# SYSTEM OF SPELEOLOGICAL INTERACTIONS

## Results of the Jósvafő Karst Research Station in its first decade

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## Introduction

The karst and speleological research has valuable traditions in Hungary. About 2000 km$^2$ of the extension of the country represents a karstic area and especially the karst-region of *Aggtelek-Jósvafő* in Northern Hungary is rich in developed karstic phenomena, being among the karstic areas of worldscale importance. The scientific study of the caves has been going on here since the beginning of the XIX$^{th}$ century from the point of view of their geodesical, cave-genetical, zoological, botanical, paleontological and archeological aspects. From the twentieth years of our century the exploration of raw materials necessitated also the study of our karst-areas as regards their geological, hydrological and morphogenetical aspects, because the centers of our coal- and bauxit-mining areas are lying in karstic regions. Therefore the problems of protection against water inflow in mines as well as those of industrial- and drinkingwater-supply highlighted also the karstwater-investigations in the country.

After World War II as a result of the important industrial development a whole network of research stations was set in throughout the country. The Karst Research Station of Jósvafő was installed in course of these developments. Prof. F. P a p p , Head of the Institute for Mineralogy and Geology at the Technical University of Budapest wanted to create a new type of observatory resp. experimental station for karst-hydrological and geological engineering research when he inaugurated the work of the research base in 1957 in the frame of the Institute. The Research Station was built in the vicinity of the *Vass Imre*-cave, explored by the Scientific Students' Association of the Institute in 1954.

A considerable help came from Prof. T. C h o l n o k y, the then rector of the University, for the installation of the Karst Research Station in Jósvafő, who organized the material contributions of 16 Institutes of the University to provide the building means for the Station, while Prof. A. R e i s c h l contributed by designing the plans of building.

## Tasks of the Research Station

Prof. F. P a p p has dealt with the solution of hydrogeological problems of Transdanubia as early as in his studies before World War II., and he discussed problems of geological engineering character of interactions of rocks and water. He realized very early that it is not sufficient to study the karstic regions from aspects of one single branch of science only, if we want to be acquainted with the present phase of the karstic development, but we have to study the originally physico-chemical processes going on in the karstic rocks and caves. It is at the first sight conspicuous how great is the complexity of time-changes of natural factors influencing the movement of karstic waters and its rules. Both the requirements of scientific cognition and those of technical praxis made it necessary that the modern geophysical and geochemical aspects should be extended to the karstic regions and used when interpretating the phenomena.

It is obvious that the karstic regions, owing to the special physical and chemical structure of carbonate rocks, occupy, together with the volcanic areas, a special place among the geological formations. Both formations deviate essentially from the other formations of the crust that on these areas the speed and intensity of the actual geological processes are greater. Owing to this fact the present geological processes can be observed best of all on the volcanic areas being still active. The actual karst-dynamics are not so vigorous and spectacular, nevertheless these provide a special observability since the karstic processes of high speed and intensity — originating from the physical and chemical instability of karstic systems — can be studied in the caves, that is inside the formations themselves. That is why conception of Prof. F. P a p p was of utmost importance that one of the basic research centers of the Hungarian engineering and hydrological geology for the investigation of natural phenomena should be created just on a karstic territory. It is therefore the aim of the Karst Research Station of Jósvafő that it should represent an observatory for the special natural phenomena taking place actually in the karst itself, it should investigate the complex interdependence of the processes and evaluate the observed phenomena from scientific and technical point of view.

## Conception of revealing karstic processes

In accordance with the original program — given in its main features by the dynamic and rich inventive power of Prof. F. P a p p — it was a fundamentally important result of the past 10 years that — basing on the investigations — we succeeded to construct such a comprehensive working hypothesis concerning the entity of karstic processes, which is apt to serve as a logical basis for detection of all processes unknown as yet. The outgoing point of the new working hypothesis is the idea that all the natural phenomena taking place on the surface of the Earth originate from the interactions of all the material systems, which are present and are of different developing stage, and these interactions assert themselves in all possible relations.

