examined many aspects of cave climate especially at and near to cave entrances and particular attention is drawn to his detailed work (Kordos, 1970, 1975).

Valuable data on the meteorological conditions of the caves of Aggtelek have been published by M. Csomor and L. Zalavári (1964). They used mainly self-recording instruments in Baradla Cave and Béke Cave. Although, "the self-recording instruments are not completely suitable for speleoclimate measurements because their measuring range is too large compared to the actual range" (Csomor—Zalavári, 1964), nevertheless, it seems expedient to use them in both entrance and interior parts of caves, although S. Holly (1956) has rejected this. If manual instruments of high resolution are operated for short periods together with long-period, self-recording instruments the latter may be precisely calibrated. Csomor and Zalavári summed up results of air pressure measurements "the variation of the air pressure is steady and uniform, irrespective of the irruption or transits of single fronts. The curves cover one another; in other words, there is no essential difference in time or in scale of change" (Csomor—Zalavári, 1964).

Climatic conditions in caves in the Bükk Mountains were investigated by Gy. Szabó and L. Lénárt (Lénárt, 1975). Detailed examination of the climate of vertical shafts in Hungary was started by A. Walkovszky (1970) who analysed variations of vertical temperature and moisture gradients in Vecsembükk Shaft.



Characteristic narrow passage in the Szabadság Cave, Égerszög (by T. Seregélyes)

L. Kordos (1975) has discussed the broad problems of environmental equilibrium, including cave climate, as a part of the question of cave protection. I. Fodor examines effects of tourists and tourism on cave microclimate. He has sought to measure the amount of the anthropogenic impact—in physical, chemical and biological terms—that the atmosphere of a cave can endure without any lasting damage; in other words to discover the physical conditions under which or by which the natural state of a cave's climate is restored or regenerated. By developing a bioclimatological classification of caves he has produced a man-centered classification scheme. This is based upon the impacts, positive or negative, that a man would have in a cave. His system is expressed by the Bradtke index which uses temperature, moisture and air circulation (Fodor, 1975).

Use of caves for speleotherapeutic purposes has already been mentioned. Following the example at Klutert Cave, medical experiments in Hungary were first undertaken in Béke Cave at Aggtelek upon the initiative of L. Jakucs (1953, 1959). Since 1969 a sanatorium has been functioning at Jósvafő above the cave. At Abaliget the first medical observations were started in 1959 and experiments have continued since that time, with physicians taking part. Regular speleoclimatological-therapeutic experiments are pursued in a portion of Tapolca cave system underlying a hospital. Similar experiments have been carried out at Tavas Cave.

First results of the Béke Cave experiments were published by L. Jakucs (1959). On the basis of the statistically significant favourable results obtained from treatment of the first 100 patients, experiments have been continued and expanded in scope. A new entrance is being opened into the cave in order to permit easier access for patients. With its Jósvafő entrance opened the Béke Cave will provide lots of possibilities for speleotherapy. A comprehensive description of the cave sanatorium is given by B. Kerényi, Zs. Bíró and M. Kirchknopf (1960).

Medical tests in Béke Cave were continued by P. Kraszkó, T. Szoboszlay and J. Jónás who conclude that cures in the cave are "Useful in the case of chronic obstructive bronchitis and chronic bronchial asthma unless a status asthmaticus, purulens superinfectio, cardialis decompensatio or other organic lung diseases are present in the period concerned" (Kraszkó, Szoboszlay, Jónás, 1972).

The climate of Abaliget Cave and its curing effect have been studied by A. Urbán (1970), L. Szabó (1963), J. Páter, E. Pintér, I. Somogyi, E. Tóth and Mrs. K. Tímár (1974) and I. Fodor (1969, 1970–71, 1970a, b, 1971, 1973, 1975). Speleotherapeutic results are summarised by Gy. Kövesi, J. Háber and M. Poniczky (1974). Patients attending Abaliget Cave spend two hours underground each day during a period of cure of one month.

Valuable scientific information on the bioclimatological conditions of Tavas Cave, Tapolca, has been published by H. Kessler, J. Mórik, Z. Morlin and

A group of patients in the Abaliget Cave

T. Várkonyi (1973). These authors examined the purity of the air, its temperature, moisture and circulation conditions and the aerosol condition of the vapour condensate. Speleotherapeutical tests began in 1969. Patients spend three week terms in the hospital above the cave, including a daily four hours inside the cave. A total of 536 persons suffering from respiratory illnesses have so far been treated at Tapolca. The two entrances of the Béke Cave have been declared to be "medicinal caves" by official decree of the Ministry of Health and the Tavas Cave at Tapolca is now being considered for this designation.

English translation revised by D.C. Ford.

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Cave divers in the lower passage of Baradla Cave (by L. Kunkovács)

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A REVIEW OF THE FAUNA OF HUNGARIAN CAVES

SUMMARY

Because of their geographical situation, the Hungarian caves are not too favourable for the development of a rich cave fauna. Nevertheless, speleobiological research, carried on for quite a long time now in this country, has shown the presence of troglobiont and troglophile animals, mainly primitive, in considerable numbers. As a result of detailed speleobiological studies, a total of 435 animal species are at present known from the Baradla Cave. Beside the Baradla, a careful processing of the fauna was carried out in the Abaliget, Mánfa and Meteor Caves as well. Apart from describing the fauna of the above caves, the author reviews the fauna of the major Hungarian caves, from the protozoans up to the mammals, picking out the more interesting indigenous and troglobiont species.

Biospeleological research has a long tradition in Hungary although the intensity of work has varied, with emphasis placed on different aspects. The main orientation has been toward faunistic description with derivative ecological work. In the 1920's and 1930's E. Dudich, with the support of A. Gebhard and E. Bokor made detailed studies of the biology and ecology of the Baradla, Abaliget and Mánfa Caves.

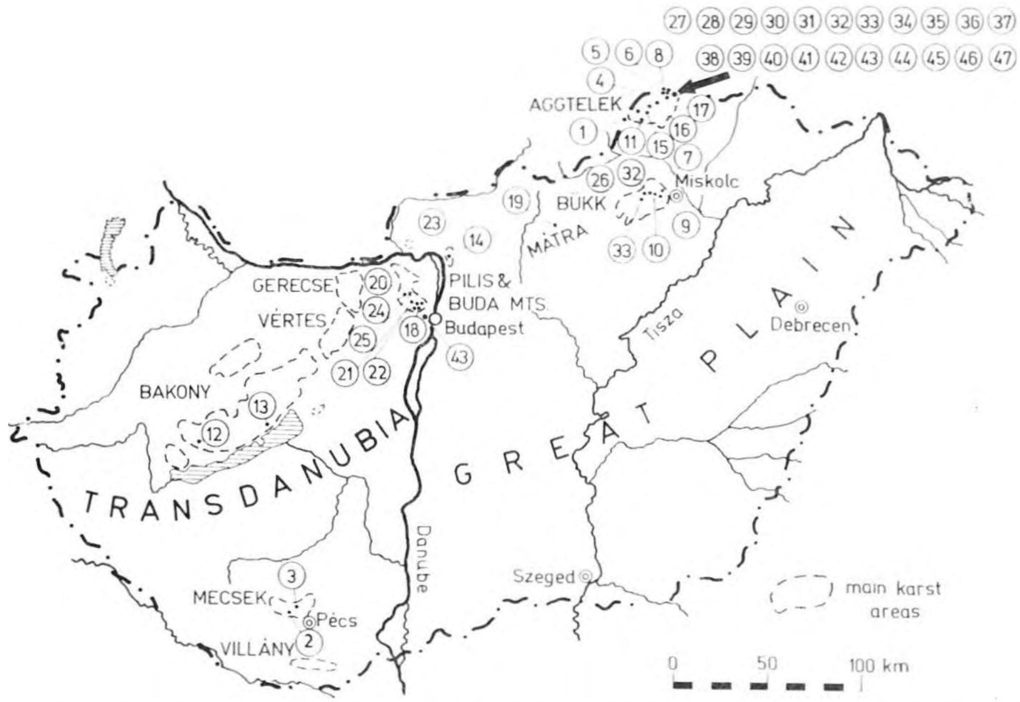
Since that time, new animal species have been found in these caves while the fauna of other caves has been examined. In 1958, again on the initiative of E. Dudich, a Speleobiological Laboratory was set up in the Baradla Cave and a number of specialists embarked on a large-scale sampling program in many caves. This program was aimed mainly at investigating cave-dwelling Protozoa, Nematoda and Collembola with a leading role in the work being taken by I. Loksa. This wide ranging work has greatly advanced understanding of cave-dwelling organisms. Whereas in 1932 Dudich was able to list "still only" 262 animal species, we are now able to list as many as 435.

Bajomi has devoted particular attention to the Meteor Cave, discovered in 1961, which has yielded 90 animal species already in work which is by no means complete (Bajomi, 1969). At present the emphasis is placed on the thematico-ecological processing of the material collected earlier rather than in further sampling. The present paper reviews, without any claim to completeness, the fauna of particular interest in Hungarian caves.

Protozoa. Although the Protozoans are the richest group in the number of animal species found in the caves, their investigation has not been pursued until the last decade. D. Dudich (1932) listed 22 species from the Baradla Cave while Gebhardt (1934) mentioned only 3 species from the Abaliget Cave; a fact probably resulting from the isolation of the water regime of this cave from the surface. More recent work by Varga, Takács and Cs. Bereczky has revealed 123 *protozoan species* in the Baradla Cave. Of these 34 belong to the Flagellata and 17 to the Amoebina, one of these being a new species, *Amoeba cavicola* VARGA (Varga, 1963). One of the 51 Testaceans identified in the cave is new also, *Difflugia baradlana* VARGA (Varga, 1963), while two new varieties were discovered, *Difflugia oblonga* var. *curvicollis* VARGA and *Pontigulasia bigibbosa* var. *minor* VARGA (Varga, 1963). Beside these, 3 Heliozoan and 48 Ciliata species occur in the Baradla Cave. The majority of the Protozoans identified are euryoecs, i.e. eurytopic forms of wide geographic distribution (Loksa, 1975).

Platyhelminthes. The Turbellaria are the most numerous of the Platyhelminthes in streams in underground caves. The presence may be noted of *Polycelis felina* DAL. in the Abaliget Cave and of *P. tóthi* MÉH. and *Dendrocoelides pannonicus* MÉH. in the waters of the Mánfa Cave (Gebhardt, 1937). It is worth mentioning that several of these Trematodes are parasites of the bats living in the caves (Dudich, 1962).

Nematoidea. Andrássy identified 23 species found in the Baradla Cave. Four of these are new to science: *Alaimus meyli* ANDRÁSSY (Andrássy, 1961), *Cylindrolaimus baradlanus* ANDRÁSSY, *Dorylaimus bokori* ANDRÁSSY (Andrássy, 1959b) and *Myolaimus amititae* ANDRÁSSY (Andrássy,



Geographical location of caves biologically studied. I. Caves studied in detail: 1 Baradla, 2 Abaliget, 3 Mánfa, 4 Meteor; II. Caves studied partially: 5 Őz Shaft, 6 Kifli Shaft, 7 Szeleta, 8 Hideglik Shaft, 9 Forrás Calktufa Cave, 10 István, 11 Szabadság, 12 Tapolca's Tavas, 13 Lóczy, 14 Násznép; III. Caves under elaboration: 15 Béke, 16 Kossuth, 17 Magas-hegy, 18 Ferenc-hegy, 19 Ágasvár, 20 Pál-völgy, 21 Szemlő-hegy, 22 Mátyás-hegy, 23 Bátori, 24 Solymári-ördöglyuk, 25 Remete, 26 Kőlyuk, 27 Soltészlik Shaft, 28 Jég No. 1 Shaft, 29 Jég No. 2 Shaft, 30 Favágó Shaft, 31 Útmenti Shaft, 32 Felső-forrástöbör Cave, 33 Csókás-forrás, 34 Banán Shaft, 35 Iskola Shaft, 36 Fenyves Shaft, 37 Töltényes Shaft, 38 Pötty Shaft, 39 Róka Shaft, 40 Cickány Shaft, 41 Gőte Shaft, 42 Körte Shaft, 43 Vár Cave, 44 Kilátó Shaft, 45 Ürgelik Shaft, 46 Éves Shaft, 47 Magasles Shaft.

1959a). The same author also described *Nothotylenchus antricolus* ANDRÁSSY from the Kőlyuk Cave at Mánfa village. Bajomi collected 15 Nematode species in the Meteor Cave, of which the troglobiont, *Mylonchulus cavensis* SCHNEIDER deserves special mention (Bajomi, 1969). The other species are, for the most part, euryoecs also found in similar biotopes on the subaerial surface.

Rotifera. Varga identified four Rotifers from the Baradla Cave; two being new species, the Bdelloid *Habrotrocha baradlana* VARGA (Varga, 1963) and *Proales baradlana* VARGA (Varga, 1959) from the Ploima group.

Annelida. The aquatic and terrestrial Oligochates and Hirudinoidea found in the Hungarian caves are mostly of no particular interest. For instance widely distributed forms such as *Tubifex tubifex* MÜLL. and the earthworm *Octalasium lacteum* ÖRLEY are common in the Baradla, Abaliget, Mánfa and Meteor Caves (Dudich, 1932; Gebhardt, 1934, 1937; Bajomi, 1969). *Troglochaetus breanecki* DEL., a primitive ancient annelid, lives in the groundwater of the Béke Cave (Andrássy, 1956). A more striking recent discovery has been the new species of earthworm *Allolobophora mozsariorum* ZICSI (Zicsi, 1974) from the Baradla-Alsó Cave. This whitish coloured worm lives with its anterior end burrowed into the silt.

The Enchytraeids of the Baradla and Meteor Caves have become familiar through work by Dózsa-Farkas. This worker determined 3 species from the Meteor Cave and 17 from the Baradla Cave. Four from the latter source are new species; *Cernosvitoviella aggtelekiensis* DÓZSA-FARKAS, *Enchytronia christenseni* DÓZSA-FARKAS (Dózsa-Farkas, 1970), *Fridericia reducta* DÓZSA-FARKAS (Dózsa-Farkas, 1974) and *F. semisetosa* DÓZSA-FARKAS (Dózsa-Farkas, 1970). Further two species are new to the Hungarian fauna.

Crustacea. The peculiar Ostracod *Candona dudichi* KLIE was found in the Baradla Cave. Several Copepods have been described from there and the Abaliget Cave (Dudich, 1932, Gebhardt, 1934). *Ceuthonectes hungaricus* PONYI and *Elaphoidella pseudojeanneli aggtelekiensis* PONYI (Ponyi, 1958), both from the Baradla Cave, *E. pseudojeanneli* PONYI from the Béke Cave and *E. bajomii* PONYI and *E. meteori* PONYI from the Meteor cave are all newly described species (Bajomi, 1969).

The blind Anaspidaceans in cave waters are relics of an ancient fauna. Hungarian representatives of the group are *Bathynella hungarica* PONYI from the Béke Cave, *B. h. baradlana* PONYI (Ponyi, 1957) from the cave giving it the subspecific name and *B. chappuisi* DEL. from the Abaliget Cave.

Several troxoglenic terrestrial oniscoids have been found at the mouths of caves. Within the Baradla and Béke Caves and the Szabadság Cave at Égerszög the white blind *Mesoniscus graniger* FRIV. has been found (Dudich, 1932). The Aselloids are represented by *Stenasellus hungaricus* MÉH (Gebhardt, 1934) in the waters of the Abaliget Cave with a subspecies *robustus* in the Mánfa Cave (Gebhardt, 1937).

The Amphipod *Niphargus aggtelekiensis* DUDICH is common in the Baradla and Béke Caves. In the Abaliget Cave *Niphargus leopoliensis molnari* MÉH. occurs in the underground stream while *N. foreli gebhardti* SCHELL is restricted to stalactitic basins (Dudich, 1932). *N. l. molnari* MÉH is found in the Mánfa Cave (Gebhardt, 1937) and *N. tatrensis* VRZ. in the Meteor Cave (Bajomi, 1969). All these species are white blind animal and the evolution of separate species within these separate Hungarian caves is worth noting.

Few Diplopod species are found. *Allotyphloiulus polypodus* LOKSA is found in the Forrás Cave at Lillafüred (Loksa, 1962) while the troglophilic *Orobainosoma flavescens* LATZ and *Archiboreoiulus pallidus* BRADE-BIRKS live in the Násznép Cave of the Naszályhegy (Loksa, 1970). *Brachydesmus troglobius* DADAY, first described in 1889 (Gebhardt, 1934), occurs in great numbers in the Abaliget Cave. Much rarer there are *Hungarosoma bokori* VERH. and *Orobainosoma hungaricum* VERH.

Chilopoda. Most of the Chilopods in Hungarian caves are trogloxenic. The exception to this is *Lithobius stygius infernus* LOKSA found in the Bátori Cave in the Buda area as well as the Mátyás-hegy, Pál-völgy, Szemlő-hegy, Ferenc-hegy and Remete Caves in the same region (Loksa, 1948).

Out of the representatives of **Diplura,** the species *Plusiocampa spelaea* STACH occuring in the Baradla and Szabadság Caves deserves to be mentioned (Loksa, 1961). *P. breviantennata* LOKSA lives in the Tavas Cave and the Lóczy Cave at Tapolca. In addition to it, there are two troglophilic species: *Eutrichocampa paurociliata* LOKSA in the Lóczy Cave and *Campodea augens* SILV. in the Tavas Cave (Loksa, 1960). The niche of Mánfa is inhabited by *C. grassii* SILV. and *C. staphylinus* WESTW. (Gebhardt, 1937).

Collembola. Numerous representatives of Collembola live in the caves concerned, e.g. 18 in the Baradla, 12 in the István Cave, 10 in the Abaliget Cave and 9 in the Meteor Cave. Their overwhelming majority are troglophilic elements. In the present review only the endemic and troglobiont species are listed: *Neanura dudichi* LOKSA and *Onychiurus kadiči* LOKSA occurring in the Őz Shaft (Loksa, 1967, Bajomi, 1968). *O. schoenviszkyi* LOKSA in the Kifli Shaft and the Meteor Cave (Loksa, 1967; Bajomi, 1969) and *O. microchaetosus* LOKSA in the Násznép Cave (Loksa, 1959). The Őz Shaft of the Alsó-hegy is inhabited by *Arrhopalites hungaricus* LOKSA, the Kifli and Hideglik Shafts are by *A. furcatus hungaricus* LOKSA (Bajomi, 1968). In the Meteor Cave lying close to the afore-mentioned karst shafts there is *A. hungaricus intermedius* LOKSA (Bajomi, 1969; Loksa, 1969). The species *A. bifidus* STACH can be found in the István, Forrás and Szabadság Caves (Loksa, 1961, 1962). The Baradla Cave accomodates, among other forms, the species *Arrhopalites aggtelekiensis* STACH. *Hypogastrura cavicola* BÖRN. occurs in the Forrás and Meteor Caves, *Folsomia antricola* LOKSA in the Meteor and Szabadság Caves (Loksa, 1959), *Pseudosinella argentea* LOKSA in the Lóczy Cave (Loksa, 1960), whereas *P. aggtelekiensis* STACH is an inhabitant of the Baradla and Szabadság Caves (Loksa, 1961). In addition, the occurrence of *Oncopodura égerszögensis* LOKSA in the Szabadság Cave deserves attention to be paid to (Loksa, 1961).

Lepidoptera. Typical representatives of hemitroglophile butterflies in the Hungarian caves are *Scoliopteryx libatrix L.* and *Triphosa dubitata L.* (Dudich, 1932; Gebhardt, 1934, 1937; Bajomi, 1969).

Coleoptera. The coleopteric fauna of the Hungarian caves is very poor, just a few blind carabuses are known. In the Baradla Cave there is *Duvalites hungaricus* CSIKI (Dudich, 1932), in the István and Kecske Caves *D. gebhardti* BOKOR (Loksa, 1962), in the Meteor Cave *D. hungaricus silicensis* CSIKI (Bajomi, 1969). In the Szabadság Cave *Atheta spelaea* ER. occurs (Loksa, 1961).

Diptera. Dudich listed 42 species from the Baradla Cave, Gebhardt 37 species from the Abaliget Cave and 29 species from the Mánfa Cave. Most of them, however, are trogloxenic or troglophile elements. The commonest families of flies in the Hungarian caves are: *Sciaridae, Phoridae, Helomysidae* and *Sphaeroceridae.* The following forms may be considered troglobiont species: *Lycoria (Sciara) ofencaulis* LDF. and *L. baradlana* KNÉZY in the Baradla Cave and *Pseudostenophora antricola* SCHM. in the Abaliget Cave (Gebhardt, 1934).

Arachnoidea. There are several orders representing Arachnoidea in the Hungarian caves. A typical representative of the Hungarian troglobiont fauna is the species *Eukoenenia austriaca vagvoelgyii* SZALAY living in the Baradla, Szabadság and Meteor Caves (Szalay, 1956; Dózsa-Farkas, Loksa, 1970).

Niphargus aggtelekiensis DUDICH (Photographed by the author)

Of the representatives of **Phalangiidea**, the species *Crosbycus bükkensis* LOKSA (Loksa, 1962) occurring in the Forrás Cave of the Bükk Mountains is troglobiont, while *Nemastoma chrysomelas* HERM., a species common in the Baradla, is troglophile (Dudich, 1932). **Spiders (Araneidea)** are represented in the Baradla by two troglobiont species: *Porrhomma errans* BL. and *P. rosenhaurei* L. KOCH. (Dudich, 1932). The second species is present in the Meteor and Mánfa Caves as well. The subspecies *P. rosenhaueri hungaricum* LOKSA is endemic in the Kőlyuk Cave. The subspecies *Lepthyhantes pisai bükkensis* LOKSA was described from the same cave (Loksa, 1970).

Troglobiont representatives of **Acaridea** occurring in a relatively great number in the caves are the following: *Eugamasus magnus var. cavernicola* TRÄG. in the Baradla (Dudich, 1932), *Myianoetus dyonychus* OUDEMANS in the Meteor Cave, *Oribella cavatica* KUNST in the Őz and Kifli Shafts of the Alsó-hegy as well as *Schviebea cavernicola* VITZTHUM which also occurs in the Őz Shaft. Hydrophile acaruses are represented by *Soldanellonyx chappuisi* WALT. in the Abaliget Cave and the Szabadság Cave of Égerszög (Dudich, 1962).