The reality of this idea is especially obvious with the study of origin of karstic processes, if — for sake of better perspicuity — we introduce some new terms. The carbonate rocks, the karstic sediments both underground and on the surface and the mineral fillings in the caves may be regarded as the "solid phase" of the karst. The karst-water containing dissolved rocks and minerals represents the "liquid phase", while the air of the caves with an Ca-Mg aerosol-content may be treated as the "gaseous phase". In any case, an important role can be attributed to the organisms living underground and to the system of physical radiations and fields affecting the whole Earth. The actual karst processes can be derived from the complex interactions in the cavity-area of karstic rocks: therefore it seems justifiable to speak about "speleological interactions". This terminology indicates the essential characteristics as regards the praxis of research too, since the karstic caves provide a possibility for the immediate observation of processes originating from speleological interactions in case of natural equilibrium conditions.

| Broker \ Reagent | Physical radiations and fields M (Microphysics) | Gaseous-phase C (Climatology) | Liquid-phase H (Hydrology) | Solid-phase G (Geology) | Living organisms B (Biology) |
|---|---|---|---|---|---|
| Physical radiations and fields M (Microphysics) | 1. M ↔ M | 6' M → C | 10' M → H | 13' M → G | 15' M → B |
| Gaseous-phase C (Climatology) | 6" C → M | 2. C ↔ C | 7' C → H | 11' C → G | 14' C → B |
| Liquid-phase H (Hydrology) | 10" H → M | 7" H → C | 3. H ↔ H | 8' H → G | 12' H → B |
| Solid-phase G (Geology) | 13" G → M | 11" G → C | 8" G → H | 4. G ↔ G | 9' G → B |
| Living organisms B (Biology) | 15" B → M | 14" B → C | 12" B → H | 9" B → G | 5. B ↔ B |

*Fig. 1.*

## System of speleological interactions

We get a good overall view of the entity of possible karstic processes if — basing on the considerations above — we put together systematically the main types of speleological interactions to be derived from all the interactions of the given material systems. The system of speleological interactions has been built up so that the material systems being present in the karst — owing to their active or passive effects — has been represented both as agents of reagents (Fig. 1.). The character-signs along the axes (abscissa and ordinate) (in the same sequence) for the representation of concepts are the initials of the names of branches of science approximating the conventional areas of karst-research, except for the notation: "M" for summarizing the subatomic systems ("Microphysics"). This branch of science represents a new tendency for the karst-research. Though the given characters (notations) do not cover fully the concept of systems being in interaction in the karst, they might be accepted in a symbolic sense, since they help us representing all the transitions between branches of science having been cultivated in separation one from another before.

The new system provides for the representing of 15 types of interaction in all. From left to right diagonally (notation 1 to 5) we find the interactions of the material systems taken as basis among themselves. The remaining 10 interactions are divided in two parts, containing partial effects of opposite directions, this being a repartition which does not correspond with the real conditions but it is useful to the praxis of research. (It is true that the investigations carried out as yet also in the individual marginal areas have discussed — in most cases — only the effect of one of the systems on the other). The notation of interactions divided into partial effects was made on both areas of the same numeration by one prime in the direction of one of the effects and by two primes in the other. On the areas to the right of the diagonal of the "own interatcions" we find the notations from 6′ up to 15′ while to the left of the diagonal the numeration goes from 6″ up to 15″ ordered in parallel rows to the diagonal.

The table of the system of speleological interactions proved to be a very useful tool of the theory of cognition. The areas enframed with thick line have been related as yet to the investigations of the karst-problem. The investigations of the Karst Research Station of Jósvafő in the past 10 years dealt with shaded areas. In the next chapter when summarizing the research results of the Station we sill indicate the results achieved in the area of one interaction (or partial interaction) by the ordinal numbers (in round brackets); in square-brackets we give the numbers of references. The areas left unshaded or without framing are the regions of karst-processes originating from interactions as yet unknown — as far as we know, i.e. awaiting new and further research. With the aid of the table, however, we are able to forecast what new interaction-types are likely to be detected in the future.

## A Summary of Research-results of the Past Decade

When setting in the works of the Research Station valuable help was received from the National Meteorological Institute, from the Research Institute for Water Resources and from the Veszprém University of Chemical Industry by providing instruments of basic importance and laboratory equipment and by organizing the first measurements. The investigations of the first 10 years at the Station extended — besides the interactions of the solid, liquid and gaseous karstic phases with themselves and with each other —

also to such karst-processes which represent the effects of living underground organisms and of certain physical fields to the karst-phases. Naturally, the collaborators of the Station payed attention to the structure and arrangement of the karst-phases resp. to the study of their chemical composition, since all the material systems being present in the karst interact also individually by means of a great number of active physical, chemical and biological form of motion or by means of passive formal factors, geometrical forms the processes taking place in their environment.

As regards the solid phase the first results of the Station consisted of a geodesical and magnetical survey and morphological investigation of the surrounding caves [14, 17, 18, 29, 40, 44, 61]. During a geological mapping on a 1:10 000 scale of the surroundings of the Station it became obvious that the triassic formations of alpine development show a rather complicated picture in petrographical, stratigraphical and tectonical respect alike. Owing to the detailed petrochemical analyses carried out at the Station the former hypothesis has been proved that between the middle-triassic dolomites and limestones all kind of transitions can be found. Supposed that the middle-triassic dolomites occur only at the Gutenstein- and middle-Ladin-niveaus, we could get a consistent picture of the stratigraphical and tectonical conditions and there was a possibility of a more detailed geological surveying of the middle-triassic formations [24, 26].

The genetical investigation of the karstic and dolina-filling sediments of the sourroundings of *Jósvafő* led to the result that these red and reddish-brown clays consist partly of dissolution-residuals of middle-triassic limestone, partly of resilicified bauxite-sediments as well as of volcanic tuffs, loess and of the organic content of actual soils. The reasons for the wide-scale mixing are: the sediment-accumulation accompanying the karstic block-building lasting for an even geologically long period, the special sediment-reserving of karstic type and the continuous reaccumulation. The age of these formations can not be determined owing to what was said above, we can state only that they are homogenized products of polygenic origin of the era from the Cretaceous up to now [3].

As regards mineralogy the collaborators of the Station were able to achieve new results investigating the formation of cave aragonite and its transformation into calcite. By means detailed investigations they succeeded to state the characteristic trace element differences in pisolites separated from cold and warm water. It became obvious that the Sr-ion content of pisolites with a higher aragonite content is generally higher, resp. their Mg-ion content generally smaller, than that of the calcite-pisolites. It could be proved that the Sr-ion exerts a stabilizing effect, while the Mg-ion can be characterized by a mobilizing influence with the aragonite-calcite transformation processes [10, 11].

Owing to the uncertainties observed in the course of aragonite-determinations we made special checking investigations regarding the mechanism of the reactions serving for the detection of aragonite. Taking into account the rules of the theory of chemical equilibrium we succeeded — by introducing standardized conditions — to elaborate a modified procedure which provided the possibility of a quantitative estimation of aragonite content too [5].

For the investigation of the influence of the liquid karst-phase exerced upon the solid one we determined the average growing-speed of the primary stalactites as a function of the feeding water supply and of the hardness of water (8′). The experiments have verified the order of magnitude of the average growing speed deduced theoretically, which value is (in case of average conditions: concerntration of 20 German hardness-degree, feeding water yield: 0,2 litre/day) about 5 mm/year [4].