Molluscs. Troglophile forms are represented by the species *Pisidium casertanum* POLI occurring in the Baradla, Abaliget and Mánfa Caves (Dudich, 1932; Gebhardt, 1934, 1937). The species *Paladilhiopsis (Lartetia) hungarica* SOÓS living in the Abaliget Cave and *P. gebhardti* H. WAGN. in the Mánfa Cave are blind, troglobiont, water-dwelling gastropods (Gebhardt, 1934, 1937). *Daudebardia hungarica* L. SOÓS, a half-shelled gastropod, is troglobiont and indigenous to the Baradla (Dudich, 1932). The gastropod *Oxychilus glaber* FER. occurs frequently in the entrance parts of the Hungarian caves.

Fish (Pisces). Interesting is the occurrence of *Phoxinus phoxinus* L. in the Tavas Cave of Veszprémtapolca, where a peculiar cave-dwelling form of this species, differing in size, colour and physiological characteristics from its subaerial counterparts, has developed (Dudich, 1962).

Mammals (Mammalia). Hosts of bats occur in the Hungarian caves, among which *Myotis oxygnathus* MONTIC (Gebhardt, 1934, 1937; Bajomi, 1968), *Myotis myotis* (Dudich, 1934), *M. bechsteini* LEISL (Bajomi, 1968), *Rhinolophus hipposideros* BECHST. (Dudich, 1934; Bajomi, 1968) and *Miniopterus schreibersi* NATT. (Dudich, 1934) are the most frequent forms.

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Dr. Lajos HAJDU

THE FLORA OF HUNGARIAN CAVES

SUMMARY

The vegetation of caves can be subdivided into three major ecological groups: plants living in the entrances of caves, plants around lamps and plants in the darkness. The harsh cave habitats are populated primarily by the representatives of Cryptogamae of extremely low ecological requirement. No specifically cave-dwelling troglobiont plant is known to occur. The plant community of a cave is of characteristically low diversity. People must seek to maintain this state. Apart from being an interesting scientific problem, studies of cave florae are very important from the practical viewpoint, as they provide the scientific background and a permanent control of protection against the proliferation of plants. At present, it would be too late and such a waste of time, to embark upon new and new experiments. Therefore all possible means must urgently be involved in the struggle against an invasion by plants, as Hungary's most beautiful caves, first of all the Baradla, are theratened to being exposed to damages beyond recovery. The most natural means of protection would be to reduce, in a most radical way, the duration and intensity of lighting.

The vegetation of the caves under consideration can be subdivided into three major ecological groups: flora of cave entrances (entrance flora), flora around lamps (lamp flora) and flora in the darkness (darkness flora).

Over the present-day area of Hungary there are very few caves with broad entrances receiving plenty of light and, at the same time, containing sufficient moisture for the growth of a considerable community of plants. The vegetation of cave entrances in Hungary was studied mainly in vertical karstic shafts. The relevant bryological data may be found in a book by Boros (1968) and the higher plants were also reviewed in 1971 (Boros). The material sampled has been deposited in the herbarium of the botanical collection of the Museum of Natural Sciences, Budapest.

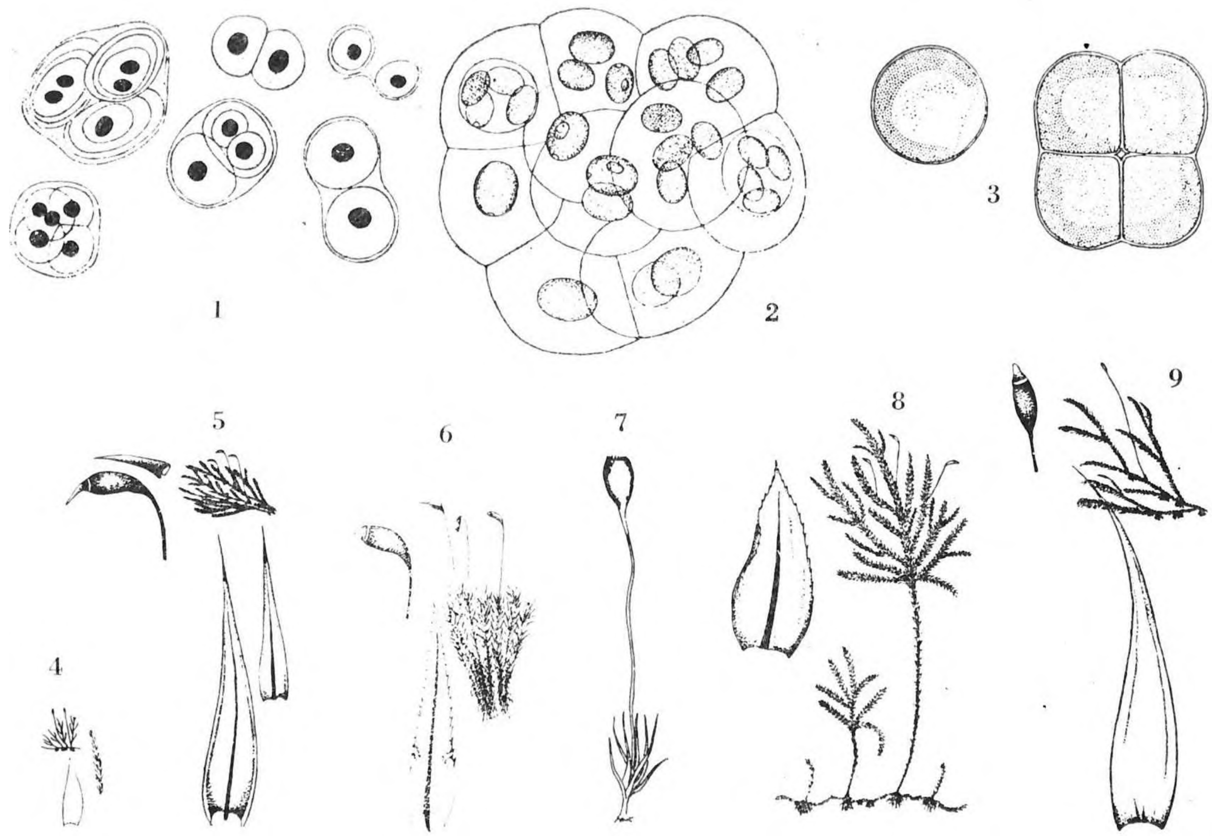
Lamp flora was absent from Hungarian caves for a long time because the lamps used were of very low candle-power and were on for a rather short time. This was because of the small number of visitors and the short duration of their respective visits. Electric light is installed in the following caves:

Aggtelek: Baradla Cave, Béke Cave, Vass Imre Cave
Lillafüred: István and Mésztufa Caves
Miskolctapolca: Cave bath, Hospital Cave
Budapest: Castle Cave (electric lighting temporarily out of service)
Pál-völgyi and Bátori Caves (the second is low power)
Balatonfüred: Lóczy Cave
Abaliget: Abaliget Cave
Tapolca: Tavas Cave

Electric lighting will soon be installed in the Szemlő-hegy Cave of Budapest.

It was in the early sixties that a considerable quantity of lamp flora appeared in the two caves of Lillafüred and in the Abaliget Cave (Verseghy, 1964; Vöröss, 1969, 1971). In the early seventies an algal growth began to develop around lamps in the Baradla and Pál-völgy Caves. The nature of the phenomenon is well-known and unless some efficient preventative measures are instituted an explosive growth of algae and mosses is expected in both places.

As far as darkness flora is concerned, it is understood as a term embracing all plants that can be grown in sterile-handled samples from caves, when the samples are exposed to light. As a consequence of the absence of lamp flora in the late fifties, algologists concentrated their efforts on investigating the darkness flora. For a review of their results the reader is referred to Hajdu (1971). Experiments proved that hosts of algal species are able to proliferate in total darkness by conducting a heterotrophic way of life and they can „scrape along" even "on the boundary of life and death", i.e. under very unfavourable conditions and even in the absence of organic substances. The practical importance, if any, of such darkness flora studies may be in providing information on the vegetation that can be expected to appear in places which



Plants common in cave entrances and in lamp-flora: 1—3 algae, 4—9 mosses. 1. Gloeocapsa montana; 2. Gloeocystis rupestris; 3. Pleurococcus vulgaris; 4. Amblystegium jungermannioides (= A. Sprucei); 5. Rhynchostegiella algiriana; 6. Timmia bavarica; 7. Seligeria pusilla; 8. Arbuscula alopecura; 9. Orthothecium intricatum.

have been exposed to electric light. The darkness flora of the Baradla Cave, for instance, is well-known, yet there is little similarity with the lamp flora now developing. Thus the predictive power of darkness flora studies does not seem to be significant.

Cave vegetation shows a rather homogeneous distribution in terms of botanical systematics, a fact easily understood by considering the special circumstances involved. Higher, flowering plants *(Spermatophyta)*, if any, are found only rarely in caves, and even if present, they are restricted to etiolated seedlings. Some fern species, however, are already common inhabitants of entrance and lamp flora communities enjoying the lasting presence of favourable environmental conditions.

Mosses *(Bryophyta)* form the bulk of the plant biomass in the caves under consideration. Mosses, when growing in caves, produce sporogonia only in quite exceptional cases. However very often even the moss-plant itself does not develop, the cave wall being covered by a network of rhyzoids and protonemal filaments. Pioneers in cave biocoenoses are, as in other harsh environments, the eukryotic and prokaryotic algae. Mainly green algae *(Chlorophyta)*, diatoms *(Chrysophyta, Bacillariophyceae)* and blue-green algae *(Myxophyta* or *Cyanophyta)* can be observed. The primary restricting factor here is light, but, in some cases, water may also greatly restrict plant growth.

Progressing from the harsh habitat towards the more favourable one, one can observe the following zoning: blue algae—green algae and diatoms—mosses—ferns. Wherever new habitats are brought about in a cave, roughly the same succession will be found. The ecological advantage of the algae is in the R-strategy, i.e. their fast reproduction allows them, at short notice, to outpace their rivals. In the long run, however, the plants of larger body will outgrow them so that mosses will finally suppress the algae. Occasionally, lichens *(Lichenophyta)* may also occur in caves. Beside the blue-green algae already mentioned, there are bacteria *(Schizophyta* or *Bacteriophyta)* which belong to the group of simple, procaryotic organisms. The bacterial flora of caves has so far been poorly studied, the species living there being heterotrophic organisms, decomposers of detritus of surface origin. No mention has yet been made of the other heterotrophic group of living organisms: the fungi *(Mycophyta)* which are rarely capable of reaching the stage of forming fruit bodies.

Botanical research in caves seldom produces surprises, as those plants found in a cave habitat may also be found in rock fissures, shady depressions, etc. The majority of the algae are ubiquitous, though there exist species of special ecological requirement, but these may occur in similar biotopes in any part of the world, since they are rapidly spread by the winds. There is no question of a special isolation of algal biotope, hence the absence of troglobiontic algae. Algal species first described from caves, as a rule, are some time later identified in surface biotope as well. Although, as already mentioned, no surprising curiosity can be reckoned with, it is nonetheless important to investigate the flora of caves, because any forecast as to potential changes to be expected in caves is impossible, unless the existing flora is well-known. The invasion of plants into caves is similar to the eutrophism of surface waters, but here the primary limiting factor has been light rather than the special kind of nutrient involved.

The practical importance of research concerning cave-dwelling plants is in the protection of caves. The plant community of cave entrances and vertical karstic shafts is a constituent of the natural environment; however, this does not apply to lamp flora. The plants finding their habitat around lamps are alien to the cave and with their massive proliferation, they may spoil the cave during a single human lifespan. It is mainly those caves with unique formations such as the Baradla and Szemlő-hegy Caves that we should be anxious about. It is always the rarest stalactites or stalagmites that are illuminated for visitors, and therefore it is these that are most exposed to the danger of being spoiled by the plants sprouting around them.

There are opinions approving of the existence of these lamp flora communities (which may well be supported from financial considerations), saying that a lamp flora makes the assemblage of detritophagous faunae more diversified. Furthermore, it is argued that these plants offer a picture of scenic beauty to visitors, etc. The purpose of environmental control should always be to preserve nature in its original state undisturbed by man's intervention, or to restore this original state, if already disturbed. Consequently, it must not be allowed to increase the nutrient resources for an animal biocoenosis feeding on a cave-offered diet, because this would necessarily lead to a change in the structure of the biocoenosium. An essential feature of cave-dwelling communities is low diversity, i.e. few species with disproportionately distributed individuals, which may be ascribed to an extremely harsh biotope, poor in energy. Human intervention will provide possibilities for new species to find a habitat to live in on all trophic levels; a factor enhancing diversity. As opposed to the usual efforts of environmental control, in the caves the existing rough living conditions with low diversity of living organisms, have to be preserved as this is the natural pattern of this type of environment.

Opening caves to tourists is intended to show the general public these beautiful creations of nature. Lamp flora, however, are nothing else than artificial products which might be reproduced in any cellar and which have nothing of particular worth. They provide, however, a really instructive example of a particular feature inherent in the flora: its being able to expand, to take possesion of a new habitat as soon as the conditions for living become more favourable. In this connection, some interesting changes e.g. etiolation, periodical growth, abnormal tissue, etc., have been seen to occur. These, however, can by no means be so interesting that irreplaceable speleological features might be exposed to the danger or being lost for ever on account of them. What tourists visiting a cave would like to see are undoubtedly stalactites or stalagmites rather than plants growing around lamps.

The most natural means of protection would be to reduce electric light in the caves (Hajdu, 1975; Hazslinszky, 1973, 1975). To achieve this, the following two basic principles should be respected:

1. a precious stalactite or stalagmite must not be exposed to continuous electric light, the switches should be replaced by pressure-operated buttons;

2. lamps of the background lighting system should be mounted in places devoid of any scenic value, e.g. concrete footpaths, areas with no formations, etc.

Any other means of protection would be much more expensive and have unwanted secondary effects. The efficiency of protective measures, in the last analysis, will be reflected by the qualitative and quantitative compositions of the flora itself.

English translation revised by R.A. Halliwell.

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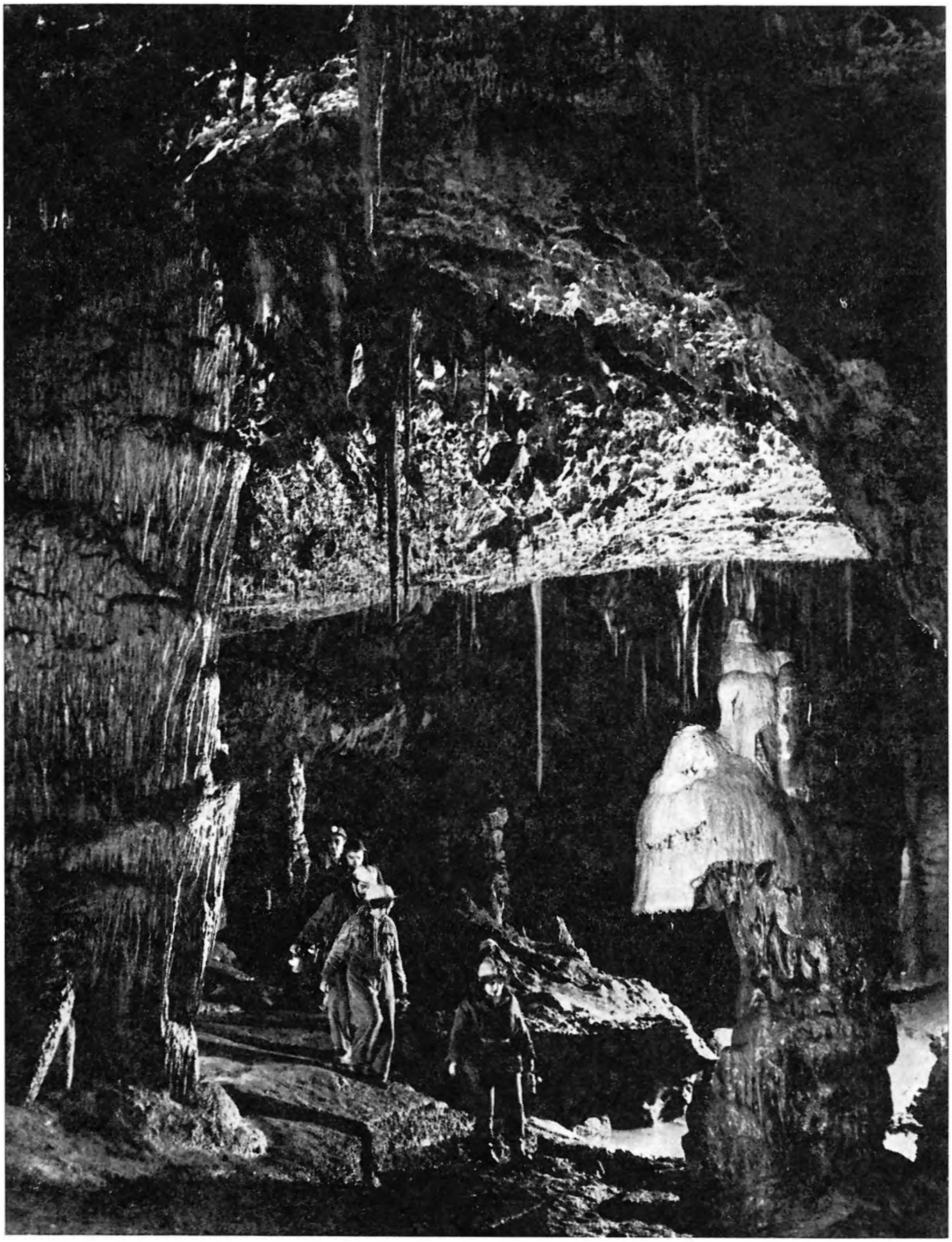

"Minerva's helmet" (right) in the main passage of Baradla Cave (by P. Borzsák and A. Prágai)

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Dr. Miklós GÁBORI

ARCHEOLOGICAL RESULTS OF INVESTIGATION IN HUNGARIAN CAVES

SUMMARY

The results of the research work of the past 25 years are summarized. Hungary is not rich in Paleolithic localities. The largest caves were explored already from the early 1900's onwards. In spite of this fact the general pattern of the Hungarian Paleolithic, the determination of its sites and cultures, has undergone remarkable changes. This is due to the fact that, on the one hand, the sites have increased in number; on the other hand, that the research has turned to tackle chronostratigraphic problems at an ever increasing rate. The major summarizing works are reviewed; the results of excavations recently undertaken at old sites and their archeological and stratigraphic revisions are expounded. In addition, the major exploratory works are discussed separately, by cultures. In this connection, stress is laid on the problems of the Paleolithic in caves. Final solution to these problems is expected from a well-coordinated study of open-air excavations and cave diggings.

Organised archeological excavations in Hungary began around 1900 in the Bükk Mountains and explored Paleolithic sites. The results were published in a great many early works and reviewed in later summarizing publications in the 1930s. Because of the physical geography, Hungary proved to be not very rich in cave sites of Paleolithic occupance. Significant sites are restricted to the relatively small area of the Bükk, Pilis and Gerecse Mountains. Therefore, the largest and most important sites were already explored during the prewar decades. There follows a brief review of recent results.

Despite limitations mentioned above, our image of the Hungarian Paleolithic, the definitions of its cultures and their chronological position have undergone remarkable revision in recent years. The number of sites, quantity of finds and artifacts recovered have increased; earlier finds have been reinterpreted; new and more exact research methods have been developed; cave research has been increasingly devoted to resolving problems of stratigraphic correlation and to more exact dating of the individual industries, i.e. to chrono-stratigraphic questions.

It must be emphasized that many of these problems are not resolved today. Because of the paucity of new, large cave sites, finds in open air situations have been given preference and have yielded the greatest wealth of recent results. But there are essential questions for which the solutions can only be expected from caves e.g., more precise archeological determination of individual cultures or groups of special character; more exact definition of their chrono-stratigraphic boundaries and their evolution; finally, the correlation of relationships between cave deposits and those outside i.e. cultures.

In this paper we summarize only the results of Paleolithic research.

Bükk Mountains

Research in recent decades has been concerned first of all with re-investigation of older collections of artifacts. First to be studied was the Moustierian — the industry of Subalyuk Cave. There are two cultural layers at the locality, separated by a considerable thickness of barren sediments. Their industries, however, show a convergent evolution. The lower cultural layer is dated as corresponding to the end of the Riss-Würm interglacial i.e. to the beginning of the Early Würm. The upper cultural layer is dated to the culmination of Würm 1 (in the central European sense). The recent work has established that both industries belong to one of the facies of the Central European Moustierian (Central European typical Moustierian) in which there appear some elements of Seletian of the Bükk Mountains. In addition to common types of implements and local variants, there are bifacial implements. This local "Seletianisation" of the Moustier-

Geographical location of caves investigated from archeological point of view. BÜKK MOUNTAINS: 1 Subalyuk Cave, 2 Büdöspest Cave, 3 Szeleta Cave, 4 Lambrecht Cave, 5 Háromkúti Cave, 6 Herman Cave, 7 Istállóskő Cave, 8 Peskő Cave. TRANSDANUBIA: 9 Jankovich Cave, 10 Szelim Cave, 11 Pilisszántó Rock Shelter No. 1 & 2, 12 Bivak Cave, 13 Remete Cave, 14 Remete-Felső Cave

ian have been substantiated by typologico-statistical and metrico-mathematical tests.

The Bükk Moustierian displays no connection with the middle Paleolithic of Transdanubia. It had a narrow distribution and was ready-made, fully developed when it first appeared in this country. Its origin remains obscure. The nature of the raw materials of the implements suggests direct geographical connections with Poland. An additional problem arises from the fact that the industry of Subalyuk and minor associated caverns comprises only a few hundred implements. It is a disproportionately small collection when the long time range of the culture is considered. Problems of the Bükk Seletian may eventually be solved by studies of artifacts from open sites.

Evolutionary connections between the Moustierian and Seletian of the Bükk were placed in a new light by renewed excavations at Büdöspest Cave. The industry there, formerly considered Seletian or in some cases to be workshop materials, is an example of re-evolution. According to our opinion it belongs to the Moustierian group, as proven by fauna from the relevant strata and their 14-C age. Particularly important, the cultural layer of Büdöspest Cave proved to be younger than the lower cultural layer of Szeleta Cave. Consequently despite many control excavations connections between Moustierian and Seletian are not yet completely known.

Amongst other achievements of recent years has been exploration of Lambrecht Cave, found to contain older material than that described above. It is not possible here to detail the entire sequence but mention may be made of the fauna of a lowermost, yellow layer. This includes *Hystrix*, *Asinus hydruntius*, *Erinacea*, *Spalax* etc., which indicates emphatically the warm phase of the last interglacial, the "Hystrix Horizon" of D. Jánossy. A few amorphous quartzite splinters, alien to the locality were recovered from this horizon. They are believed not to be implements but they prove the presence of Man. Similar pre-Moustierian finds are known in a few other parts of Central Europe.