The study of formation of helictites led also to new results. It is obvious that two main types can be distinguished: the first of them is represented by generally curved helictites containing in the inside a capillary, while the other type consits of needle-like formations without capillary. The building mechanism of the needle-like formations could be deduced from the effect of the gaseous phase exerted upon the solid one (11′). We succeeded to apply the analogy of rime — accreation to these types, taking into account the aerosol-content of the air of the caves (c.f. later the discussion of the gaseous phase) [13]. Investigations on cave colourations at the Station concerning the origin of black coatings corroborated the previuos view that these coatings are in connection with the metabolism of manganese and iron bacteria, i.e. these present the influence of living organisms on the solid phase (9″). The black colouration of samples collected in the vicinity of settlements of prehistoric men in the stalactite cave of *Aggtelek* originated nearly completely of soot- and bitumen-content. Contrary to this the black coating to be find along the cave-streams the water or which is rich in solute oxygen could be proved to consist in 97—99% of ferric-oxide-hydrates and in 1—3% of manganese-oxide and to be in a mineralogically amorphous psilomelane form. Thus because the bacteria of iron and manganese obtain the energy necessary to their vital process from chemosynthesis, it is highly probable that the manganese and iron ion content of the cave-streams will be accumulated by these organisms and precipitated to the surfaces frequently contacting waters rich in oxygen (12′, 9′ 9″) [48, 51].

In connection with the colouring of the stalactites the investigation of yellow-brownish coatings posed also interesting questions. It has been known since long that the stalactite resembling straw resp. the innermost primary ring of all stalactites are in all cases free from colouring, while the layers originating from outer afflux contain often iron resp. manganese. The problem has been cleared by the result of investigation, which pointed to the surprisingly small oxygen content of the waters dropping out from inside of the stalactites. The idea came up that the precipitation of iron and manganese content is bound to oxydative zones, i.e. to the aerated, spacious duct-systems. But the narrow ducts filled completely with water in the karst can be regarded as parts of the reductive zones, where the iron and manganese ions remain in solution. Thus the primary stalactites are free of colouration if they come out of the waters of the reductive zone (8′) [46, 52].

The demonstration of tidal phenomena of the karstic water-level — one of the most important achievements of the Station — we will be summarized later, together with the results of investigations of the liquid phase. The investigation of this phenomenon has cleared the influence of the lunisolar variations of the gravitational field to the rigid karst-phase (13′) [1, 31, 32]. In this connection came up also the problem of interactions between earthquakes and the deformation of the crust owing to tidal forces [4].

We may report also methodological results achieved by the research Station in connection with the solid phase. New method has been elaborated for the photogrammetric cross-sectioning of caves, for a numerical characterization of mineralogical-petrographical conditions of caves, for the exact measuring of the growth of stalactites and helictites, for the demonstration of development of needle-like helictites by means of an "aerosol-effect" and for the on-the-spot as well as telemetric investigation of karstic lithoclase-fluctuation [4, 13, 15, 31, 32, 38, 39, 42, 43].

During the past decade 31 scientific papers were published, concerning of investigations of the solid phase (c.f. list of references).

The studies of the liquid-phase started at the Research Station with an experimental investigation of hydrographical connections of the surrounding area. Tracing made with fluorescein and salt led to detection of new connections between the *Vass Imre*-cave and the *Milada*-cave in Slovakia, between the *Lófej*- and *Nagytohonya*-spring and between the *Kistohonya*- and the *Szabókút*-spring too [35, 36, 57, 59].

Besides the initital research-results one of the most important part of the 10 years activity of the Station were the investigations on springs with special instruments. The measurements were related to the yield of the springs in the vicinity of the Station, to their temperature and chemical analysis by means of on-the-spot invetigations and to the determination of electric conductivity. In the second 5 years of the activity of the Station we had the opportunity to make many new observations by the continuous registration of the discharge of three big karst-springs. It became obvious that the yield-changes of karstic springs are much more differentiated and they depend on a greater number of natural factors than it was thought before. Besides the well known climatic factors (precipitation, air-pressure etc.) the discharge-registratum of several years' period have thrown light on many kind of aclimatic variations hardly known before. Two of the springs investigated *(Nagytohonya-* and *Lófej*-springs) have shown a varied series of syphon-outbursts, so that we were able to get a very extended mass of informations about the functioning and structure of karstic syphons. The collaborators of the Station succeeded to prove — by means of hydraulic model-experiments — that in the underground water-system of the *Lófej*-spring a special combination of three syphons causes the aclimatical outbursts, the preceding minimums and the pulsations between the outbursts. It was possible to observe to the first time that at the end of every syphon-outburts an after-peak or — in form of a secondary peak — a regular increase of the water output sets in. The model-experiments proved that this "end-effect" follows from the mechanism of emptying the syphon. Thus we obtained an experimental proof of the conception that the greatest abrupt aclimatical yield-changes of the karstic springs originate really from the syphon-functioning (8″) [31, 32].

The investigation of the karstic-syphon-springs, however, enabled us to demonstrate the existence of other unknown aclimatical factors. The statistical processing of the graphs of yields led to a spectacular result. It became obvious that the starting time of the outbrusts of both syphon-springs were fairly exactly at 6, 12, 18 and 24 hours in 30% of the cases investigated. Starting from this conclusions we succeeded to prove the existence of a tidal phenomenon of the karst water level, by comparing several statistical studies (independent one from another) among themselves as well as the yield-graphs with the lunisolar variations of the gravity field. According to our present knowledge of the influence of the lunisolar variations (of a period of 12-24 hours) of the gravity field tidal deformations of the same period take place in the solid crust too (13′). Owing to these on the karstic areas along the vertical faults 6>12 hourly transversal contractions occur, the extent of which amounts to 2—3 microns according the measurements. This causes variations of the same periods in the interspaces of the karstic water-reservoir and as a result of this the level of the karstic water shows oscillations with an amplitude 10—20 cm (8″). These tidal waves will be transferred through the underground currents feeding on the karstic water-level in form of pressure-waves against the springs where they produce variations of the yield of 150 l/min order showing the same periodicity of 6—12 hours. The karstic syphons formed in the water system of the springs act like sensitive hydraulic relays and begin emptying — with an average probability of 40—50% — at the impact of incoming tidal (rising) waves (3.) Because the extremes of the lunisolar gravitational changes set in at new moon and full moon, or at quadratures $\pm 1$ day, at 6, 12, 18 and 24 hours, the tendency for outbursts of the karstic syphons falls most probably on these times. Thus we were able to demonstrate the tidal motions of karstic waters basing on the observation of syphon-bearing karstic springs. Nevertheless, we could observe also the tidal waves setting in immediately in springs without syphons in form of an yield-change of a few per cent. The collaborators of the Station succeeded to the first time — by means of instrumental on-the-spot measurements — to demonstrate in the *Vass Imre*-cave at *Jósvafő* the transversal fluctuation of vertical karstic lithoclases originating from crustal deformations (4) [1, 31, 32].

The continuous registration of temperature and water-chemical parameters of karstic wells could be realized — owing to technical reasons mainly — only for shorter periods. In that research-domain the investigation of the *Nagytohonya*-spring — gaining its waters from deep karstic region too — led to new results. On the basis of temperature—and electric conductivity — measurements, carried out once a week for several years, once a day for a whole year and for one occasion once in every 10 minute for 10 days, we could conclude the following: in the subsiding phase of floods the connection between yield and temperature is for several months a hyperbolic one, i.e. owing to the mixing of the ascending warmer and of the descending colder karstic water components one encounters a reversed change of the yield and of the temperature. Regarding the deep-karstic-water-component it could be proved that its yield and temperature is nearly constant, while both parameters of the descending component are subjected to greater variations. On the basis of the connection between specific conductivity and temperature it became obvious that also the total hardness of the deep karst component is lower than that of the descending component. Completing the observations in situ by hydraulic model-experiments we succeeded to clear up that the deep-karst-waters take also part in the hydrological cycle and the higher temperature of this component can be attributed to the heatflux of the solid crust (8″).