Other recent results include assignment of the "Varbo Horizon" (Varbó Cave) to the latest phase of the Riss-Würm. Verifying excavations have been made at all known cave sites. The last work of L. Vértes was aimed primarily at examining Hungary's cave sediments by the Lais method and this permitted chronological identification of the individual layers (Szeleta, Büdöspest, Háromkúti and Herman Caves and some caves and niches of Transdanubian).

Despite countless preliminary reports and partial publications the material of the Szeleta culture of the Bükk has not been summarised as yet. But all available information on the Seletian has been published with revision and a new proposed new sub-division. Control excavations were undertaken at the eponymous site (Szeleta Symposium), but new problems have since arisen which cannot be solved unless a new site is found and explored.

Like the Moustierian, the Seletian of the Bükk is a culture restricted to a rather small area. It is represented by two layers in Szeleta Cave, once again separated by an extremely thick deposit that is archeologically sterile. The industry of the lower layer is termed "Early Seletian" and that of the upper layer "Advanced Seletian". The so-called "leaf-points" in the lower layer, the main type of this culture cannot be fully proven as they are worn off (concassé) due to rolling, only the cores being preserved. Strangely, this phenomenon is observed only on this "type". The assemblage also includes Moustierian and Late Paleolithic types. The industry of the upper layer, the so-called "Hochseletian", comprises mainly flatpoints that are finely fashioned in the shape of a willow leaf. Otherwise, the proportion of Moustierian type is even higher than in the lower layer. The industries of the other sites can be associated with either layer. Repeated examinations have been made and present evidence suggests that the lower culture layer at Szeleta Cave may have had a Moustierian culture underneath. It remains unclear however whether the material of this lower layer is not, in reality Middle Paleolithic and whether its evolution may not be interrelated with the implement assemblage (young in character, almost fresh) of the upper layer. Finally, it is entirely uncertain when the upper, Advanced Seletian period ended. The author believes the Advanced Seletian of the Bükk to represent an almost independent, special culture with hosts of Moustierian elements and Late Paleolithic types. As far as the more or less similar "Seletian deposits" of adjacent areas are concerned, they are developed from other roots.

Significant information upon the Aurignacian of Hungary was obtained during recent excavations at Istállóskő Cave by J. Hillebrand and L. Vértes. The latter worker established the statigraphy during the 1950s—lowermost sterile layer: Würm 1; Aurignacian soil layer above it: Würm 1—2 interstadial; uppermost "Magdelanian layer": Würm 3. Systematic diggings recovered an Aurignacian layer hitherto unknown which contain a very rich bone industry. The new finds clarified the cultures and groups of the Würm 1—2 interstadial. The industry of the new layer consisted primarily of bone implements—bone points with cleft base *(pointes à base fondue)* very small arrowheads, different types of laceheads, amulets, shafts, a bone flute etc. 40% of the assemblage was of bone; stone implements belong to the Aurignacian *sensu lato*. The culture is called "Middle European Aurignacian 1". It is replaced in the overlying layer by the so-called "Middle European Aurignacian 2" or "Olschewin". The ratio of bone to stone implements here is the inverse of that in Aurignacian 1 and includes bone points and spearheads of great size amongst the 20 or so types of implements.

In the upper culture layer (??) a single, well developed Seletian leaf point was also found which, together with other observations proves the contemporeneity of the Aurignacian and Seletian of the Bükk. Two entirely different cultures ethnically, must have lived side by side in the eastern and western parts of the Mountains respectively.

Worthy of attention are remnants of fire places ringed with stones (or, possibly, foundations of a hut?) and burials containing skulls of cave bear. Regarding these latter and their suggestion of a "bear cult", we can only accept them with some reservation in view of experiences in Austria and Switzerland. New investigations in other countries have rendered the definition and even the existence of the Hungarian Aurignacian 1 and 2 rather doubtful. It appears that this small ethnic group of people with a peculiar, highly developed bone industry was an independent group whose origin is for the moment obscure. Without taking a position on this question, let us acknowledge that it warrants further research in the Hungarian Paleolithic.

The excavations at Istállóskő Cave were followed by digging at nearby Peskő Cave. Only one of the Aurignacian layers was found but it has contributed substantially to our knowledge of the statigraphy of the Würm 1—2 interstadial.

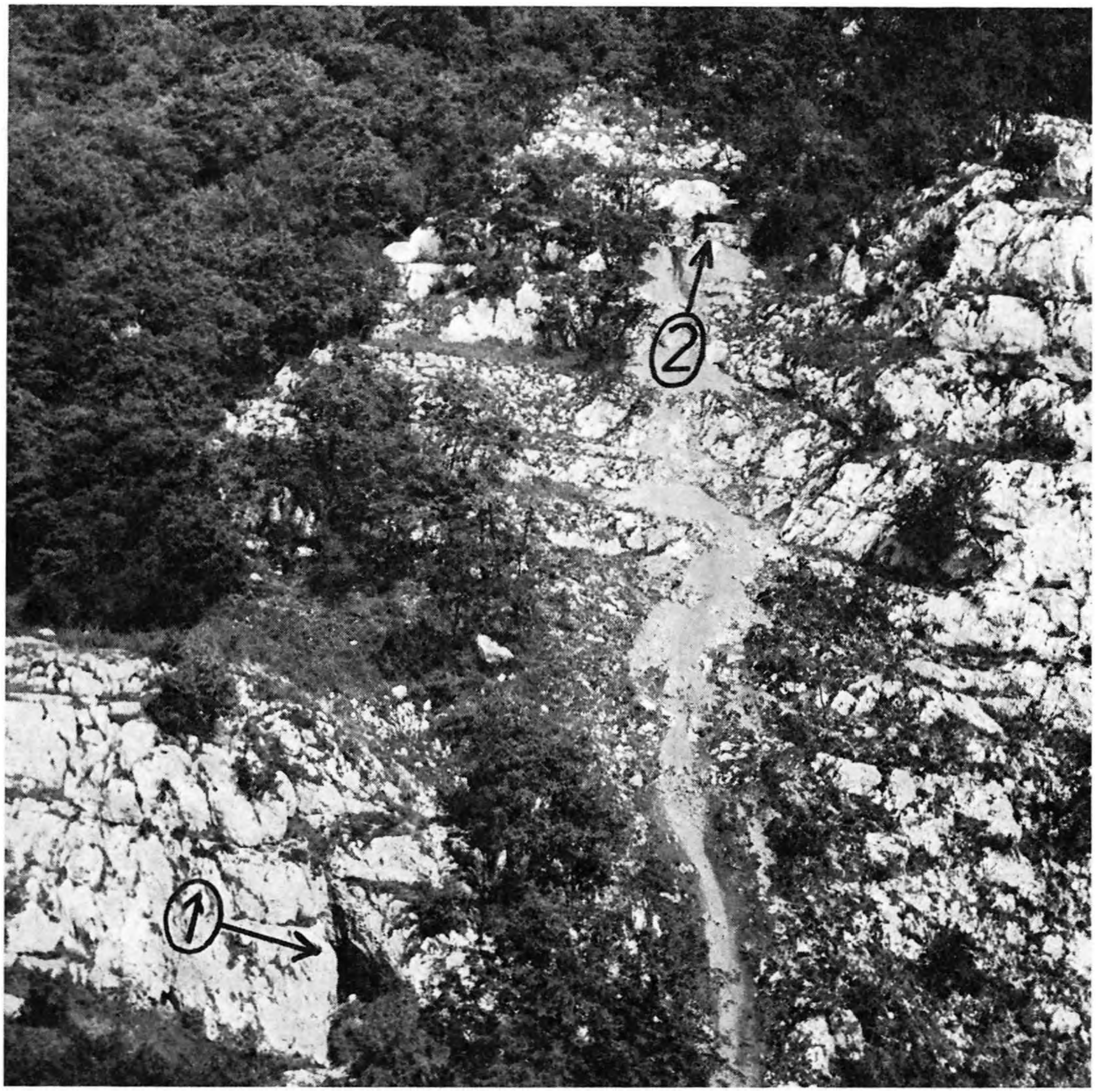
Excavations in Transdanubia

Turning to the western part of Hungary, Transdanubia, the cave excavations worthy of mention have been many fewer. A peculiarity is that excavations in the caves of the Bakony Mountains, part of the Transdanubian Mountain Range, proved abortive. New control diggings were undertaken there in Jankovich Cave, Szelim Cave and Niches 1 and 2 at Pilisszántó. New discoveries are Bivak Cave (Pilis Mountains) the Remete Cave and Remete-Felső Cave near Budapest. The western part of the country has yielded remarkable results from open-air sites—Vértesszőllős, Middle Paleolithic sites of Érd, new excavations at Tata etc.

Remete-Felső Cave during the excavations

Description of new results must begin, once again, with a revision of the old sites. Concerning the Middle Paleolithic, no cave site was known in the area and Aurignacian or similar cave industries have not been encountered. We consider the most important result here is re-evaluation of the so-called "Transdanubian Seletian" which was enhanced by excavations at Remete-Felső Cave a couple of years ago. To summarise, the Hungarian Seletian like the "Moustierian", has been found to belong to two regional groups—Bükk and Transdanubian. The question of the Moustierian has been resolved mainly by a complete excavation and interdisciplinary investigation of the open air sites at Érd. Its industry is a local modification of the South European Charentian. In addition, these investigations furnished a very detailed and interesting picture of the physical conditions and ecology of the Middle Paleolithic. Two cultural layers, the upper containing five horizons or occupation levels were found, yielding 50,000 pieces of animal bones suitable for complex investigation. The culture of the Tata site (known since the 1900s) proves to be a special "Moustierian" different in character, which did not develop into Seletian.

Caves of Remete Hill's Canyon — 1. Remete Cave, 2. Remete-Felső Cave



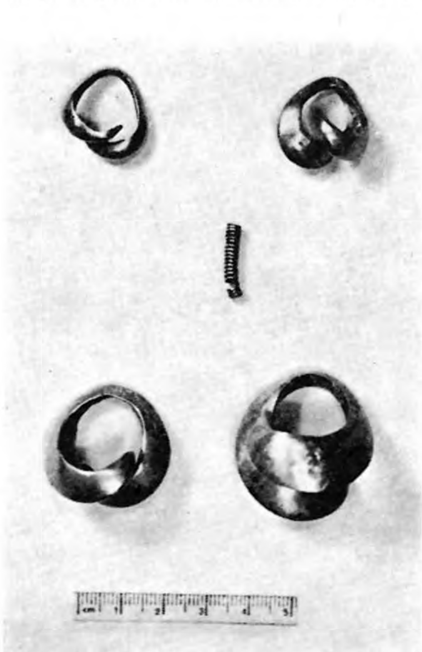
An important question raised by the "Transdanubian Seletian" industry is whether it is truly a facies of the Seletian complex *sensu lato*. Jankovich Cave is the most important site and there are evidences at a few smaller caves in the northeastern corner of Transdanubia. Revision of the material and the stratigraphy has shown that this culture has no connection with the real Seletian of the Bükk Mountains, not even in the genetic sense. Consequently the term "Seletian" does not apply. The assemblage of implements comprises leaf-shaped scrapers and massive-base "leaf points", thus being explicitly archaic and Moustierian in character: a rather bifacial, "Blattspitzenführendes Mittelpalaolithikum" (Faustkeil-Blattschaber-Komplex) which may be compared with similar industries occurring farther west. It follows that its age is not the first interstadial but corresponds to Würm 1 and, locally, to immediate post-Würm 1. The new name of this industry is "Jankovichian".

Resolution of this problem was greatly aided by explorations at the new Felső (Upper) Cave of Máriaremete. In this small cave, directly below the Holocene humus the Würm 1 layer was recovered. Fauna of the cultural layer displayed an artificial composition to quite a degree, a result of hunting. Faunal species place the age of the layer at a date before culmination of Würm 1. The few implements recovered belong to the afore-mentioned culture and were found together with three intact teeth of Homoneanderthalensis. It is also interesting to

Middle Bronze Age necklace found in the Remete-Felső Cave

record that a Bronze Age treasure was found in the upper, Holocene layer, concealed in a specially dug pit. It comprises about 50 pieces (bronze pectoral ornament, diadem, bracelet, bronze axes, golden lock-rings, amber beads, etc.) which can be precisely dated.

Gold finds found in the Remete-Felső Cave



New excavations have been carried out in Bivak Cave (Pilis Mountains), where traces of the Jankovichian and a much later "Cave Gravettian" industry were discovered. Revision of the relevant faunal, sedimentalogical, etc., investigation led once again to a clarification of the chronological position of the Jankovichian. Its age can be placed somewhere around Würm 1.

New verification excavations have been made in the niches, Pilisszántó I and II. Results from the first led to the change of definition of the "Magdalenian" described above.

The youngest Paleolithic culture found in Hungarian caves is the so-called "Cave Gravettian". This was earlier believed to be Magdalenian. New research has shown that this civilization, essentially quite a small group is one of the varieties of the Gravettian known in open-air loess areas. Once again, localities are restricted to the northeastern corner of Transdanubia. A peculiar feature is the fact that only two kinds of the range of implements of the group have been found in caves. These are the microgravette point and the blunt-backed blade (*pointe micro-gravette* and *lame à dos abattu*). This restriction of the assemblage is quite striking as is the fact that these cave sites all occur at highland margins facing an open plain. It seems that they were merely casual occupation sites of hunters. This probability is also suggested by the remains of hunted fauna; only the humerus and joints of reindeer were left, suggesting removal of the trophy.

Recent research, therefore, indicates that the microgravette group must have been connected with open air Gravettian stations. However, we should like to find such an open air station where *these same implements* occur! The age of the group is the last culmination of the Würm (Würm 3 in Hungary) and in some cases the period immediately subsequent.

Material of the same culture was recovered from Niche II at Pilisszántó and, finally, in Remete Cave where entrenchment to a depth of 11 metres only reached the base of the post-glacial layer. The prime significance of Remete Cave is that it offers an unparalleled cross-section of the archeological history of the Budapest region. Beginning with the Holocene, finds of 12 cultures have been recovered. There is an upward succession of representatives of the Neolithic, the Copper Age, several Bronze Age episodes and cultures and Celtic-Eraviscian populations followed by traces of occasional occupation in Roman and mediaeval times up to the 13th and 14th centuries.

Only the major archeological results of recent speleological research have been touched upon in this brief review. Because of lack of space it has not been possible to cite all caves surveyed, excavated etc. in recent decades. This review has stressed selected problems and results dealing with the Paleolithic at a few key sites. It is emphasised once more that there has also been research at a much greater number of open-air stations. Hungarian Paleolithic research projects extend to both loess and travertine areas and to both old, classic caves and newly discovered ones. Future research will be founded upon discovery of new cave sites.

English translation revised by D.C. Ford.

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RESULTS OF PALAEONTOLOGICAL EXCAVATIONS IN CAVES OF HUNGARY

SUMMARY

The author gives a brief summary of the vertebrate palaeontological material yielded by caves and karstic cavities in different territories in Hungary during the last decades. A series of newly discovered localities and the re-examination of some old ones resulted chiefly in the following: a northern Carpathian parallel of the for a century known classical stratotype of the Villány Mountains became known: the twenty localities of the Osztramos Hill. A series of localities of the hitherto insufficiently known Middle Pleistocene time span were discovered: they represent the Tarkő-, Uppony-, Castellum and Solymár Faunal Phases. Lambrecht Cave (Varbó-Phase) and some other localities of the same age have been used to define a new horizon of the Upper Pleistocene and to refine its stratification.

The palaeontological investigation of caves, karstic cavities and fissures in Hungary has yielded a microstratigraphic series based on vertebrate remains, chiefly of the Pliocene and Pleistocene, which may justifiably be called one of the most important in Europe.

The first description of vertebrate remains from karstic sediments of our country dates from the middle of the nineteenth century (Petényi, 1864), and his diagnoses of small mammal species are still useful, correct and up-to-date. Since then, there has been an almost uninterrupted tradition of such investigations in Hungary (Méhely, 1914; Kormos, 1937; Kretzoi, 1956, 1962; Jánossy, 1969, 1973).

Palaeontological work has been especially vigorous during the last thirty years. Nearly all our limestone mountains contain some karstic cavities, many of them newly discovered, which have been explored from a palaeontological point of view; these will now be reviewed in order of different geographical units.

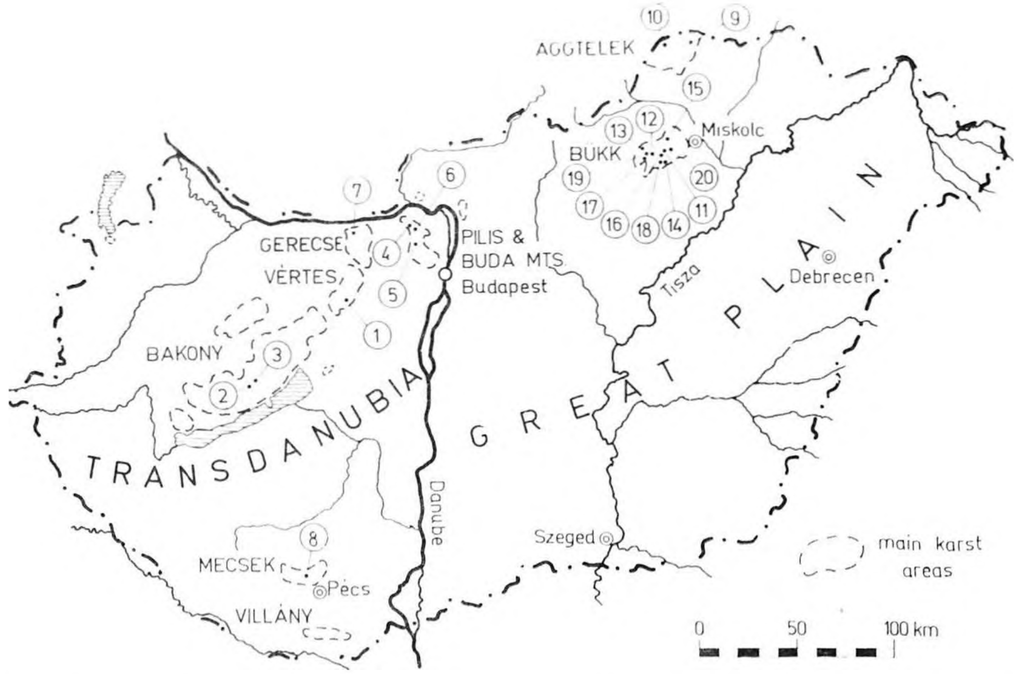
Transdanubia

In Transdanubia there are only a few examples of karstic phenomena with vertebrate palaeontological remains. Up to the present the oldest fauna was found in the sediment of the lower layer of the Csákvár (Esterházy) Cave in the Vértes Mountains. The sediments of Lower Pliocene age were reinvestigated by M. Kretzoi (1954). The richest known "Hipparion Fauna" in Europe was explored in this locality.

The revision of the remains collected over more than a hundred years from nearly forty localities in the Villány Mountains, undertaken initially by Kretzoi (1956) and more recently by Jánossy (from 1976), yielded much new information in this field. This sequence provides the basis of the stratigraphy of the Upper Pliocene—Lower Pleistocene, not only in Hungary but in the whole of Europe. The type localities of the newly established Pliocene and Pleistocene stratigraphic units (Csarnótian, Beremendian, Villányian, Nagyharsányhegy-Phase and Templomhegy-Phase) all lie in these mountains or close by.

During the last decades the exploration of geologically younger cave sediments in Transdanubia was very sporadic. It must be mentioned that excavations were carried out by M. Roska in the Szárazgerence Cave (Bakony Mountains) which yielded very rare palaeontological remains (Varrók, 1955) from the threshold of the Last Glacial. The southern limit of the Pleistocene distribution of the Collared lemming (*Dicrostonyx torquatus* Pall.) is found at the Abri of Tekeresvölgy, in the same region (Bertalan—Kretzoi, 1962).

Some Upper Pleistocene sequences were explored in the Pilis Mountains and Buda, in the Bivak Cave, Remete Cave (Jánossy, 1953, 1957) and the Rockshelter II of Pilisszántó (Vértes, 1955) as well as



Geographical location of caves with paleontological remains. TRANSDANUBIA: 1 Csákvár Cave, 2 Szárazgerence Cave, 3 Abri of Tekeres-völgy, 4 Bivak Cave, 5 Remete Cave, 6 Pilisszántó Rock Shelter No. II, 7 Jankovich Cave, 8 Mély-völgy Rock Shelter. NORTHERN MOUNTAIN RANGE: 9 Caves of Osztramos Hill, 10 Porlyuk Cave, 11 Kövesvárad, 12 Tarkő Rock Shelter, 13 Uppony Rock Shelter, 14 Hórvölgy Cave, 15 Lambrecht Cave, 16 Poroslyuk Cave, 17 Istállóskő Cave, 18 Subalyuk Cave, 19 Petényi Cave, 20 Rejtek Rock Shelter

the sediments in the outer part of the Jankovich Cave (Excavations of Jánossy, in: Herrmann—Kretzoi—Vértes, 1957) in the Gerecse Mountains. The palaeontological material of all these localities greatly increased our precise knowledge of the characteristic faunas of the "Upper Würm". The stratigraphy of the Jankovich Cave provides very important information relating to the problem of the Pleistocene—Holocene boundary.

In the Mecsek Mountains only the Rockshelter Mélyvölgy has been investigated; this yielded some Pleistocene material (Vértes, 1955) of little importance. During the last decades much new palaeontological data has been obtained from the karstic cavities of the Northern Chain of the Central Mountains of Hungary.

North Hungary

Greatest importance must be atteched to the large number of sites in the Osztramos Hill of the Aggtelek Karst, where some twenty localities cover the period from the Middle Pliocene to Middle Pleistocene. This is a good northern parallel to the sequence of the Villány Mountains and the use of the old name Esztramos (for Osztramos) is well justified in expressions such as Esztramontian (a stratigraphical stage in the terrestrial Middle Pliocene) and *Estramomys simplex* (a newly discoverep Eomyd rodent Lower Pliocene) (Jánossy, 1969).

At present the unique palaeontological material from the different localities of Osztramos has made it possible to describe 17 species and subspecies of mammals new to science as well as the similarly new stratigraphic unit, the Torna-Phase (Jánossy, 1970, 1971, 1972, 1973, 1975).

In the same region is the Porlyuk Cave, whose fossil remains represent the threshold of the Last Glacial (Jánossy—Kordos, 1973). Some newly discovered localities show an interesting picture of the changes in the Microvertebrate fauna of the early Holocene (Nagyoldal, Kordos, 1975).

The Bükk Mountains in Northern Hungary contain a very rich series of new or recently revised localities. The oldest of them is Kövesvárad, where the first Lower—Middle Pleistocene fauna in this area was discovered (Jánossy, 1963). One of the richest Middle Pleistocene localities in this area is the red clay of the Rockshelter Tarkő, which yielded a unique stratigraphic series containing several thousand bone remains. The new Tarkő-Phase stratigraphic unit was based on this series (Jánossy, 1962, 1969).

The least known parts of the Middle Pleistocene are those represented by the fossil remains in the sediments of the Rockshelter-Uppony at the northern edge of the mountains (the type locality of the newly named Uppony-Phase), and those in the Hórvölgy Cave in the southern part of the same region. The Hórvölgy Cave can be considered as containing the type fauna of the former Solymár-Phase (Jánossy, 1969 and unpublished data).

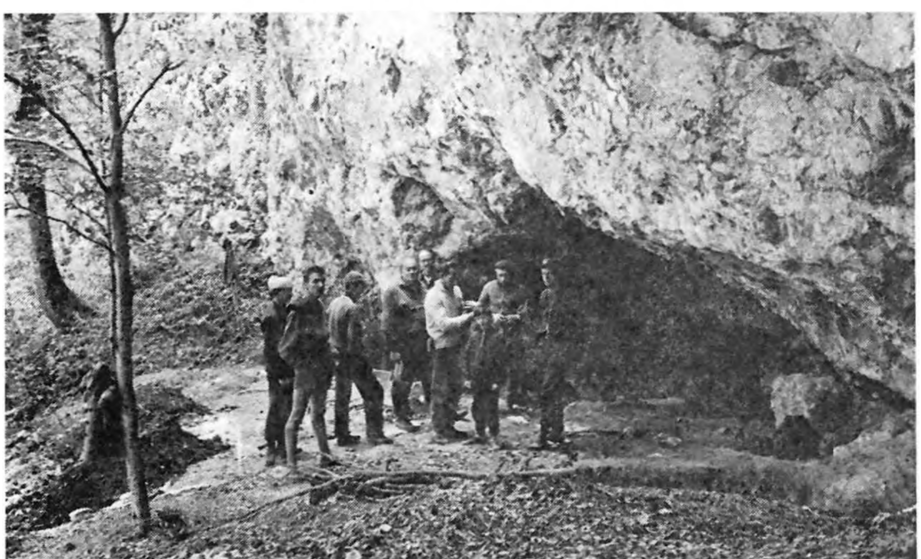
The Lambrecht Cave, containing numerous remains of small and large mammals (including man, for which this is the second known locality in our country), is stratigraphically taken to be the threshold of the Last Glacial (Varbó-Phase, "Hystrix-Horizon"). The Poroslyuk Cave near Répáshuta, has yielded an equivalent fauna but so far has yielded no archaeological remains (Jánossy, 1964 and unpublished data).

A new examination of the Istállóskő locality, known for more than fifty years, has yielded much archaeological material and abundant palaeontological remains. As a result, this cave has been defined as a type locality of the "Middle Würm", the typical faunal assemblage of the Last Glacial in our country (Istállóskő Phase, Jánossy, 1955). The re-examination of some remains from the deposits of the long-known Subalyuk Cave has shed fresh light upon the microvertebrate life of the Subalyuk-Phase (Würm "I", Jánossy, 1960).

Finally, the Petényi Cave (Peskő Hill) and the Rockshelter Rejtek, both on the southern edge of the Bükk Plateau, together with the already mentioned Jankovich Cave in Transdanubia, form a very important stratigraphic series, transitional between the Pleistocene and Holocene (Jánossy—Kordos, 1976).

Remains of Hystrix vinogradovi atavus from the site No. 8 of the Osztramos Hill

Foreground of the Tarkő Rock Shelter



This brief summary of the palaeontological research in Hungarian Caves shows the considerable advances in this field during recent decades. It is to be hoped that in the future we may be able to correlate the stratigraphic succession in our country with that in Europe as a whole.

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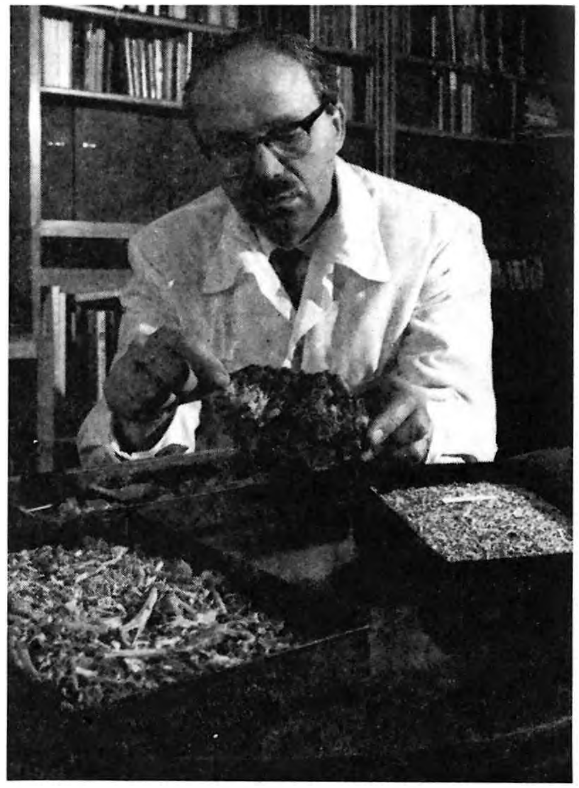

The author with the bone remains of the sites No. 2 and 8, Osztramos Hill

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SOME ASPECTS OF DEVELOPMENTS IN HUNGARIAN SPELEOLOGY THEORIES DURING THE LAST 10 YEARS

SUMMARY

The authors report on those results obtained by Hungarian workers which may be of international interest. The circumstances of the formation of vertical shaft-caves, hot spring caves and helictites as well as the tidal movements of the karst water table are discussed. In addition, the theoretical system of speleological interactions of knowledge is dealt with.

The genesis of karst shafts

Numerous theories were proposed in an attempt to account for the origin of vertical shafts. One of the earliest ideas attempted to explain this karst feature by relying on the analogy with the formation of glacier-mills. According to another widely-held opinion, vertical shafts would have been formed as a result of the gradual collapse of the roof of horizontal caves. Other interpreted the shafts as fossil sinkholes formed on the margins of an impervious cover subsequently removed by erosion. Gèze was the first to emphasize the existence of a close relationship between dolines and shafts, as shown by the examination of the topography of French caves (Igue del Garrel, Henne Morte).

There are several types of shafts, which substantially differ from one another. In the case of huge cleft-dolines or caves with a collapsed roof (Macocha, Czechoslovakia; Castellana Grotte, Italy) there is no great difference between the horizontal and vertical dimensions of the cavern *(Fig. 1a, b)*. In these cases the caves developed by the mechanical disintegration of the rock. Sinkhole-caves form a special group, produced mainly by erosion at the end-point of permanent water courses, or at the boundary of an impervious caprock with the underlying limestone *(Fig. 1c, d)*. Hereafter, only a third type of shaft is dealt with, those developed on plateaux with dolines. These are not connected with as large a catchment area as is implied by the considerable size of the caverns concerned *(Fig. 1e)*.

The volume of a cave with a collapsed roof increases upwards, the shafts of sinkhole type do so mainly laterally, while the volume of a typical karst shaft increases downwards as will be shown in the following discussion.

Kósa, one of the most successful workers on Hungarian karst shafts, recognised that karst shafts developed underground and their entrances opened later. He confirmed his observation by opening up several new karst shafts. Since he did not accept the earlier theories on the origin of karst shafts, he developed his own theories. According to this, initially a vertical cleft is widened over its whole depth by solution, after which it is filled up with falling debris and insoluble residue, and it is not until the final phase that the mouth of the shaft opens (senile phase).

This hypothesis gave rise to heated debates, after which the present writers formulated the theory outlined here (Sárváry, 1970; Müller—Sárváry, 1971). The theory accounts for the origin of karst shafts developed on barren karst plateaux.

The surface of such an area is dotted with dolines and there are places where the number of karst shafts, apparently distributed at random, is as high as 5 or 6 per square kilometre. In terms of this theory both the karst shafts and the relevant dolines are essentially of corrosion origin. Beneath the dolines there is a solution zone a few metres thick, where the water becomes saturated before flowing on. If the solution zone is intersected by a tectonic fissure a few millimetres wide, the corrosion zone is broken and water will rapidly reach the base of the zone and exert its dissolving effect there. Consequently a karst shaft is located at a breach in the corrosion zone, where corrosion can proceed more efficiently (higher CO_2 content, higher temperature etc.). The volume of karst water of average con-

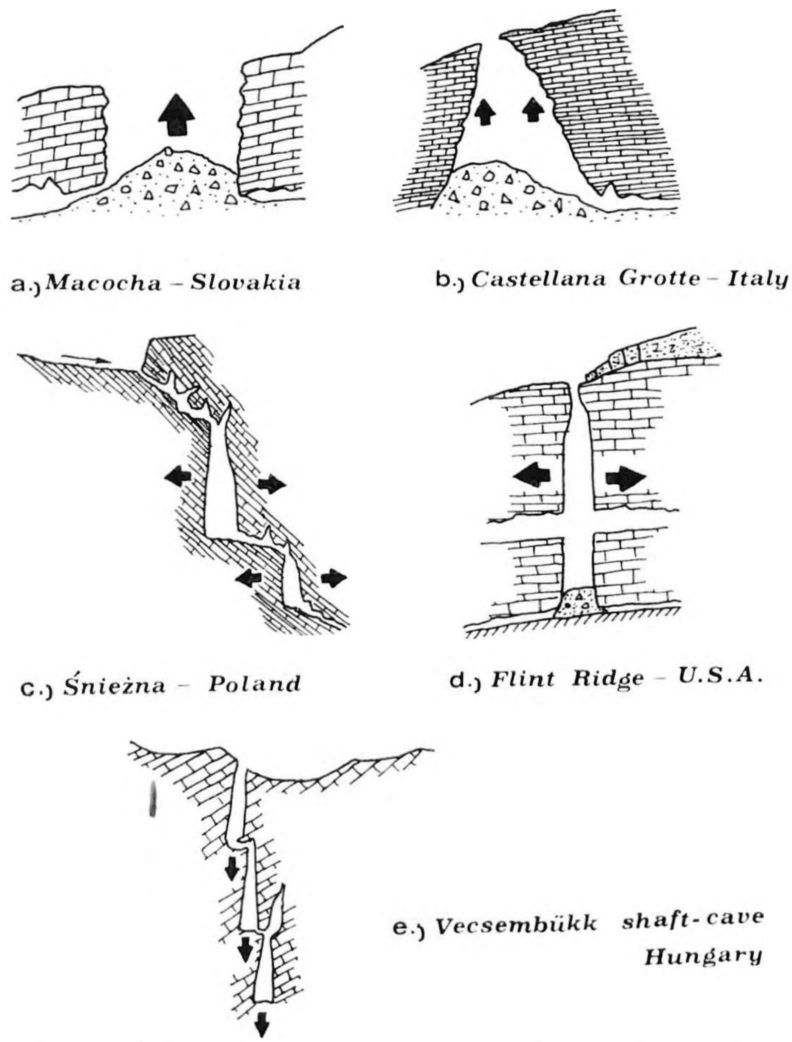


Fig. 1 Types of shaft-caves with the main directions of volume growth. a, b: Rooms with roofs collapsing owing to geomechanical causes. c, d: Sinkholes widening due to erosion and partly to corrosion. e: Vertical karst shaft deepening owing to purely corrosive processes

centration resulting from precipitation upon the surface of one doline is sufficient to dissolve, during the Pleistocene, the mass of rock corresponding to the size of the relevant karst shaft.

A karst shaft develops from the top downwards. Corrosion acts mainly in the corrosion zone at the bottom of an already existing cavern. Consequently, it is the process of deepening that is crucial to the increase of the shaft's volume. Erosion and collapse can only modify the shape of the cavity.

A karst shaft always begins to evolve at the deepest point of a doline, but this development removes water and slows down the lowering of the bottom of the doline. For this reason, the deepest point of the doline will move. At the new deep point a new shaft will start developing and because of the larger catchment area available, this new shaft will deepen more rapidly than the old one and finally drain it. This process may be repeated several times. In practice, because of asymmetric effects such as the dip of strata, the draining effect of the first shaft and the meteorological conditions, etc., the second shaft will be shifted towards the doline's centre to a much smaller extent than the theoretical value *(Fig. 2)*.

Because of the great number of dolines and the opening up of the entrance in a late phase, it may be supposed that unknown karst shafts are more numerous than known ones.

In the course of his investigations in the "classic" karst-shaft area of North Hungary, speleologist Szenthe found the, already hardly recognisable, traces of a one-time mantle layer of volcanic tuff origin. This impermeable layer seems to have been removed by regressive erosion and the sinkholes seem to have developed from pre-existing, narrow, corrosion produced shafts as a result of their widening. So the combined effect of several factors seems to have been responsible for the development of the larger shafts (Szenthe, 1971).

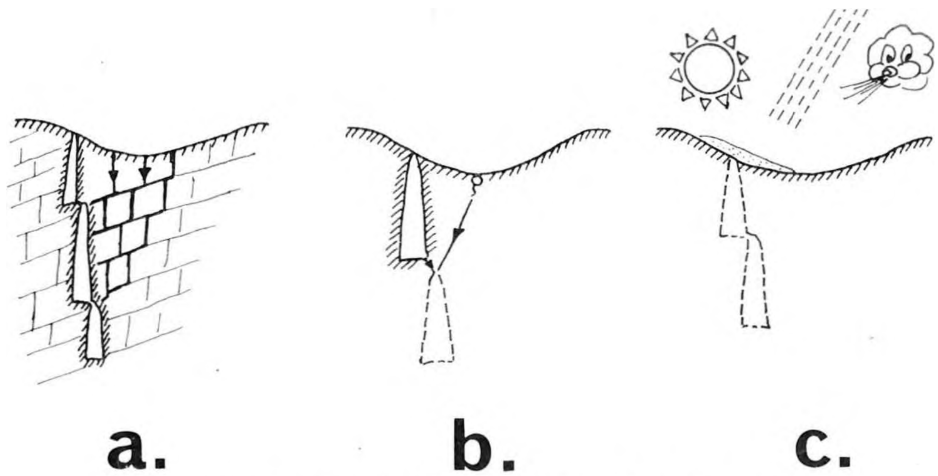


Fig. 2 Asymmetric effects on vertical karst shaft formation

The genesis of hot spring caves

In Hungary the formation of hot spring caves and the origin of their morphological forms have been thoroughly studied by Jakucs during the last thirty years. Ernst and Markó have studied the chemical aspects of the problem and the same problem has recently been tackled by Müller from the point of view of speleogenesis.

Information on the origin of hot spring caves can be obtained by studying caverns which are still active.

1. Metamorphic processes produce CO_2 in the base of geosynclinal troughs during the process of orogenesis. If carbon dioxide encounters water-saturated rock on its upward path it will enable the water to dissolve the rock and thus allow karst development deep underground. The same process in the region of springs encourages mixing corrosion, as a result of the warmer waters travelling at great depth underground, as a rule, absorbing a larger quantity of carbon dioxide, compared with colder waters.

2. Hot springs, as a rule, rise at the lowest level of major karst areas. For this reason, and partly also because of convective water movement, they form the location for the mixing of waters arriving from different directions *(Fig. 3)*. Evidence for this fact is the occurrence of springs of different water temperature close to one another. Since the waters have different concentrations, the spring water will again become capable of dissolving the rock (mixing corrosion).

3. Hot and cold waters in the system of rock pores are subhorizontally layered above each other, as is the case with the layering of saline and fresh waters in coastal karst areas. This seems to be responsible for the, often conspicuous, horizontal arrangement of the passages in hot spring caves *(Fig. 4)*.

4. Since the temperature of the water is higher than that of its surroundings, convection currents will develop, leading to the formation of vertical vents or possibly spherical niches *(Fig. 5)*. Convective movement may be combined with flow-induced eddying to produce transitional forms between scallops, whirl-kettles and spherical niches.

5. Convective currents may develop even in the air above the hot water in a cave. These result in water vapour precipitation on the cold walls of the cave. Distilled corrosive water dissolves CO_2 from the air, and seeping down the wall may produce spherical solution cavities *(Fig. 6)* in accordance with the spheroid form of the convective cell (Müller, 1971, 1974).

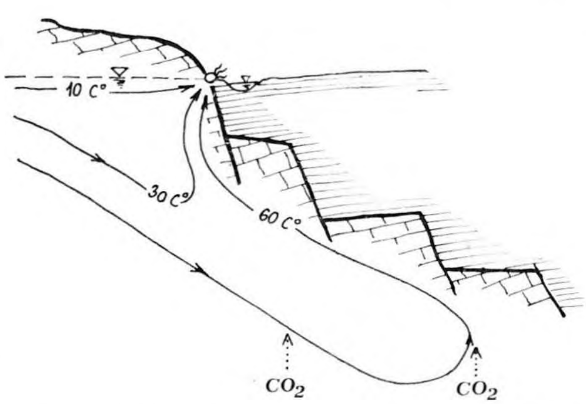


Fig. 3 Underground CO_2 migration increases the effect of mixing corrosion

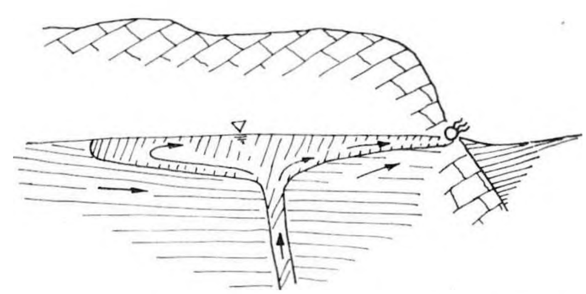


Fig. 4 Waters of different temperature stratified in a vertical succession at spring entrances

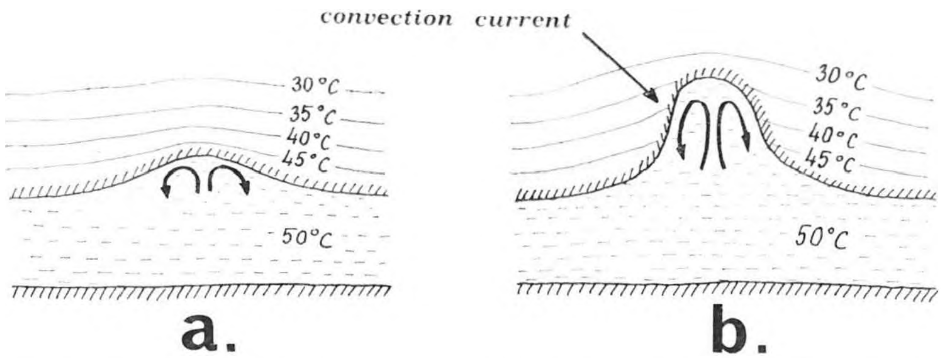


Fig. 5 Convective currents have dissolved cavities similar to whirl-kettles in the upper part of the entrance of a thermal cave gallery

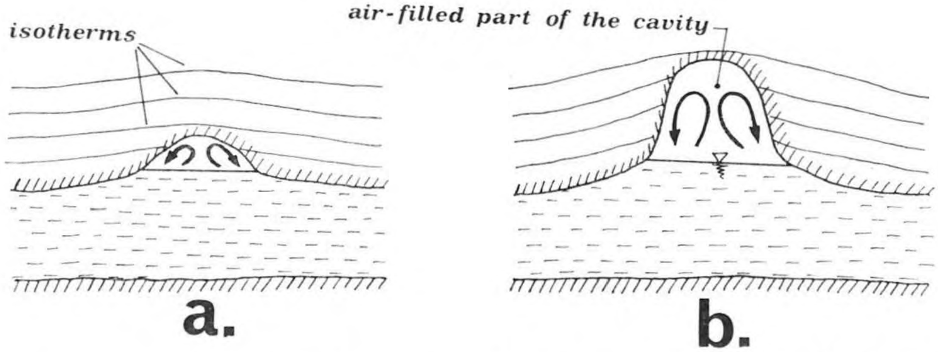


Fig. 6 Convective currents developing in the air space above thermal water have produced spherical niches

The genesis of helictites

The formation of helictites, also known as eccentric formations or curved stalactites, is a problem which has been considered by numerous foreign workers over many years. Both the Belgian speleologist Prinz and the French speleologist Trombe, envisaged lattice failure as the cause of irregular growth. Viehmann, a Romanian speleologist, considered the air currents in caves and the role of surface capillary action to be important. According to Gèze, a well-known French expert, solution of capillary origin produce a limestone deposit which will lengthen the original capillary, while actual crystal growth factors will influence the direction of growth. Heller suggested that bacterial action is involved in the process.

Hungarian workers started to investigate the formation of helictites being already familiar with the above theories. A set of experiments involving diverse and sophisticated techniques was undertaken. The main results can be summarized as follows.

Helictites in the Vass Imre Cave, Jósvafő (by L. Gazdag and P. Szilvay)

Helictites in the Vass Imre Cave, Jósvafő (by L. Gazdag and P. Szilvay)

Helictites can be assigned to the following three basic types:

I. Colourless, acicular helictites

These helictites are calcite monocrystals of polycrystals of oriented intergrowth, 0.2 to 3.0 mm thick, subtriangular in cross section, rectilinear or broken angularly, lacking an inner capillary tube. The tip of a helictite coincides with the vertex $(10\bar{1}1)$ of a cleavage rhombohedron, the crystallographic *c*-axis being independent of the shape of the helictite, and equally oriented in every point. Accumulations of helictites of type I usually occur in closed cavities where "the wall is being washed by ascending air-currents" *(Fig. 7-I)*.

II. Opalous, curved helictites

These are calcite polycrystals of 2 to 10 mm thickness, circular or rounded-triangular in cross-section, always with an inner capillary tube a few hundred microns in diameter. The crystallographic *c*-axis is parallel to the orientation of the capillary, following the direction of growth. Accumulations of type II helictites develop along cracks and fissures, though they can often be found on stalactites as well *(Fig. 7-II)*.