The investigation (both for temperature and chemical features) of the underground currents and cave streams is important from the point of view that we could obtain a picture of the role of the influence of climate of the caves on the liquid phase (7′). In this connection a study of the *Komlós*-spring of the *Béke*-cave showed that theie appears a tendency for reaching equilibrium also between the air-space of the caves and the currents. As a result of the temperature-adjusting, the temperature of the cave-streams increases in winter and decreases in summer when progressing towards the spring. Under the same condition the dissolved oxygen-content of the underground waters is decreasing, their equilibrium-carbon-dioxide content, i.e. their hardness is increasing [36].

Concerning the investigation of the dropping waters in the cave we reached many interesting results during the past 10 years. The collaborators of the Station built up at ten spots in the *Vass Imre*-cave electric telemetric systems for the continuous registration of the yield of waters dropping from the stalactites. The on-the-spot receiving equipments work in siphon-impulse mode and their informations are recorded in the laboratory of the Station by cable-connections of 300—600 m. length. The results of several years' measurements have cleared at first the seepage-conditions. It became obvious that according to earlier suppositions the dropping-intensities may be rather different from point to point depending on the composition of the rocks. The constant dropping yield is 0.2 l/day on the average and during the spring melting of snow: 2.5 l/day. For the time-variations of dropping-intensity is characteristic that before setting in of the development of the vegatation and after its stopping, i.e. in early spring and late autumn the yield of dropping reaches its maximum. (In case of water dropping out from inside the stalactites this maximum may reach a value of 5 l/day, while with superficial flows a maximum daily amount of 10—20 l/day is also possible.) In these seasons and during very mild winters also as a result of minor rains we encounter quick oscillations even in form of daily changes too. During the vegetation-period, however, even the influence of major thunderstorms may not be perceptible owing to the high water-consumption of the vegetation (12″) [4, 6, 7, 19, 20, 22].

The investigation of chemical composition of the dropping waters in the cave and the study of changes of the most important consituents was going on for one year at 50 dropping sites of the *Vass Imre*-cave. Between the overall hardness of the waters and the specific electric conductivity a clear-cut connection could be established in mathematical form. It became obvious that the dropping waters of the cave can be arranged in two groups as regards hardness. The waters dropping out from stalactites have an average hardness of 25 German degree to while the degree of concentration of waters seeping on the surface of them is 15 German degree on the average. It could be stated that the hardness of dropping waters is highest in the vegetational period and lowest in winter. Thus, the soil has a decisive influence on the karstification process. During summer the carbon dioxide supply of microorganisms living in the soil increases essentially the dissolution activity of precipitation-waters seeping into the soil. We encounter on one dropping site a difference of even 8—10 German degree between hardness values of summer and those of winter (12″) [4, 7].

In connection with the study of liquid karst phase also some new research methods could be worked out at the Jósvafő Station during the past 10 years. An important achievement of the collaborators of the Station has been the development of a procedure for the detection of caves based on comparative spring-investigations. New methods have been worked out for the remote measuring of yield of dropping waters by means of electrical methods, for the determination of Mg-ions of cave-waters by means of luminescent indicators, for sample-taking in connection of the determination of oxygen-content dissolved in the dropping waters of the caves, for a quick photometric determination of Cl-ions which could be used for connection-investigations with tracing and for modelling-experiments for the investigations of syphon-systems and deep karstic-regions [7, 8, 9, 19, 20, 22, 25, 30, 33, 36, 37, 47, 50].

The number of publications of the collaborators of the Station dealing with investigations of the liquid phase amounts to 24 (c.f. list of references).