III. Colourless, stalactite-like helictites

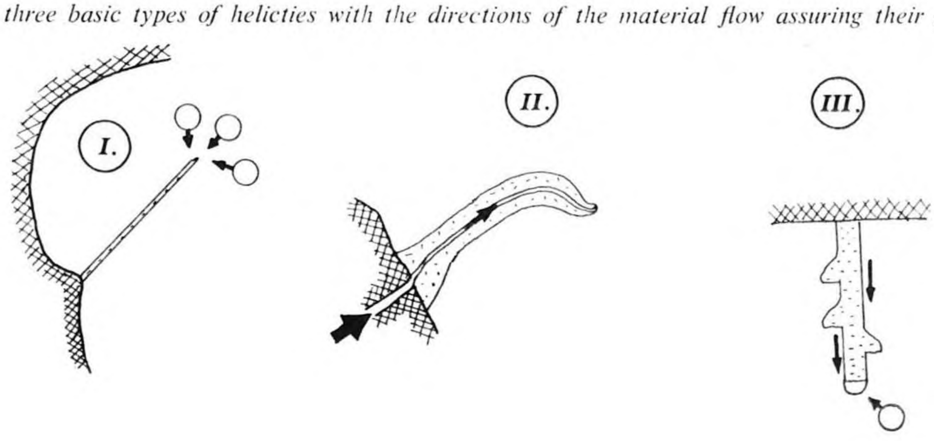
These are calcite monocrystals of 2 to 4 mm thickness, without an inner capillary tube. The crystallographic *c*-axis is not interrelated with the direction of growth. Their lower end is flat, parallel to one of the faces of the calcite monocrystal and always carrying a water droplet suspended at, but never dripping off, its base. Accumulations of helictites of type III can be found at the base of horizontal surfaces *(Fig. 7-III)*.

In practice, most of the helictites are combinations of the above three types. A base of type II with a tip of type I often occurs.

Investigations have shown that acicular helictites develop in a similar way to hoar-frost. The material necessary for their growth is obtained from matter suspended in the cave atmosphere. $CaCO_3$-saturated solution droplets can reach 10^{-3} to 10^{-5} centimetre in diameter, their rate of deposition being approximately 1 micron per second. If a water droplet of this kind adheres to the cave wall or to another nucleus of crystallization, $CaCO_3$ will immediately precipitate from the supersaturated solution. If a given crystal vertex is present, this precipitation will be oriented. Falling solution droplets are never electrically neutral. Because of the electric point effect there is a higher probability of the droplets precipitating at the tips of the vertices of calcite rhombohedra, forming a thin needle.

The growth of type II helictites takes place at the end point of the capillary, its direction being controlled by the actual circumstances of crystallization.

Fig. 7 The three basic types of helicties with the directions of the material flow assuring their growth



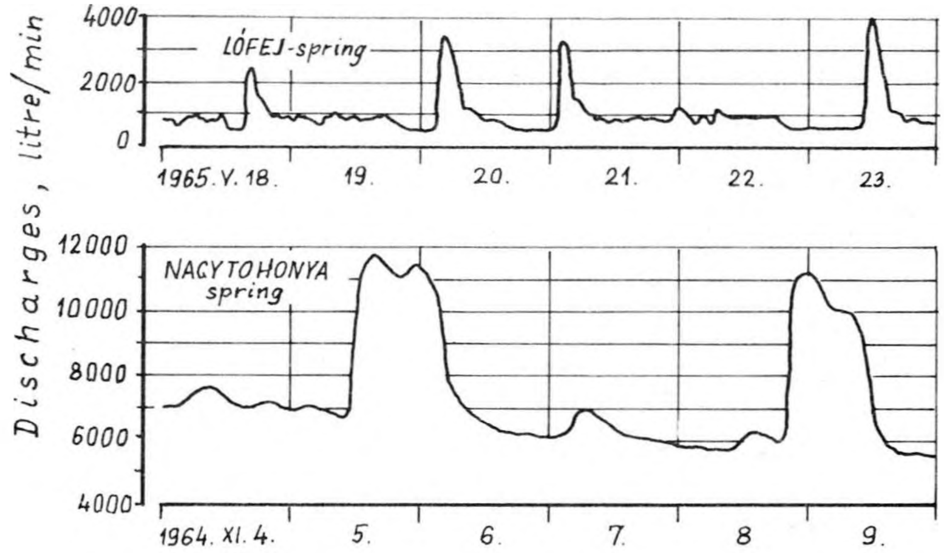


Fig. 8 Characteristic changes in the water yield of siphon springs

Rapid, concentric segregation does not allow the growth of a monocrystal, thus the resulting helictite will be a polycrystal.

Helictites of type III result from surface capillary action. The solution percolating through the roof of a cave will collect in droplets. The water evaporates slowly from the solution, whilst material in suspension coalescing with the large droplets will provide a constant recharge. Thus the very low rate of evaporation results in a slow crystal growth and in the formation of a monocrystal having the same diameter as the droplet itself.

Numerous quantitative methods of measurement and experimental instruments are described in the papers by Cser (1967) and Cser—Maucha (1968). The problem of staining helictites and stalactites and the relationship of this staining to the hydrological and climatic conditions are discussed by Pályi (1960, 1962, 1964).

Siphon springs and the tidal movement of the earth

Springs showing a regular and periodic variation of water yield independent of rainfall are known to occur in many parts of the world. Workers on this phenomenon have been rather few in number. Anker of Zürich, in 1962, was the first to show on the basis of instrumental measurements, that discharges and fluctuations could be explained by the action of siphons in the spring-entrances.

At the Jósvafő Research Station, North Hungary, the water yields of several intermittent karst springs have been continuously monitored since 1963 *(Fig. 8)*. Surprisingly, the yield was often observed to increase at noon and midnight. More exact measurements revealed that these times corresponded with the times of extreme gravitation values resulting from the apparent movement of the sun and moon *(Fig. 9)*. The increase in water yield in some springs was regularly preceded by other phenomena such as oscillation, sudden decrease in water yield, etc.

The discharges occurring at the time of extreme gravitation values showed convincingly, the existence of a relationship with tidal movements in the earth crust. Tidal phenomena in the earth's crust were observed as early as the end of the last century. Over the past decades, many workers have indicated that the water levels in mines and boreholes varied in a similar way to water levels in caves. Therefore they supposed that the siphons of the observed springs acted as hydraulic relays. The following idea was suggested to explain their mechanism. A filled siphon at the spring's entrance may remain in an unstable state for a relatively long time. During this time the usual water yield is continuously discharged via minor overflows. The tidal action of the earth crust will lift the karst water level by a few centimetres. As a consequence of this, the flow rate of the underground river feeding the siphon is thought to increase very rapidly. This increase will cause a rise in water level in the siphon and consequently the siphon will act. The resulting siphon action will to some extent accelerate the originally very slight fluctuation of the karst water level and release hundreds of cubic metres of water per unit time.

Large-scale investigations have proved the truth of the hypothesis. Research workers have been able to record a periodicity in the fluctuation of the karst water level. Through experiments on hydraulic models explanations could be found for all the characteristics of the water yield pattern of the intermittent springs. From 18 to 24 August 1966, the tidal movement of the earth's crust was observed directly. Micrometers were used for the first time to measure the relative movement of two sides of a cave passage. After this more and more precise and

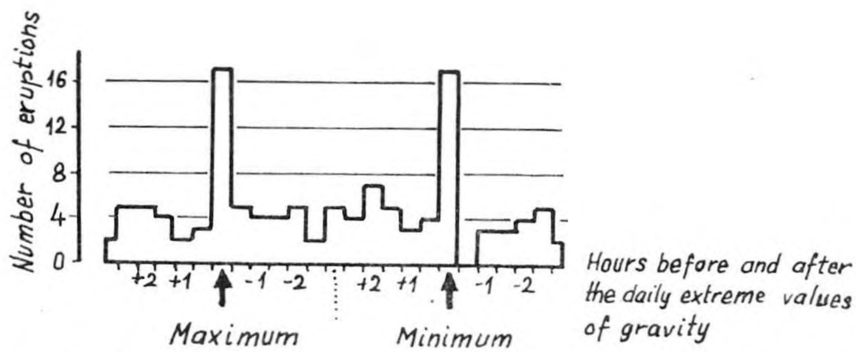


Fig. 9 The eruptions of siphon springs are more frequent at the times of occurrence of extreme gravitation values

sophisticated electronic instruments were developed for the monitoring of rock movement. The problem remaining to be solved was that the calculated frequency of extreme gravitation values and their signs did not always correspond to the measured hydrological changes. The measured rock movement was often in the opposite direction to that expected from calculated changes in gravitation.

A solution to the problem was achieved by a detailed examination and analysis of the results of many years of research work. It was found that the earth crust movement generated by gravitation will change the volume of pores in the rock. Consequently, the underground water level will either rise or fall. The water level fluctuations will load the water-containing rock and thus may cause secondary dislocations to occur. The resulting dislocation depends on the state of equilibrium of the rock slabs or blocks concerned at that time. This mechanism accounts for the fact that gravitation changes of similar sign may sometimes cause dislocations in opposite directions (Maucha, 1968, 1975).

The system of speleological interactions

Hungarian scientists have developed and attach great significance to the following philosophical system in the coordination of speleological research. The basic concept upon which this system is built is that the interaction of various processes in a cave's environment are responsible for the phenomena dealt with in speleology. In the course of these processes at least one agent producing an effect and at least one reagant exposed to that effect interact with each other. Agents and reagents are grouped as follows:

1. Agents of solid phase.
2. Agents of liquid phase.
3. Agents of gaseous phase.
4. Agents in the state of physical radiations and fields.
5. Agents in the state of living organisms.

In speleology and related sciences, the phenomena connected with solid substances belong to the scope of geology, those of liquid phase to hydrology, and those of gaseous phase to climatology. The manifestation in the form of radiations and physical fields are dealt with by microphysics and the phenomena of living substances by biology.

Matter in the karst and caves occurs in all four physical phases and also in the form of organisms. Matter present in different phases can enter all the possible interactions with one another. These possibilities are shown in the following table.

For instance, the dissolution of a rock (the effect of liquid-phase water upon the solid-phase rock) is a subject belonging to field 8, whilst its effect on speleoclimatic conditions and the distribution of living organisms belongs to field 14.

In the table the fields with which the speleologists have been mostly concerned have been shown hatched. The remaining types of interactions are still rather neglected research fields at the present time. Accordingly, certain groups of phenomena, deemed to be subjects for future research work, can to some extent be indicated (Maucha, 1971).

Reagent / Agent	Radiations & fields M. physics	Gases Climatology	Liquids Hydrology	Solids Geology	Livings Biology
Radiations & fields M. physics	1.	6.	10.	13.	15.
Gases Climatology	6'.	2.	7.	11.	14.
Liquids Hydrology	10'.	7'.	3.	8.	12.
Solids Geology	13'.	11'.	8'.	4.	9.
Livings Biology	15'.	14'.	12'.	9'.	5.

English translation revised by R.A. Halliwell.

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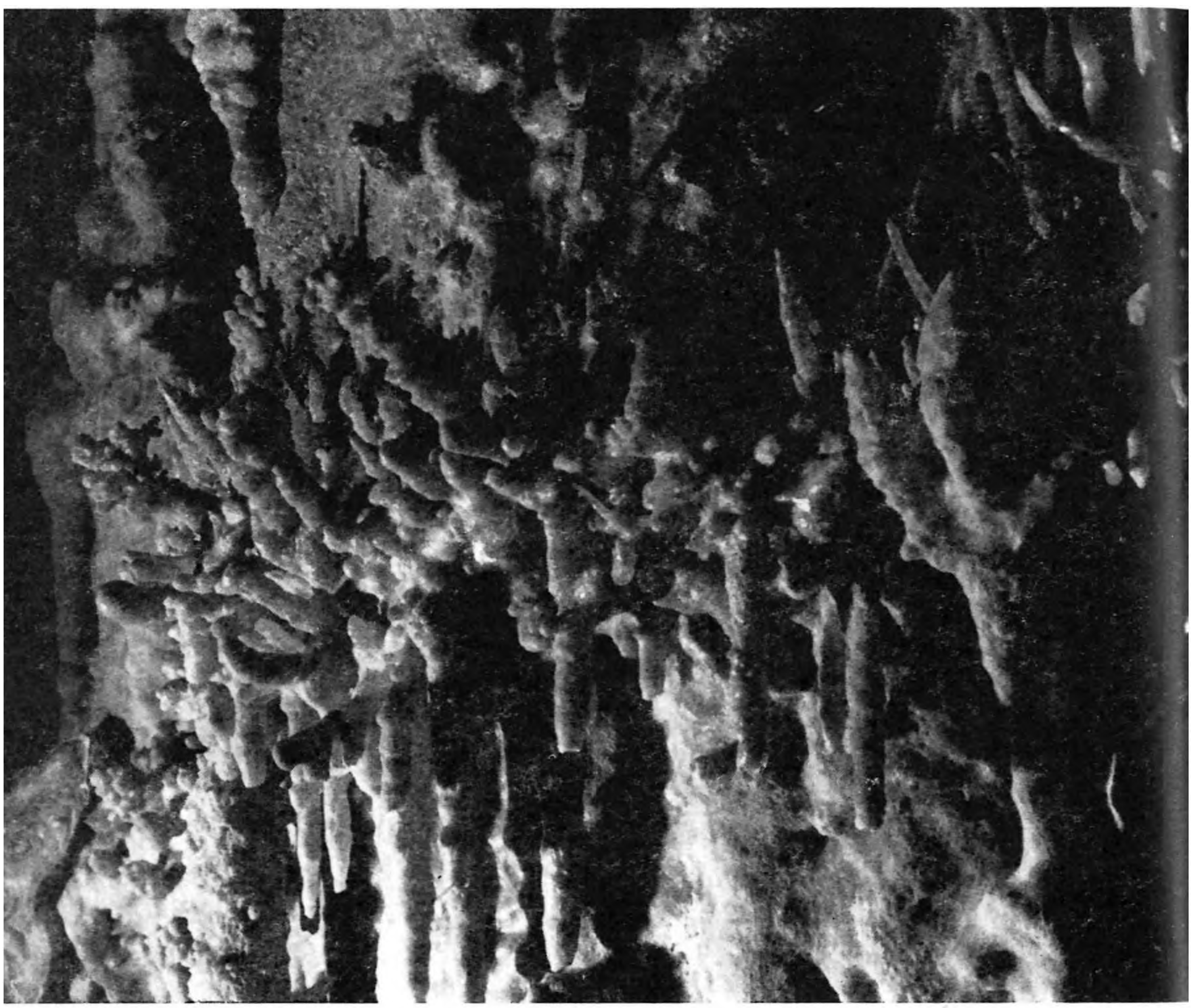


BRIEF INFORMATIONS

Dr. Károly BERTALAN

DATE RECORD ON THE HISTORY OF HUNGARIAN SPELEOLOGICAL RESEARCH

1037 Date of issue of a written document recording the name of Odvaskő—the first Hungarian name of speleological implication ever recorded.

1549 Date of issue of G. Werner's work—the first record on the Aggtelek Cave.

1719 György Buchholtz prepares a longitudinal section of the Deményfalvi Cave. (The first cave profile ever made in Hungary, according to present-day knowledge.)

1725 F. E. Brückmann publishes a report on the "Dragon Caves" of Liptó County. (The alleged dragon bones found in them were later identified with the remnants of cave bear.)

1723—1735 Mátyás Bél describes numerous Hungarian caves in his Latin language work.

1768 József Mattenheim, a miller, discovers a cave, today's Abaliget Cave, while penetrating into a spring in the Mecsek Mountains.

1774 Elek Nedetzky describes the Funaca Cave in Transylvania, already relying on his own experiences.

1794 Mining-engineer József Sartory maps the first part of the Aggtelek Cave. (His work is the first engineer-made planimetric map ever made of a cave in Hungary.)

1801 Keresztély Raisz, an engineer of Gömör County, surveys Aggtelek's Baradla Cave and prepares a layout, a plan and a longitudinal section of it. These are published in 1807 together with a German language description of the cave.

1819 Vince Kölesy explores, surveys and describes in detail the Abaliget Cave. His work is published the following year in the Tudományos Gyűjtemény (Scientific Collection).

1825 (1 June) Imre Vass, an engineer of Gömör County, discovers that part of the Aggtelek Cave situated beyond the Vaskapu (Iron Gate). He resurveys the cave widened this way and gives a monographic description of it, published in both Hungarian and German: the first bilingual monograph ever published on a cave.

1869 Geologist József Szabó carries out research in the Ágasvár Cave: the largest of the Hungarian caves of nonkarstic origin up to date.

1876 Jenő Nyáry undertakes large-scale archeological excavations in the Baradla Cave.

Sartory's map of the Aggtelek (Baradla) Cave, from 1794

1882 At Balatonfüred in the course of quarrying at the foot of Mt. Tamás people find a cave presently known as Lóczy Cave.

1884 J. Chalupny, parson of Abaliget, has the Abaliget Cave developed and made suitable for being visited by tourists.

1891 At Miskolc, during house foundation works, people find stone implements in which Ottó Herman recognizes at once the tools used by Ice Age man. The discussion about these finds gives an impetus to subsequent, very successful paleoarcheological excavations in caves.

1900 Antal Koch publishes a review on Hungary's fossil vertebrate remnants and localities, including hosts of famous caves.

1902 In Tapolca village speleologists find a cave opening and, traversing it by crawling, they discover the first rooms of what is called Tavas Cave today.

1904 (23 June) Pál Kornél Scholtz and János Bagyura, while examining the cavities of the Pálvölgy quarry in Budapest, discover today's Pálvölgy Cave.

1906 (14 November) Ottokár Kadić begins his large-scale excavations in the Szeleta Cave.

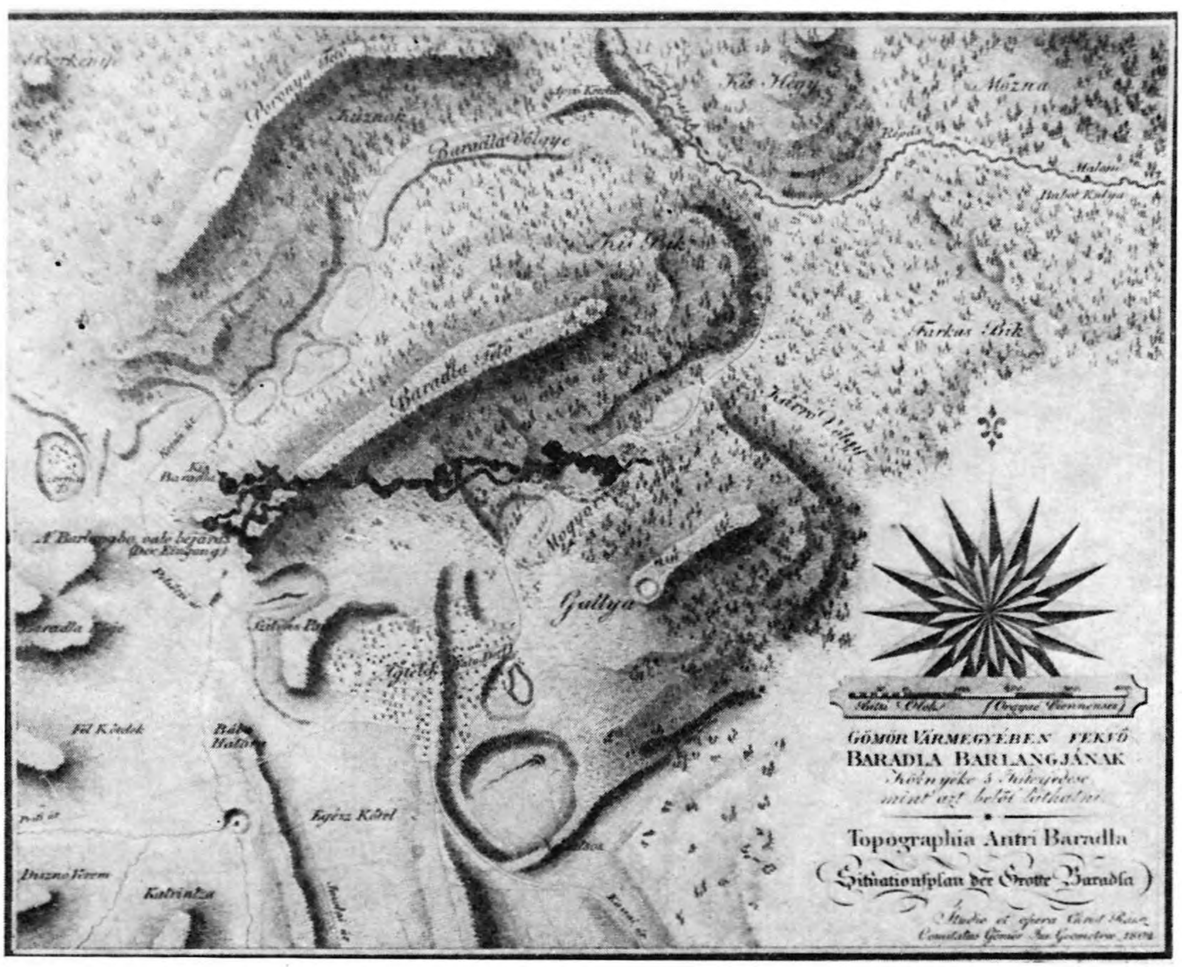
1910 (5 January) At the meeting of the Board of Elected Officers of the Hungarian Geological Society, Lajos Lóczy submits a proposal on the formation of a Commission on Speleology.

1911 (August) At the International Archeological Congress in Tübingen, Ottokár Kadić convinces the specialists that the Paleolithic artifacts found in the Szeleta Cave are true and thus he creates the basis for the international reputation of Hungarian speleoarcheological research.

1913 (20 February) The Commission on Speleology of the Hungarian Geological Society becomes an independent section and starts with issuing the "Barlangkutatás—Höhlenforschung" — a bilingual periodical of its own.

1914 (27 December) Ottó Herman, the first honorary member of the Speleological Section of the Hungarian Geological Society, the founder of Hungarian paleoanthropology, the iniciator of speleological excavations and the last Hungarian polymath, dies at 79 years of age

The map of Baradla Cave and its surroundings, surveyed by K. Raisz, from 1801



(The Hungarian Speleological Society has instituted a memorial medal dedicated to him.)

1914 Year of publication of a bibliography of references concerning the Hungarian caves compiled by Henrik Horusitzky, the first systematized Hungarian bibliography of this kind.

1926 (20 February) Date of founding of an independent Hungarian Speleological Society including the members of the Commission on Speleology of the Hungarian Geological Society, cave-exploring tourists and all people interested at large. This Society continues the publishing of the periodical "Barlangkutatás" (Speleological Research) and institutes a new popularizing serial — the "Barlangvilág" (Cave World), too. (The Society and its two periodicals ceased at the end of the Second World War.)

1927 (14—15 September) An international meeting of German and Hungarian speleologists is held in Hungary. First penetration into the deepest Hungarian karst shafts.

1929 The Jósvafő exit from the Baradla Cave is completed on the basis of measurements and design by chief engineer Péter Kaffka. Thus the cave can be traversed over its total length without the need for returning to its entrance at Aggtelek.

1930 (20 September) In the course of levelling the ground on the plot of a pharmacist on Szemlő Hill in Buda people find a cavern: the first portion of today's Szemlő-hegy Cave explored by Hubert Kessler.

Dr. Ottokár Kadić, founder of the Hungarian speleological research

Prof. Endre Dudich, founder of the Hungarian biospeleological research

1932 (21 August) Hubert Kessler and his companion penetrate from the Aggtelek Cave via the streambed of the underground river Styx into the Domica Cave, Slovakia, thus evidencing the existence of a passable communication between the two caves.

1932 Date of publication, in German, of Endre Dudich's great monograph on the biology of the Aggtelek Cave: a pioneering work even when considered on the international scale.

1935 (17 August) The Várbarlang (Castle Cave) and the relevant Barlangmúzeum (Cave Museum) are opened in Buda.

1952 (20 March) A special meeting on karsts is organized by the Geography Department of Budapest's Eötvös Loránd University, under the direction of Professor Béla Bulla.

1952 (4 August) László Jakucs and his colleagues penetrate into the Felfedező (Explorator) branch of the Béke Cave. This is the first, theoretically founded, purposeful cave exploration and development ever undertaken in Hungary.

1954 (31 August) Speleologists of the Budapest Technical University led by László Maucha succeed in penetrating into the first cavern of the cave named after Imre Vass. The main branch cannot be opened until a blasting is carried out on 18 August, 1955, when the total length of the cave is increased to 1 km.

1954 (14 November) After several months of hard work, Dénes Balázs and his companions, penetrate into the exploratory branch of the Szabadság Cave at Égerszög, thus opening the way to the stalactitic cave of 2717 m length.
1956 (9 February) The exploratory adit driven by the staff of the Research Institute of Water Resources Development reaches the cavern system of a cave which is subsequently named after Lajos Kossuth—a cave whose existence was theoretically predetermined by Hubert Kessler and László Jakucs.
1957 (27 February) Dr. Ottokár Kadić, professor of university and founder of scientific research in Hungarian speleology, dies at the age of 81. In the first four decades of this century he was the brain of Hungarian speleological research, the promoter of this Society's life, and the editor of both periodicals, etc. (The Hungarian Speleological Society has instituted a memorial medal dedicated to his name.)
1957 (28 February) László Jakucs and his associates discover the first stretch of the Baradla-Alsó (Baradla-Lower) Cave.
1957 (10 November) Upon initiative and under direction of Professor Ferenc Papp a research station is established at Jósvafő, close to the Vass Imre Cave by Budapest's University of Construction Engineering, Communications and Polytechnics. (The station is later taken over and widened by the Research Institute of Water Resources Development. For good two decades now this has been an important centre of scientific speleological research in Hungary.)
1958 (12 December) The Hungarian Speleological Society is re-founded in subordination to the Ministry of Heavy Industries and with this act the Hungarian speleology has again a centralized social body of its own.
1959 (14 May) A cave-bath is opened in the warm waters of the Tavas Cave at Miskolctapolca.
1959 A sanatorium for the treatment of people suffering from illnesses of respiratory organs is instituted in the Béke Cave at Jósvafő.
1960 A Speleobiological Laboratory is established in the Aggtelek Cave under the direction of Professor Endre Dudich.
1961 (1—9 January) Divers traverse by swimming a subaquatic gallery system of 300 m length in the Tavas Cave of Tapolca. They turn the first motion picture on cave diving ever made in Hungary.
1961 (6 August) Led by György Dénes, cave-explorers of the Vörös Meteor Society of Nature-Lovers succeed in penetrating into the big cave system of Alsó-hegy which has been searched for several years and which they name the Meteor Cave. (This cave hides one of the biggest cave rooms of Hungary: the so-called Hall of Titans nearly 100 m long.)
1961 (24 December) A new nature conservancy law is adopted, according to which all Hungarian caves are to be conserved.
1961 Date of issue of the first two numbers of the periodical Karszt- és Barlangkutató (Karstology and Speleology) provided with a coloured cover and hosts of pictures. [Carrying the name Karszt és Barlang (Karst and Cave), this richly illustrated magazine has become the most diversified representative of the Hungarian speleology.]
1962 (9 June) Explorers of the Létrástető Cave in the Bükk Mountains reach the main branch, thus increasing the length of the cave to 2 km.
1971 (12—27 June) An expedition organized for the continued exploration of the Vecsembükk Shaft reaches, under the direction of István Szenthe, down to 245 m depth, thus exploring the deepest cave of Hungary.
1971 (5 February). Professor Endre Dudich, honorary chairman of the Hungarian Speleological Society, dies at 76 years of age.
1972 (27 September to 1 October) An International Symposium of Speleo-Therapy is organized in Budapest by the Hungarian Speleological Society (H. Kessler).
1974 (3—4 September) An International Symposium on Karst and Climate is held at Pécs.
1975 (8 May) The National Nature Conservancy Office establishes a Speleological Institute.
1975 (26—29 August) The Hungarian Speleological Society organizes an international conference labelled "Baradla 150" which is mainly concerned with the conservation of the natural values of caves.

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THE LONGEST AND DEEPEST CAVES OF HUNGARY (DECEMBER 31, 1975)

Length and depth calculations on caves have been standardized in accord with the resolutions of the International Speleological Congress, Ljubljana 1965. Accordingly, the total length of a cave should be understood to be the value measured along the longitudinal axis of the cave passages and recorded on the survey; the depth of a cave should be considered as the difference in level between the highest and lowest points of the cave.

Hungary's most significant caves have already been listed in several publications (BUCZKÓ, 1961, Karszt- és Barlangkutató; CZÁJLIK—DÉNES, 1962, Karszt és Barlang; DÉNES, 1968, 1970, Karszt és Barlang). New large-scale explorations and developments have made it necessary to establish a more detailed list, including all caves longer than 200 m and deeper than 50 m.

THE LONGEST CAVES OF HUNGARY

	Length in meters	*Geographical setting*
1. Baradla—Domica Cave System	25 000	Aggtelek Karst
2. Béke Cave (Peace Cave)	8 743	Aggtelek Karst
3. Mátyás-hegy Cave	4 200	Buda Mountains
4. Ferenc-hegy Cave	4 000	Buda Mountains
5. István-lápa Cave	2 940	Bükk Mountains
6. Szabadság Cave (Freedom Cave)	2 717	Aggtelek Karst
7. Létrás Cave (sinkhole-cave)	2 000	Bükk Mountains
8. Solymári-ördöglyuk (Devil's Hole of Solymár)	2 000	Buda Mountains
9. Szemlő-hegy Cave	1 962	Buda Mountains
10. Létrás-tető Cave	1 660	Bükk Mountains
11. Pál-völgy Cave	1 200	Buda Mountains
12. Abaliget Cave	1 160	Mecsek Mountains
13. Vass Imre Cave	1 000	Aggtelek Karst
14. Tavas Cave of Tapolca	1 000	Balaton Highland
15. Fekete Cave (Black Cave)	1 000	Bükk Mountains
16. Jávor-kút Sinkhole-cave	1 000	Bükk Mountains
17. Borókás No. 4 Sinkhole-cave	1 000	Bükk Mountains
18. Alba Regia Cave	800	Bakony Mountains
19. Viktória Cave	800	Bükk Mountains
20. Cserszegtomaji-kútbarlang (Cserszegtomaj's Well Cave)	800	Keszthely Mountains
21. Mexikó-völgy Cave	700	Bükk Mountains
22. Kossuth Cave	633	Aggtelek Karst
23. Vénusz Cave	600	Bükk Mountains
24. Hajnóczy Cave	584	Bükk Mountains
25. Bolhás Sinkhole-cave	520	Bükk Mountains
26. Meteor Cave	500	Aggtelek Karst
27. Csőszpuszta Cave No. 1—12.	500	Bakony Mountains
28. Szirén Cave	400	Bükk Mountains
29. Lengyel Cave	450	Gerecse Mountains
30. Baradla-Alsó Cave (Baradla Lower Cave)	400	Aggtelek Karst
31. Ezüst-hegy Cave No. III.	400	Pilis Mountains
32. Kecske-lyuk Cave	400	Bükk Mountains
33. Kórház Cave (Hospital Cave)	380	Balaton Highland
34. Kőlyuk No. 1 Cave	350	Bükk Mountains
35. István Cave	350	Bükk Mountains
36. Legény Cave (Young Man Cave)	350	Pilis Mountains
37. Sátorkőpuszta Cave	350	Pilis Mountains
38. Diabáz Cave	300	Bükk Mountains
39. Barátságkert Cave	273	Bükk Mountains
40. Pénzpatak-Cave (sinkhole cave)	260	Bükk Mountains
41. Mánfa Cave "Kőlyuk"	253	Mecsek Mountains

[Cave]	[Length in meters?]	[Geographical setting]
42. Üröm Cave (sinkhole-cave)	250	Pilis Mountains
43. Vecsembükk Shaft	250	Aggtelek Karst
44. Pisznice Cave	247	Gerecse Mountains
45. Harcsaszájú Cave ~~(or Bagyura Cave)~~	225 294 m	Buda Mountains
46. Rákóczi Caves No. I.	200	Aggtelek Karst
47. Rákóczi Caves No. II.	200	Aggtelek Karst
48. Esztramos Cave	200	Aggtelek Karst
49. Leány Cave (Girl Cave)	200	Pilis Mountains
50. Great "Kaverna" Cave of Dorog	200	Pilis Mountains
Kő-lyuk II.	213 m	

THE DEEPEST CAVES OF HUNGARY

	Depth in meters	*Geographical setting*
1. Vecsembükk Shaft	245	Aggtelek Karst
2. István-lápa Cave	240	Bükk Mountains
3. Alba Regia Cave	170	Bakony Mountains
4. Létrás Cave	166	Bükk Mountains
5. Borókás No. 4 Sinkhole-cave	160	Bükk Mountains
6. Meteor Cave	150	Aggtelek Karst
7. Fekete Cave (Black Cave)	140	Bükk Mountains
8. Pénzpatak Cave (sinkhole-cave)	130	Bükk Mountains
9. Bányász Cave of Középbérc	130	Bükk Mountains
10. Baradla—Domica Cave System	116	Aggtelek Karst
11. Jávor-kút Sinkhole-cave	~~115~~ 87	Bükk Mountains
12. Kis-Kőhát Shaft	110	Bükk Mountains
13. Borókás No. 2 Sinkhole-cave	110	Bükk Mountains
14. Mátyás-hegy Cave	106 107,6	Buda Mountains
15. Csőszpuszta Cave No. 1—12	105	Bakony Mountains
16. Hajnóczy Cave	99	Bükk Mountains
17. Nagy-Kőmázsa-völgy Cave	94	Bükk Mountains
18. Almási Shaft	93	Aggtelek Karst
19. Szeleta Shaft	92	Bükk Mountains
20. Vártető Cave	90	Bükk Mountains
21. Hársas Cave	87	Bükk Mountains
22. Létrás-tető Sinkhole-cave	85	Bükk Mountains
23. Vértes László Cave	82	Gerecse Mountains
24. Mexikó-völgy Cave	80	Bükk Mountains
25. Bolhás Sinkhole-cave	80	Bükk Mountains
26. Tés No. 1—28 Sinkhole-cave	76	Bakony Mountains
27. Szabó-pallag Shaft	76	Aggtelek Karst
28. Lengyel Cave	73	Gerecse Mountains
29. Rejtek Shaft	72	Aggtelek Karst
30. Rákóczi Caves No. I	70	Aggtelek Karst
31. Tábla-völgy Cave	65	Bakony Mountains
32. Bodzás-oldal Shaft	65	Bükk Mountains
33. Róka-hegy Cave	60	Buda Mountains
34. Ezüst-hegy Cave No. III.	60	Pilis Mountains
35. Naszály Cave (sinkhole-cave)	60	Naszály Mount
36. Bolhás No. III. Sinkhole-cave	60	Bükk Mountains
37. Nagy-nyelő Cave (Great Sinkhole-cave)	60	Gerecse Mountains
38. István Cave	55	Bükk Mountains
39. Kis-nyelő Cave (Little Sinkhole-cave)	55	Gerecse Mountains
40. Nagy-Kőmázsa Cave	51	Bükk Mountains
41. Pócsa-kő Cave (sinkhole-cave)	51	Aggtelek Karst
42. Jószerencsét Shaft	50	Mecsek Mountains
43. Kurtabérc Cave	50	Bükk Mountains
44. Viktória Cave	50	Bükk Mountains

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HUNGARY

István PLÓZER

SITUATION OF HUNGARIAN CAVE DIVING IN 1976

At present three organizations are dealing with underwater speleological research in Hungary: the Amphora Cave Diving Sport Club, the Delfin Cave Diving Club and the Nautilus Cave Diving Club. In 1975 these three organizations established the Commission on Subaquatic Speleology of the Hungarian Speleological Society. This decision was confirmed by voting at the general meeting of the Society on April 24, 1976.

The aim of the Commission has been to co-ordinate the work of organizations dealing with underwater speleological research in Hungary and to serve as a representative body responsible for the development of collaboration between home and foreign organizations in this field. The staff is distributed among the teams working under the Commission as follows:

Amphora Club — 19 persons
Delfin Club — 14 persons
Nautilus Club — 10 persons.

The areas investigated by these teams are as follows:

Amphora Club — Beremend and vicinity, Kossuth Cave, spring crater of Lake Hévíz;

Delfin Club — Molnár János Cave and surroundings of József Hill, Esztramos Hill, Rákóczi Caves;

Nautilus Club — Tapolca's Tavas Cave and vicinity, Baradla-Alsó Cave.

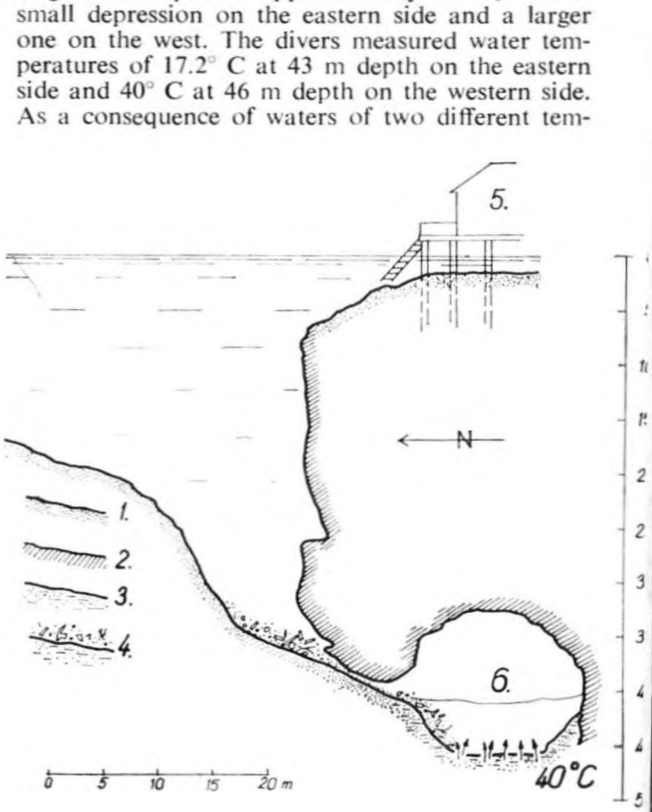
A considerable part of Hungary's underwater caves are of thermal origin and at present most of them still debouch a clear water of high temperature. The cave of the Hévíz spa-lake near Lake Balaton is interesting and significant from the sporting and the economic point of view.

The area around the lake is characterized by a heavily faulted structure and the spring-crater, which is still active at the present time, seems to have been formed along a major fracture line of approximately N-S direction. The spring-crater, which is 36.4 m below the water surface, rests on Pannonian clays and sandstones underlain by Triassic Hauptdolomit. The spring-crater and the chamber associated with it seems to have been formed by the thermal waters ascending along the fracture line and penetrating the clays and sandstones underlying the peaty topsoil. They then carved out the 50 × 70 m springcrater and the associated spring-chamber along existing fissures. The quantity of water welling up from the 46 m deep spring-chamber is 30,000 to 40,000 litres per minute and its temperature at the entrance of the spring chamber is 38.8° C.

Exploration by divers was begun on January 25, 1908, when divers of the Fiume Naval Authority carried out dives in Requayrol-Denayrouzen diving dress. In 1953, divers in Dräger diving dress went down the crater, but even they could not penetrate the spring-chamber. Aqualung techniques, developing at an ever increasing rate from the 1950's, enabled the Hungarian divers to attempt to penetrate the spring-chamber. However, their irregular and insufficiently well-organized efforts failed to bring any worthwhile result.

In March 1972 professional divers of Hungary's Flood Control Service worked for more than a month at 38 m depth in the spring-mouth. They tried to clear the slot, plugged by long term accumulated construction rubble, but because of repeated silt collapses they had to stop the operation.

In February 1975, two divers of the Amphora Club were the first to enter the spring-chamber. After the necessary financial backing and materials had been obtained, regular exploration and development were started. On average, 8 to 10 divers went down for a 20 minute dive twice a day. A total diving time of about 300 hours between September 1975 and May 1976 was sufficient to survey and map every detail of the spring-chamber accessible to man. Divers found that the spring-water flowed into the crater from a chamber 14 m high and 17 m in diameter. This spring-chamber is split by a silt ridge at a depth of approximately 40 m, with a small depression on the eastern side and a larger one on the west. The divers measured water temperatures of 17.2° C at 43 m depth on the eastern side and 40° C at 46 m depth on the western side. As a consequence of waters of two different tem-



Section of the spring crater in Lake Hévíz. Legend: 1. peaty topsoil, 2. sandstone with claybanks, 3. sludge bed, 4. construction rubbles etc., 5. house of public bath, 6. Amphora spring chamber.

peratures mixing, the water which enters the spring-crater through the slot is at a temperature of 38.8° C connecting it with the spring-chamber. Thus cold water represents only 3 per cent approximately of the total water yield. At the base of the warm-water side may be found a light-brown, gelatinous coat averaging 3 cm in thickness, which has been formed by a thermophilic Actinomyces species in association with other bacteria. It can be sampled on the wall of small cavities between marcasite blocks, where the rate of water flow is the highest. Microorganisms forming long white filaments live on the roof of the cave and are probably also bacteria. Filamentous blue algae can be observed over a width of approximately 3 to 4 m on the steep wall of the cave where the warm water wells up to the surface. Freshwater sponges covering areas of 1 to 2 m^2 were found in several places of the crater wall where the water temperature was 26 to 30° C.

At the request of the Research Institute for Water Resources, the divers of the Amphora Club collected water samples. Analyses of these showed the age of the cold water to be approximately 8 thousand years and the warm water 12 thousand years. This period covers the time from the infiltration of precipitation into the soil to re-appearance of the water at the rising.

The interesting underwater Tavas Cave of Tapolca, 10 km from Lake Balaton, occurs at the contact of Sarmatian limestones and the Lajta Limestone (Leithakalk). The temperature of the water at the thermal cave entrance, in the centre of the town of Tapolca, is 18.6° C. Research work began there in 1957, when several entrances and the initial series of the underwater cave system were explored. In 1960—61, divers of the Hungarian National Defence Sport Association explored 300 m of swimming passage, of which they surveyed 214 m. During their dives they made a black and white underwater film which they presented in Vienna in 1961 at the IIIrd International Speleological Congress.

The recent investigations are carried out by the members of the Nautilus Cave Diving Club. Since 1967 they have explored 7 new air filled chambers and underwater passages of 300 metres. During the explorations, they have developed a new type of air pipe signal-system, not used in Hungary before. This equipment is well applicable in horizontale underwater cave passages at average water depth of 3—4 m. The aim of the exploration in Tavas Cave is to find a connection with the dry Hospital Cave or explore further dry chambers in which curing areas for patients with respiratory diseases could be accommodated.

The water brought to the surface by springs from the cave is collected in a lake, within the municipal area of the town, in which hosts of Phoxinus phoxinus live. This cavernophilic fish can be found everywhere in the flooded cave system.

Since 1968 the Delfin Diving Club have also taken part in further investigations thereby promoting the full exploration of the cave. The cave is open to the public but since the entrances to the flooded system are in the "paddling lake stretches", diving is possible only at night.

From the observations and measurements described above, the length of underwater cave can be estimated at several kilometres presenting an enormous challenge to Hungarian cave divers.

One of the thermal springs rising at the foot of József Hill in the heart of Budapest leads to a marvellous underwater cave. Although the existence of the cave had been known as early as 1858, it was not until the Spring of 1972 that divers of the Delfin Club succeeded in penetrating the flooded system. Formed in Upper Eocene marls, the cave is almost entirely under water. So far the explored length is 250 m, the greatest depth 30 m and the temperature of the water, harnessed by the nearby Lukács Bath, is 22° C.

In the north-eastern part of the country, near the Baradla Cave, are three additional underwater caves; the Baradla-Alsó Cave, the Rákóczi Caves of Esztramos and the Kossuth Cave.

During visits abroad, divers of the Amphora Club explored the 100 m long 23 m deep sump in the Csarnóház Cave, Romania. Beyond the sump they penetrated and explored 4.5 km of virgin cave. Again in Romania, members of the Nautilus Club attempted to enter the spring-cave of Izbîndis, exploring the sump for a distance of 140 m.

Divers surveying the newly discovered Amphora spring chamber in the Lake Héviz

Great difficulties have been met with in purchasing diving equipment for the three clubs mentioned here. Nevertheless, all have equipment suitable for carrying out underwater speleological investigations. Single hose regulators of the following types are mainly used: Scubapro Mark II, Scubapro Mark V, Scubapro Mark VII, Dacor Olympic 400, Snark Silver, Amphora Silver, Royal Mistral, P-11, Ukraine II. The same holds true for other equipment e.g. telephone, underwater lamps and photographic facilities. Due to difficulties in buying equipment, the majority is home-made.

A historical review of the work done and a list of the relevant literature were published, together with abstracts in English and Russian, in issue II, 1974, of this periodical.

English translation revised by R.A. Halliwell.

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HUNGARY

Kinga SZÉKELY

INSTITUTIONS AND RESEARCH-WORKERS DEALING WITH SCIENTIFIC INVESTIGATION OF CAVES AND KARST AREAS IN HUNGARY

I. Government Institutes, University Departments and State Enterprises

1. Mining Research Institute, Mining Hydrological Branch (Bányászati Kutató Intézet, Bányavizvédelmi Osztály)
H-1037 Budapest, Mikoviny u. 2–4. Tel.: 687-260.
Topics: fundamental and applied research devoted to karst water control in mines; karst hydrogeology; karst hydraulics; technology, equipment and systems of karst water control.
Director: Dr. A. Schmieder, head of research department
Staff: I. Bagdy, works engineer; Mrs. Ö. Gessler, research associate; I. Havasy, research associate; Dr. Zs. Keserű, senior scientist; G. Szilágyi, research associate; T. Willems, senior scientist

2. Hungarian Geological Institute (Magyar Állami Földtani Intézet)
H-1143 Budapest, Népstadion út 14. Tel.: 837-940
a) Department of Hydrology
Topics: hydrogeology of the karstic and non-karstic mountain areas of Hungary and the problem of karst features hidden deep underground.
Director: Dr. L. Szebényi, head of research department, geologist
Staff: Dr. P. Müller, research associate, geologist, I. Venkovits, geologist
b) Museum
Topic: Pleistocene vertebrates
Dr. L. Kordos, research associate, geologist

3. Transdanubian Research Institute of the Hungarian Academy of Sciences (Magyar Tudományos Akadémia Dunántúli Tudományos Intézete)
H-7601 Pécs, Kulich Gyula út 22. Tel.: 10–489
Topic: speleoclimatology.
Dr. I. Fodor, senior scientist, candidate of sciences

4. National Nature Conservancy Office, Speleological Institute (Országos Természetvédelmi Hivatal Barlangtani Intézet)
H-1121 Budapest, Költő út 21. Tel.: 366-744.
Topics: Establishment of a National Cadastrial Register of Caves and continuous registration of new entries in it. Development of plans for selected research subjects of outstanding importance. Co-ordination of speleological research works conducted in various scientific institutions with existing plans of research, exploration and cave-harnessing. Checking works stipulated in licences for the exploration and utilization of caves given to social organizations. Development, construction, equipment and operation of selected caves and/or fulfilling the duty of technical supervision in nature conservancy matters in caves given over to other organizations for operation. Collecting and evaluating reports on speleological research and on exploratory activities and submitting proposals as to the relevant forms of utilization The Institute performs its technical supervision of nature conservancy in caves in a close cooperation and coordination with the governmental and nongovernmental organizations interested.
Director: I. Saskó, director in charge
Staff: G. Magyari, geologist; T. Borza, geologist

5. Research Centre for Water Resources Development, Institute for Hydrology (Vízgazdálkodási Tudományos Kutató Központ Vízrajzi Intézet)
H-1095 Budapest, Kvassay Jenő u. 1. Tel.: 140-620
a) Department of Subsurface Hydrology, Karst Water Section
Topics: hydrogeology and hydrology connected with karst and nonkarstic springs, and fundamental research in hydraulics. Study of the effects of human intervention. Expertises for mine objects, water supply, etc. connected with karst water.
Staff: Dr. Gy. Dénes, research associate, geographer; Á. Lorberer, research associate, geologist; Dr. Ö. Ráday, research associate, geographer; L. Maucha, research associate, geologist; Dr. I. Sárváry, research associate, engineer
b) Hydrological Network Department, Karst Water Section
Topics: operation of the national karst water observation network and data collecting. The works are carried on by the staff of the Gellérthegy Laboratory of Karst Hydrology.
c) Data Bank Department
Topic: primary processing and storage of the data of the national karst water observation network
Staff: Dr. I. Sugár, research associate, geologist
Coordination of the works conducted at the above three departments is done by Dr. T. Böcker, candidate of sciences, scientific adviser.

6. Historical Museum of Budapest, Prehistorical and Ancient Section (Budapesti Történeti Múzeum, Ős- és Ókor történeti Osztály)
H-1053 Budapest, Károlyi Mihály u. 16. Tel.: 173-893
Topic: Paleolithic research
Staff: Dr. M. Gábori, department head, doctor of historical sciences
Mrs. M. Gábori, senior scientist, candidate of sciences

7. Natural History Museum, Geological-Paleontological Department (Magyar Nemzeti Múzeum Őslénytár)
H-1088 Budapest, Múzeum krt. 14–16. Tel.: 337-171
Topic: research devoted to Pliocene-Pleistocene vertebrates
Dr. D. Jánossy

8. Hungarian National Museum, Archeological Department (Magyar Nemzeti Múzeum Régészeti Osztály)
H–1088 Budapest, Múzeum krt. 14–16. Tel.: 130-678
Topic: Paleolithic research
Dr. T. V. Dobosi

9. Hungarian Natural History Museum, Botanical Department (Természettudományi Múzeum Növénytár)
H–1146 Budapest, Vajdahunyadvár
Topic: algal flora of caves
Dr. L. Hajdu, research associate

10. Department of Physical Geography, Eötvös Loránd University (Eötvös Loránd Tudományegyetem, Természetföldrajzi Tanszék)
H–1083 Budapest, Kun Béla tér 2. Tel.: 343-963
Topic: karst morphology
Dr. S. Láng, university professor, doctor of geographical sciences
Topic: surface karst morphology
Dr. L. Zámbó, first assistant

11. Ho Shi Minh Teachers' Training College (Ho Si Minh Tanárképző főiskola)
H–3300 Eger, Széchenyi tér 2.
Topic: karst hydrology and morphology of the Bükk Mountains
Dr. G. Tóth, first assistant

12. József Attila University of Szeged, Physical Geography Department (József Attila Tudományegyetem, Természetföldrajzi Tanszék)
H–6722 Szeged, Táncsics Mihály út 2.
Topic: complex research in karst morphogenesis
Dr. L. Jakucs, university professor, doctor of geographical sciences

13. Technical University of Heavy Industry, Miskolc, Department of Mineralogy and Petrography (Miskolci Nehézipari Műszaki Egyetem, Ásvány- és Kőzettani Tanszék)
H–3515 Miskolc-Egyetemváros
Topic: karst hydrological investigations of the Bükk Mountains
Department head: Dr. T. Polyák

14. Bakony Bauxite Mine Enterprise, Hydrological Department (Bakonyi Bauxitbánya Vállalat, Hidrológiai Osztály)
H–8003 Tapolca, Kossuth Lajos u. 2. Tel: 460
Director: I. Kiss, engineer, department head

15. Bauxite Prospecting Enterprise, Hydrological Department (Bauxitkutató Vállalat, Vízföldtani Osztály)
H–8220 Balatonalmádi, Rákóczi u. 10. Tel.: 38-161
Director: Gy. Hőriszt, department head, hydrogeologist
Staff: István Hegedűs, geologist-engineer

16. Administration of the Bathing Establishment of Budapest, Department for Water Resources Management, Laboratory of Balneology (Fővárosi Fürdőigazgatóság Vízkészletgazdálkodási Csoport, Balneotechnikai Laboratóriuma)
H–1369 Budapest, Pf. 328. Orlay u. 5–7.
Tel.: 460-700/177 460-762/13
Topics: Genetical problems connected with those subthermal to hot springs welling up on the eastern margin of the Buda hills whose waters of karstic character are used by the spas of the capital.
Director: G. Szalontay, chemist, engineer specialized in environmental control
Staff: G. Regőczy, hydraulic engineer, 4 technicians and 8 assistants

17. Municipal Sanitary-Epidemic Station (Városi KÖJÁL Járványügyi Állomás)
H–3529 Miskolc, Lévai u. 2.
Topic: Water pollution testing and evaluation
Director: Dr. J. Bársonyos, head physician

In addition to the above, there are hosts of enterprises and rese arch institutions which, along with their production activities, carry on scientific research devoted to karst and caves. So, for example, at the *Geology Department of Fehér County Bauxite Mines* (Fehér megyei Bauxitbányák Földtani Osztálya) (staff geologists); various departments of the *Dorog Coal Mine Enterprise* (Dorogi Szénbánya Vállalat), the *Tatabánya Coal Mine Enterprise* (Tatabányai Szénbánya Vállalat, Dr. P. Gerber, hydrogeologist), the *Geology Department* (Dr. A. Juhász, chief geologist) and the *Department of Exploration and Explosion Engineering* (F. Hegedűs) *of Borsod Coal Mine Enterprise* (Borsodi Szénbányák Vállalat Kutatási és Robbanástechnikai Osztálya); the *Geological Section of the Exploration and Drilling Unit of the Mecsek Ore Mining Enterprise* (Mecseki Ércbányászati Vállalat (hydrotechnician L. Rónaki); *South Transdanubian Territorial Geological Service of the Hungarian Geological Institute* (Dr. M. Kassay, geologist); *Baranya County Council* (Baranya megyei Tanács) (B. Vass,, chief engineer).

II. Scientific Research Stations

1. Jósvafő Karst Water Research Station, Research Centre for Water Resources Development (Vízgazdálkodási Tudományos Kutató Központ (VITUKI) Jósvafői Karsztvízkutató Állomása)
H–3758 Jósvafő, Tel.: Jósvafő 8
Topics: Scientific investigation of the Aggtelek-Jósvafő area at the surface, in caves and boreholes; karst-hydrological measurements and fundamental research. Examination of the karst-hydrological and speleological effects of geophysical agents.
Director: P. Szilvay, geotechnician
Staff: G. Izápy, works engineer, Mrs. G. Izápy, geotechnician, 2 instrument operators and 3 unskilled auxiliary workers.

2. Gellérthegy Karst-Hydrological Laboratory, Research Centre for Water Resources Development (Vízgazdálkodási Tudományos Kutató Központ (VITUKI) Gellérthegyi Karszthidrológiai Laboratórium)
H–1111 Budapest, Szent Gellért tér. Tel.: 669-875
Topics: observation, registration and processing of hydrological data on hot springs on the left bank of the Danube. The Laboratory is the centre of the National Observation Network.
Staff: 4 technicians, 6 operators, 2 mechanicians.

3. Eötvös Loránd University, Department of Zoosystematics and Ecology, Speleobiological Laboratory, Aggtelek (Eötvös Loránd Tudományegyetem Állatökológiai Tanszék Barlangbiológiai Laboratóriuma, Aggtelek)
H–1088 Budapest, Puskin u. 3. Tel.: 339-929
Topics: regular investigations of the bios in the Baradla Cave and its relations to the environment; examination of the biology of the individual species concerned. Study of the conditions of living of various soil-dwelling animals under cave-laboratory conditions. Faunistic research in other Hungarian caves.
Director: Dr. A. Zicsi, titular professor, doctor of biological sciences.
Staff:
a) research in zoology:
K. Dózsa-Farkas, first assistant (*Enchytraeidae*)
Dr. I. Loksa, candidate of biological sciences, senior lecturer (*Arachnoidae*)
Dr. A. Zicsi, titular professor, doctor of biological sciences (*Lumbricidae*)
M. Pobozsni, research associate (*Diptera*)
I. Baranyi, senior scientist (environmental effects of the nervous system of lacustrical bivalves)
b) research in botany:
Mrs. Z. L. Igali first assistant (primitive fungi)

III. Scientific Collections

1. Bibliotheca Speleologica
Special Speleological Library of the Hungarian Speleological Society (Magyar Karszt- és Barlangkutató Társulat szpeleológiai szakkönyvtára)
H–1055 Budapest, Kossuth Lajos tér 6–8. II. 225.
Tel.: 311-793
The Library was instituted in 1959. Numerous foreign periodicals can be found, in Hungary, only here. No lending of literature. The stock of the Library is available only for being consulted on the spot.
The Library is on duty on Wednesdays from 4 to 7 o'clock p.m. In cases of emergency, exceptional visits, upon personal request, may be permitted.

2. Speleological Map Library
A special collection of the Documentation Section of the Hungarian Speleological Society.
H–1055 Budapest, Kossuth Lajos tér 6–8. II. 225.
Tel.: 311-793
Librarian: J. Horváth
No lending of maps, the material of the Library is available for being consulted on the spot on Wednesdays, from 4 to 7 o'clock p.m.

3. Speleocadastrial Archives
Field-reports of members of the Hungarian Speleological Society.
H–1055 Budapest, Kossuth Lajos tér 6–8. II. 225.
Tel.: 311-793
Responsible in charge: Dr. L. Kordos

4. Register of the Hungarian caves
Materials (descriptions, maps and bibliography of Hungarian caves) under elaboration

Hungarian Geological Institute (Magyar Állami Földtani Intézet)
H–1143 Budapest, Népstadion út 14. Tel.: 837-940
Responsible in charge. Dr. K. Bertalan, geologist

5. Cave Inventory
National Nature Conservancy Office, Speleological Institute (Országos Természetvédelmi Hivatal Barlangtani Intézet)
H–1121 Budapest, Költő u. 21.
Responsible in charge: T. Borza, geologist
The Inventory can be consulted by permission of the director of the Speleological Institute.

6. National Register of Springs and Karst Water Observation Wells (Országos Forrás-nyilvántartás és Karsztvíz megfigyelő kutak nyilvántartása)
Register of data on the Hungarian karst springs processed by the Data Bank Department of the Institute for Hydrology of VITUKI
H–1095 Budapest, Kvassay Jenő út 1. Tel.: 140-620

IV. Speleotherapeutical Institutions

1. Jósvafő Sanatorium of the Miners' Trade Union (near the Béke Cave) (Bányaipari Dolgozók Szakszervezetének Jósvafői Gyógyüdülője)
Sponsor: The Borsod Coal Mines Enterprise
H–3525 Miskolc, Kazinczy út 19. Tel.: 18–461
Director: Dr. B. Adorján, county head physician
Patronage by: Dr. P. Kraszkó, head physician in phthisiotherapy, Institute of Phthisiotherapy, Edelény; Dr. S. Takács, head physician, county sanitary-epidemic station
The patients treated in the Sanatorium are mainly miners.
The Sanatorium is in service from May to September, receiving patients in 7 turns, comprising 60 persons each.

2. Cave Health Resort of the Hospital of Tapolca (Tapolcai kórház barlangi gyógyhelye)
Operated by the Municipal Council of Tapolca
H–8300 Tapolca, Municipal Council
Director of scientific research: Dr. J. Somogyi, head physician in internal medicine
Staff: Dr. I. Fábsics, specialist in pulmonic diseases, dr. R. Czehelnik, laboratory specialist

3. Aspecific Local Unit of the Institute for Consumptives of the Council of County Baranya, (Baranya megyei Tanács Tüdő Gyógyintézetének Aspecifikus kihelyezett részlege), Abaliget. Operated by the Balneological Institute of the Council of Baranya.
Director: Dr. J. Hábel, head physician. Pécs-Mecsek, Tel.: 13-755
Scientific research work is directed by: Dr. Gy. Kövesi, section head physician.

4. Experimental Health Resort on Gellért Hill (Gellérthegyi Kísérleti Gyógyhely)
Topics: Investigation of possibilities for developing a speleotherapeutical health resort in dolomite rocks by utilizing natural resources. Under construction.
Investment by: the Administration of the Bathing Establishment of Budapest (chief engineer J. Horváth)

V. Touristic Establishments

1. Aggtelek-Jósvafő Cave Administration (Aggtelek-Jósvafői Barlang Igazgatóság)
H–3758 Jósvafő, Kültelek 2. Tel.: 7
Operated by the County Tourist Office "Borsod Tourist".
H–3525 Miskolc, Széchenyi út 35. Tel.: 14-876, telex: 62-273.
Head of office: I. Tózsa, tel.: 35-592.
Cave Director: mining engineer Gy. Zsolczai
Deputy Director: B. Várnay, Aggtelek, Hotel Barlang
The cave is open to visitors: April 1 to October 31 from 8 a.m. to 6 p.m. November 1 to March 31 from 8 a.m. to 4 p.m. Upon request previously presented, special trips may be conducted to the cave even in "off-duty" hours.

2. Lillafüred Cave Organization, István Cave and Forrás (Petőfi) Cave
Operated by the County Tourist Office "Borsod Tourist".
H–3525 Miskolc, Széchenyi út 35. Tel.: 14-876, telex: 62-273
Head of office: I. Tózsa, tel.: 35-592.
Cave operation directed by Lajos B. Tóth, economist specialized in business administration.
H–3525 Miskolc, Széchenyi út 35.
Managing director of the *István Cave:* Mrs. H. Dévai. H–3517 Lillafüred, István Cave.
Managing director of the *Forrás (Petőfi) Cave:* Edit Kovács. H–3517 Lillafüred, Forrás (Petőfi) Cave. The caves are open to visitors every day but Monday from 9 a.m. to 5 p.m.

3. Cave Bath of Miskolc-Tapolca (Miskolc-Tapolcai Barlangfürdő)
Operated by the Municipal Waterworks, Bathing Establishment and Canalization Works Enterprise (Miskolci Vízművek, Fürdők és Csatornázási Vállalat)
H–3532 Miskolc, Vas u. 18. Tel.: 16-438.
Director: Dr. B. Konczvald.
Operation directed by M. Delneky, technician. Address of the bathing establishment: Thermal and Cave Bath, Miskolc-Tapolca, Tel.: 33-451
Open from 9 a.m. to 6. p.m. the year round (closed at Christmas and on 1 January).

4. Földváry Aladár Cave (Esztramos-Felső-barlang) Operated by the Speleological Institute of the National Nature Conservancy Office.
Managing director: I. Saskó.
H–1121 Budapest, Költő u. 21. Tel.: 366-744.
Upon special declaration, the cave can be visited by research workers, specialists and members of study tour groups.

5. Lóczy Cave of Balatonfüred
Operated by the Tourist Office of Veszprém County.
H–8201 Veszprém, Münnich F. tér 3. Tel.: 13-750.
Director of the office: Mrs. J. Papp
Director of the cave: J. Simon
The cave is open to visitors round the year every day but Monday: April 1 to October 31 from 9 a.m. to 1 p.m. September 1 to March 31 from 10 a.m. to 12 a.m. and from 2 p.m. to 6 p.m.

6. Tapolca's Tavas Cave
Operated by the Tourist Office of Veszprém County.
H–8201 Veszprém, Münnich F. tér 3. Tel.: 13-750.
Director of the cave: Mrs. L. Oravecz
The cave is open round the year: May 1 to September 30 from 8 a.m. to 5.30 p.m. October 1 to April 30 from 8 a.m. to 4.30 p.m.

7. Szemlő-hegy Cave
Operated by the Speleological Institute of the National Nature Conservancy Office.
Managing director: I. Saskó
H–1121 Budapest, Költő u. 21. Tel.: 366-744.
The cave is under construction and is to be opened in 1978.

8. Pál-völgy Cave
Operated by the Speleological Institute of the National Nature Conservancy Office.
H–1121 Budapest, Költő u. 21. Tel.: 366-744
Managing director: I. Saskó.
Director of the cave: P. Börcsök.
The cave is open Fridays, Saturdays and Sundays from 10 a.m. to 5 p.m.

9. Buda Castle Cave
Operated by the Hungarian Speleological Society.
H–1055 Budapest, Kossuth Lajos tér 6–8. Tel.: 311-793.
Director: K. Barátosi, engineer.
The cave is open on Sundays from 10 am. to 5 p.m. (Presently closed because of repair.)

10. Tata's Kálvária Hill
Nature Conservation Area administered by the Hungarian Geological Institute.
H–1143 Budapest, Népstadion út 14. Tel.: 837-940.
Carbonate rocks of different age and type are shown "in situ". Visits are possible upon previous agreement with the administering organization.

11. Buda's Sas Hill
Nature Conservation Area administered by the Budapest State Forest Administration.
H–1054 Budapest, Széchenyi-rkpt 6.
Original open-air show of Hungary's dolomite flora. Only organized visits directed by expert guides are possible.

12. Paleokarst of Urkut.
Nature Conservation Area administered by the Hungarian Geological Institute.
H–1143 Budapest, Népstadion út 14. Tel.: 837-940.
The Nature Conservation Area comprises tropical karstic landforms of Cretaceous age unearthed in the course of the extraction of manganese ore.
Visits can be organized with participation of the staff of the Hungarian Geological Institute.

Kinga SZÉKELY,
Hungarian Speleological Society
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Kossuth Lajos tér 6–8.
HUNGARY

Tamás HAZSLINSZKY

ON THE SOCIAL ORGANIZATION OF HUNGARIAN SPELEOLOGY

Speleologists in Hungary began formal collaboration within the Hungarian Geological Society. In 1910 with the encouragement of a brilliant natural scientist, Ottó Herman, they constituted an independent Commission on Speleology. With the passing of time, the Commission was repeatedly reorganised and re-named, finally becoming the Hungarian Speleological Society. The Society (in Hungarian: Magyar Karszt- és Barlangkutató Társulat, shortened: M.K.B.T.) was last reorganised in 1959. It has a total of about 800 active members and is a member of the Hungarian Federation of Technical and Scientific Societies. Executive functions are administered by an Executive Board composed as follows:

Chairman:
Dr. Sándor LÁNG

Associate Chairman:
Károly JAMRIK
Dr. András JUHÁSZ
Dr. György DÉNES

Secretary General:
Dr. Tivadar BÖCKER

Secretaries:
Zoltán HÁZI
Tamás HAZSLINSZKY
Gyula HEGEDÜS
István SOHÁR

Board Members:

Dr. Dénes BALÁZS	Dr. Miklós GÁBORI
Dr. Jenő BÁRSONYOS	Dr. László JAKUCS
Dr. Károly BERTALAN	Dr. Dénes JÁNOSSY
Dr. István FODOR	Lajos RÉVÉSZ

In addition, the Society's business is managed by a permanent secretariat directed by Kinga SZÉKELY, a full time appointee.

The aim of the Society is to conduct scientific research on karst regions and caves and to publish the results; to co-ordinate work by karst and speleological specialists with that in cognate fields of science; to serve as forum for all theoretical and practical research in speleology and karst studies in Hungary.

The Society's scientific work is conducted in a framework of sections and/or commissions:

Section of Karst Hydrology and Geology
Section of Documentation
Commission on Speleoclimatology and Speleotherapy
Commission on Biology
Commission of Karst Morphology
Commission on Paleontology
Commission on Archaeology
Commission on Education and Training
Commission on Subaquatic Speleology

In addition, ad hoc committees will be formed to tackle specific tasks and there are standing committees such as editing committees and the Castle Cave Comittee which direct continuing operations. Such committees are entrusted by government agencies etc., to undertake special research in karst and speleology that may be required from time to time.

Society members conduct their research in *speleological research teams*. There are a total of 30 such teams within the Society at present. As a rule, individual teams operate within the organisation and financial framework of other entities such as sports clubs, academic institutions etc. The Society's function is to supply technical supervision, management and co-ordination. Close association between teams and the Society is assured because the Board of Trustees of the Society includes the heads of the teams, as well as its elected officers. The work of different teams within particular major karst regions is co-ordinated by a series of *territorial organisations* of the Society.

Significant events in the Society's calendar are report meetings held on Mondays from September to May, when speakers report upon their research or describe study tours abroad. Discussion meetings devoted to selected scientific problems of special importance are convened two or three times a year; the most prominent representatives of the appropriate scientific fields exchange and discuss their findings. Finally, theoretical and practical training courses in various subjects are organised occasionally for junior speleologists. An agenda of meetings is published monthly. For discussion of topics of international significance or to celebrate notable anniversaries etc., international conferences or other special meetings are arranged.

The Society has two regular serial publications: *Karszt és Barlang* ("Karst and Cave") is issued twice a year, in Hungarian and with English and Russian abstracts in most instances. It contains brief scientific communications reports on major national and international scientific achievements. *Karszt- és Barlangkutatás* ("Karst Studies and Speleology") is the year book of the Society and publishes larger papers of high scientific standing, mainly in selected foreign languages.

The Society's expenses are met from membership fees, contributions by government organisations and industrial enterprises as well as considerable subventions by the State. The Society holds the nation's only official speleological library, which maintains efficient ecxhange arrangements with other important speleological institutions and organisations around the world.

English translation revised by D.C Ford

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HUNGARY

Dr. György DÉNES

ON THE HUNGARIAN CAVE RESCUE SERVICE

Occasional cave accidents occured in Hungary before 1930, but with the increase in cave exploration from 1930 onwards cave accidents became increasingly frequent especially in the 1950's. In a metropolis with 2 million inhabitants, caves of thermal water origin occur, both in the suburbs and in the heavily built-up central area. The many high avens as well as deep fissures and a labyrinth of underground tunnels have always attracted both speleologists and large numbers of young people searching for adventure. Armed with an old clothes line and occasionally with a couple of candles or a single torch, young people have often attempted to penetrate such underground labyrinths, being unaware of the many dangers a cave may keep in reserve for the inexperienced visitor.

On several occasions the frayed clothes line did break and the young men hanging from them fell to their deaths in the deep shafts or suffered serious injuries. Similar accidents also occured to cavers groping about in the dark or in flickering candle light. Large or small groups of people who are unfamiliar with caving often lose their way in the complex labyrinth of thermal caves, their torches become run down or their candles burn out. When they continue groping about in the dark, they may easily fall down a pit or deep rift. While helplessly stuck and in danger of dying they are awaited anxiously by their families. In despair, members of their family will ask the police for help. In order to find and rescue people lost and/or injured in a cave, the police will automatically call for the assistance of skilled cavers. There was a case when, because of a delay in informing the police, rescuers were requested to search for four young people a week after their disappearance. Searching all the caves of the region one after the other, they succeeded nevertheless in rescuing the unlucky foursome, still alive, though unconscious.

In order to reduce any loss of time due to the lack of an efficient cave rescue organization and to be able to bring assistance as quickly as possible to injured cavers the present writer organized the Hungarian Cave Rescue Service in 1961, and has directed it ever since. The authorities welcomed the establishment of this organization and made use of it for every cave accident as well as in other cases where the situation was similar to cave conditions.

The Hungarian Cave Rescue Service is part of the Hungarian Red Cross, but its staff are recruited from members of the Hungarian Speleological Society and the Hungarian Federation of Nature-Lovers. The Headquarters of the Service is in

Embleme of the Hungarian Cave Rescue Service

Budapest, but rescue teams have also been organized in the country's major karst regions.

The core of the Service is represented by the so-called "alert teams". Their members undergo a high-level training in first-aid and rescuing people from caves and attend both theoretical and practical refresher courses. The personal and communal equipment of the "alert team" is kept constantly ready for use in the depots of the Service. In case of an alarm the "alert teams" are able to reach the site of the accident within one hour.

In case of accidents needing a larger number of rescuers the members of a second-level rescue-service are alerted. They have undergone a medium-level training in first-aid and rescue techniques and have passed the relevant examination. In cases, where even these forces are still insufficient, the Service is allowed to invite any organized, active caver to participate in the rescue operations.

Accidents and disappearances are usually reported to the police, who ask the head of the Service to call its duty "alert team". The police also provide vehicles to transport the rescuers to the site of the accident. Depending on the rescue work to be undertaken, the members of the "alert team" collect the required equipment from the nearest depot en route to the site of accident.

Taking part in rescue operations is the voluntary and honourable duty of every caver and the Cave Rescue Service is highly appreciated by both the general public and official bodies. As a result of saving lives on many occasions several of its members have been awarded State decorations. The greatest pleasure of each active member of the Service is that of having been able to help people in trouble and of seeing people rescued safely from grave danger.

English translation revised by R.A. Halliwell.

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MAJOR HUNGARIAN SPELEOLOGICAL PUBLICATIONS

The origins of Hungarian speleological literature can be traced back to the 16th century, the first record of caves in Hungary dating from 1549. Hungary's speleological bibliography for the three centuries prior to 1830 comprises some 120 items in all.

The first independent speleological work, the description of the Aggtelek Cave with a survey and longitudinal section, was published in 1831 by Imre Vass. He was far ahead of his time and used a natural scientific approach to deduce conclusions which are still valid today. His survey is still the most accurate and detailed ever made of this cave.

After 1830, devoted to speleological subjects were published at an ever increasing rate, so that their number had increased by a further 780 items by the turn of the century. This trend did not decline and the bibliographic files for the year 1945 comprised more than 4,400 titles. Re-organised after the Second World War, speleological research has been given an unprecedented impetus so that recently the Hungarian speleological bibliography has been increasing by an annual average of 500 items.

From this wealth of bibliographic materials, the speleological periodicals and the recent publications of the Hungarian Speleological Society which are still obtainable at present have been listed here.

Periodicals:

Barlangkutatás — Höhlenforschung (Speleology). In Hungarian and German languages, 27 parts issued in 17 volumes from 1913 to 1944.

Barlangvilág (World of Caves). 27 parts issued in 13 volumes from 1926 to 1943.

Karszt- és Barlangkutatási Tájékoztató (Information Bulletin on Karstology and Speleology). 1 to 12 parts issued annually, exclusively in Hungarian, from 1956 to 1974.

Karszt és Barlang (Karst and Cave 1 or 2 parts). issued annually since 1961, in Hungarian, with abstracts in German in earlier times, recently in English and Russian.

Karszt- és Barlangkutatás (Évkönyv) (Karst Studies and Speleology, Yearbook). 1 part issued at 1—2 yearly intervals since 1959, a total of 7 issues up to the present, mainly in English and German.

Periodicals for sale:

Karszt és Barlang, from the 1962 volume onwards.

Karszt- és Barlangkutatás (Yearbook), Volume II to VII.

Other publications:

Symposium on Karst-Morphogenesis. Papers. Budapest, 1973, 304 p.

Beszámoló a Nemzetközi Barlangtani Unió Barlangterápiai Szakbizottságának magyarországi (II). szimpóziumáról (Report on the Symposium (II) of the Commission on Speleotherapeutics of the International Speleological Union). Budapest, 1975, 168 p.

Baradla 150 Nemzetközi Konferencia 1975 (International Conference "Baradla 150", 1975). Budapest, 1975, 246 p. (in Hungarian and English).

Field-trip guide to the International Conference Baradla 150. Budapest, 1975, 45 p. (English).

Out of the above, the following items are still obtainable:

Symposium on Karst-Morphogenesis and *International Conference "Baradla" 150*.

The publications can be purchased at the *Hungarian Speleological Society (H-1055 Budapest, Kossuth Lajos tér 6—8)*. Upon written request, the Society is ready to send interested persons publications on exchange as well.

English translation revised by R.A. Halliwell.

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HUNGARY

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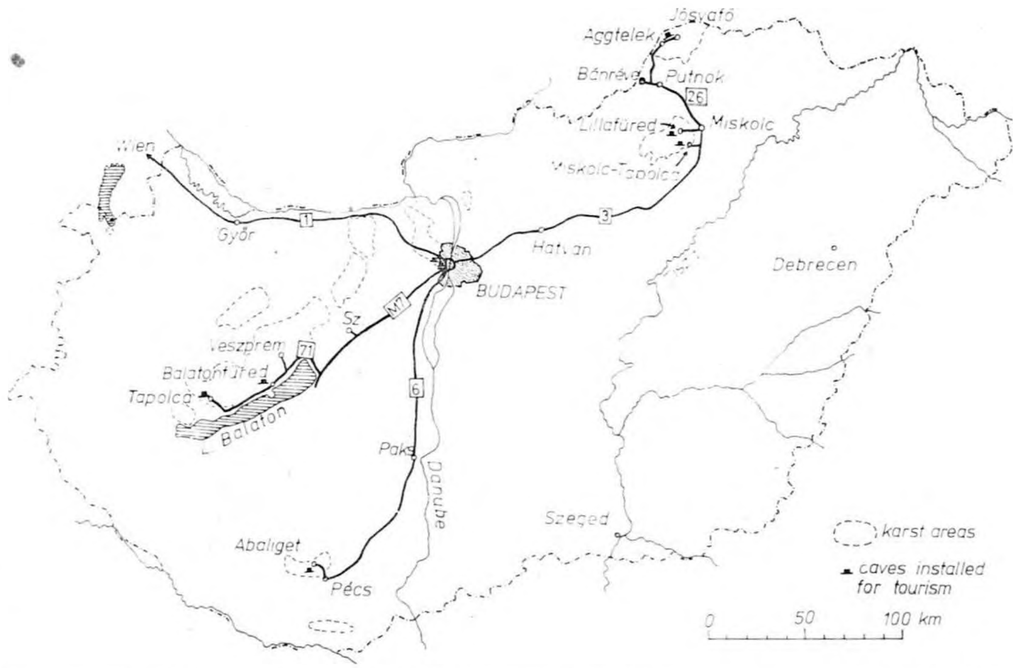
TOURISM IN HUNGARIAN CAVES

Prehistoric man visited the Hungarian caves as early as many thousand years ago, as he there found protection against the vicissitudes of weather. Visits to caves, motivated by mere curiosity or by the longing of people for explorations, began in the first half of the 18th century. It was in the first place the strange underground realm of the Baradla Cave at Aggtelek that attracted hosts of visitors. In the 19th century almost all Hungarian notabilities paid visits to the cave. Poets and writers referred in their works in superlatives to the scenic beauties they had seen there. Scores of famous foreign visitors did also come to see the Baradla, so for example, the British traveller R. Townson in 1793, who gave a detailed description of the cave in his book (Travels in Hungary, London, 1797).



Locations of the Hungarian caves installed for tourists and their accesses on road from Budapest

Beside the Baradla, several other caves were made accessible to the public in the late 19th and early 20th centuries. Touristic facilities were further improved in the Baradla, too: in 1935 electric lighting was installed and hotels were built near its entrances. Because of difficulties in transport and communications, access to the cave was and still is uneasy. Notably, Aggtelek village lies at the Nation's northeastern frontier, far away from the capital, being out of reach of any railway line even today. So tourism to both the Baradla and other Hungarian caves could develop in a large scale only after Second World War.

At present, nine Hungarian caves are installed for and open to receiving tourists. Here they are:

Baradla Cave (Aggtelek Karst Region, Jósvafő and Aggtelek villages)

István Cave (Stephen's Cave, Bükk Mountains, Lillafüred resort)

Forrás Cave (Spring Cave, also called Mésztufa Cave — Travertine Cave — or recently, Petőfi Cave; Lillafüred resort)

Miskolc-Tapolca's Cave-bath (Bükk Mountains)

Abaliget Cave (Mecsek Mountains, near Abaliget village)

Tapolca's Tavas Cave (Lake Cave at Tapolca, Balaton Highland)

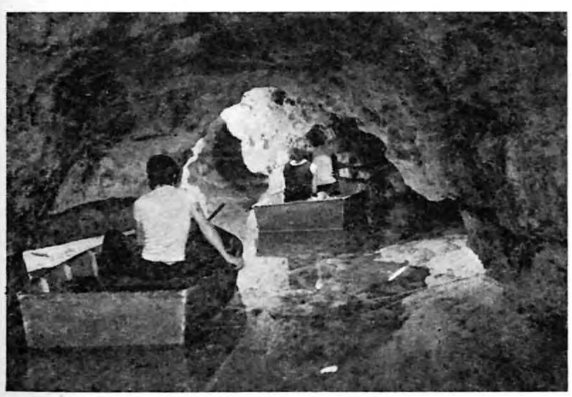
Lóczy Cave (Balaton Highland, near Balatonfüred)

Pál-völgy Cave (Buda Mountains, Budapest)

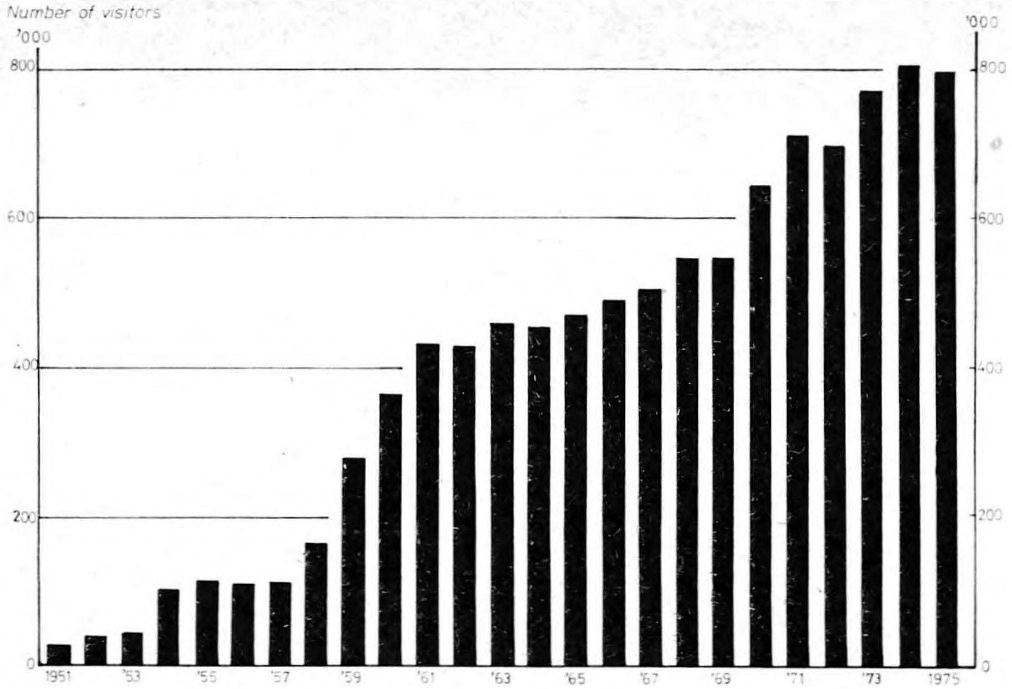
Várbarlang (Castle Cave on Castle Hill, Budapest)

During the past 25 years (1951—1975) a total of more than ten million persons, nearly equalling the total of Hungary's population, visited those Hungarian caves installed for tourists. Let us quote a couple of figures to illustrate the visits paid to the most favourite caves:

Baradla Cave	2,605,705 persons
Lillafüred Caves	1,862,968 persons
Tapolca's Tavas Cave	1,818,745 persons
Abaliget Cave	705,793 persons
Other caves	484,736 persons
Miskolc-Tapolca's Cave-bath	2,663,684 persons
Total	10,141,631 persons



Boating in the Tapolca's Tavas Cave



Increase of tourism in Hungarian caves in the past 25 years

The Baradla is still the most popular of all, receiving more than 200,000 visitors a year. The cave has three main entrances, a natural entrance in Aggtelek village and two artificial ones near Jósvafő village. The cave administration organizes short, medium-size and long trips for visitors. A long trip, from Aggtelek to Jósvafő along the main passage of the cave, takes 5 hours. Visitors of the Aggtelek part of the cave can enjoy the pleasure of paddling in boats on the underground river. In the summer period, concerts are organized in one of the big cave chambers.

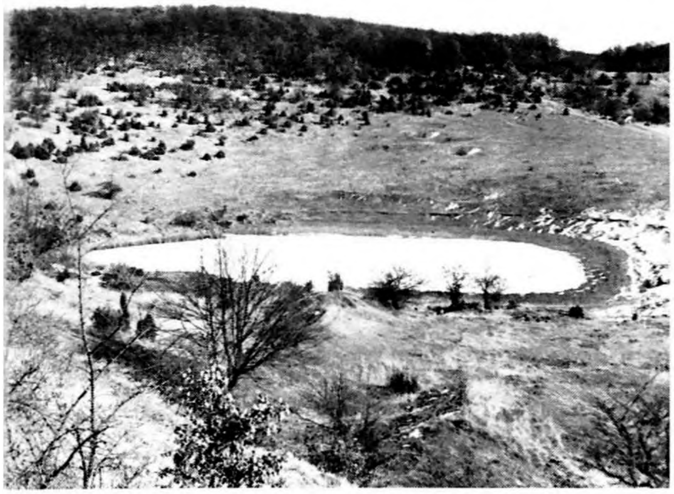
A very great number of people pay visits to the Tapolca Cave-bath near the city of Miskolc. Installed in a natural cave chamber, this bathing pool is fed by a hot spring yielding daily 8 to 15,000 m^3 of water with a temperature of 31° C. The warm water containing iodine, bromine, potassium and radium-emanation is very good for curing circulatory trouble, blood-vessel disorder and different nervous complaints.

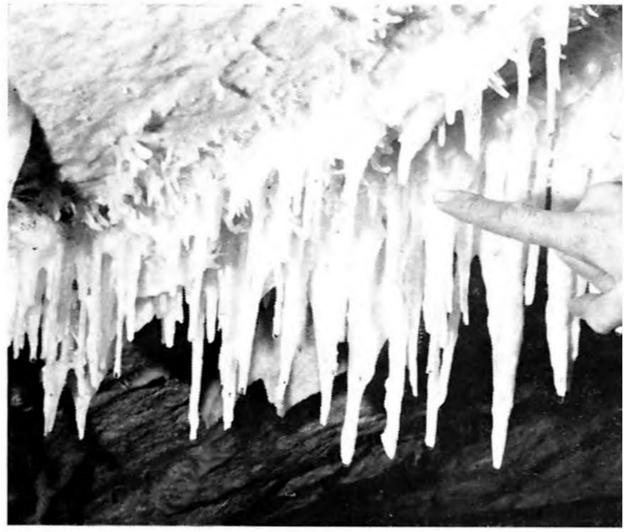
To conclude, let us mention Budapest, the capital of Hungary, often referred to as the City of Caves. Really, a labyrinth of caves extends over many kilometres beneath the Buda parts of the metropolitan area, sometimes just a few metres below residential houses. These caves, however, would be less spectacular to the public, being all the more instructive for speleologists and enthusiastic young cavers. The nicest cave in Buda, the Szemlő-hegy Cave, is now being installed for tourists, and is soon to be opened for the public.

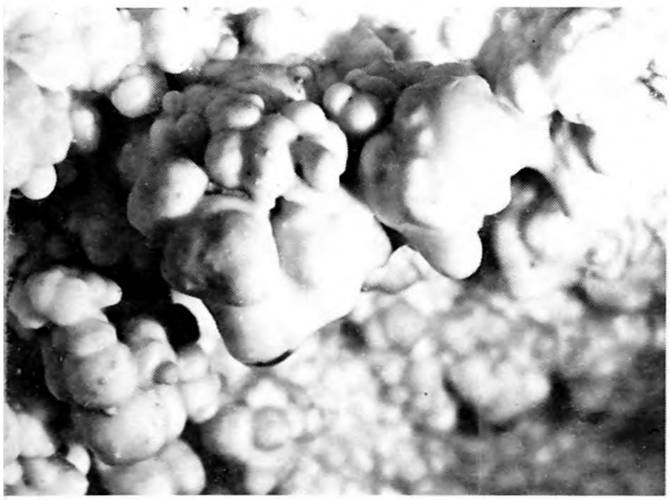
Acknowledgements

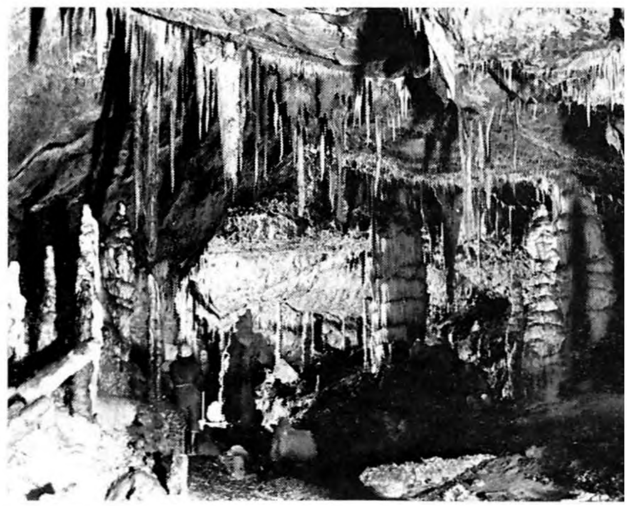
The editorial board of Karst and Cave wish to thank *Prof. D.C. Ford* and his co-workers, *Mrs. M. Karolyi Bourque* and *Mrs. A. Pluhar*, McMaster University, Dept. of Geography, Hamilton, *Dr. A. C. Waltham*, Trent Polytechnic, Nottingham and *Mr. R. A. Halliwell*, Academic Office, The University of Hull, for their carefull revision of the English translations of the papers.

Back cover photo: The bottom of Almási Shaft, Alsó-hegy Plateau, North East Hungary









First line left: "Vörös-tő" (Red Lake) doline lake at Jósvafő, right: Stalactite nursery in the Meteor Cave (by P. Tihanyi)
Second line left: "Pea stone" formations in the Ferenc-hegy Cave, Budapest (by L. Gazdag), right: Main passage of Baradla Cave near the "Minerva sisakja" (Minerva's helmet, by P. Borzsák and A. Prágai)
Below left: Dripstone drapery in the Giant's Chamber of Baradla Cave, right: Portion of a column in the Baradla Cave (by P. Borzsák)

Karst and caves in Hungary