The investigation of the gaseous-phase has covered mainly the study of microclimate of the *Vass Imre*-cave. It was the intention of the collaborators of the Station from the beginning on that the most important climatic elements (temperature, humidity, air pressure and air-flow) should be recorded steadily and as continouosly as it was possible. Owing to the fact that the variation-velocity of these elements in the cave is much lower than of those on the surface, it is necessary that we should be able to record very minute differences of these elements in the frame of a rather narrow measuring range. Thus, in cave-conditions the presence of the observer could cause in case of unfavorable conditions a stronger change in the microclimate than it would set in under natural conditions in course of a year. This difficulty can be eliminated — in principle — by using telemetric instruments or suitably sensitive autorecording equipment on the spot, but in practice the continuous use of highly sensitive instruments in an atmosphere of nearly 100% relative humidity and high Ca-Mg-aerosol-content is hardly realizable owing to the high degree of corrosion. This problem must be taken into account especially in case of meterological instruments since the measuring elements can not be separated from the air of the cave [19, 36].

Owing to these difficulties the observation of temperature and relative humidity on the observing stations of the *Vass Imre*-cave was made using conventional Beckmann-thermometer pairs (of a high resolving power) with dry- and wet-bulb, the observations being carried out once a week: this repetition rate is sufficient owing to the low speed of changes encountered with the investigation of microclimatic changes in caves. As an exception of this we have quicker and stronger variations in the entrance-zone of the caves. Therefore, in the vicinity of the *Vass Imre*-cave we carried out measurements of temperature and humidity using a normal- as well as a thermistor-psychrometer and normal hygro-thermograph too. When observing the Beckmann-thermometer-pairs (psychrometer) the disturbing influence of the observator could be avoided in a sufficient manner using a remote switch illumination from backwards and reading off the instruments by means of a telescope. The observation of the air pressure was made by means of a conventional barograph, while for the measuring of the airflow a photo-transistor-anemometer — basing on frequency-measurement — has been developed by the collaborators of the Station [19, 34, 36, 55, 59].

The results of climatic measurements performed during the past 10 years can be summarized as follows. Based on the measurements of temperature and relative humidity the collaborators of the Station succeeded to state the penetration depth of the climate of the surface, taking into account the variation of data observed on the individual stations. The extreme values observed in the years 1964—1967 are: At a distance of 25 m. from the entrance: −13,5 and +8.6 C°; at 60 m: +3.9 and +8.9 C°; at 160 m: +8.0 and +9.6 C°; at 270 m: +9.13 and +9.87 C° were measured as minimum resp. maximum. For the distribution of the difference between the extremes along the longitudinal extension of the cave we succeeded to find a more accurate mathematical expression than that previously known from literature. Thus it became obvious that owing to the inflow of air during the cold season the cooling effect of the cold air of the surface reaches at about a distance of 300 m. from the entrance. The observed minimum of the relative humidity during this period in the entrance hall of the cave was 70%, while the relative humidity of the air of the cave in the inner parts of the cave approaches effectively 100%, as it could be stated by means of the reliable observation of the telescope-red Beckmann-thermometer-psychrometer, whereby differences of 0.002 C° value could be accurately observed.

It is characteristic not only for the *Vass Imre*-cave but for all karstic caves that the average temperature of the air is lowest in the vicinity of their entrances at the foot of the mountain. (At the *Vass Imre*-cave during the above period at a distance of 25 m. from the entrance the mean temperature was +6.4 C°, while in the inner parts of the cave the average temperature was nearly +10.0 C°.) The reason for this — in case of the caves in moderate climates — can be found in the inflow of the external air in winter and the outflow of the internal air in summer. The parts of the cave around the entrance are under an asymmetrical thermal influence. The temperature of the inflowing external air can reach even −20 — −30 C°, the temperature of the outflowing internal air is generally not warmer than +10 — +15 C° (e.g. *Kossuth*-cave). The steady cooling down of the cave-walls in the entrance-zone (pit-fall effect) (11′, 11″) and the forming of flood-waterplugs delaying the outflow of air in spring (syphon-effect) (7″) play a strong conserving role in bringing about the above phenomenon. In addition, it is characteristic for the air-flow conditions that in spring and autumn, when the average temperature outside falls between +5 and +15 C°, the airflow stops. In all seasons, in case of a strong daily warming and night-cooling the airflow in the cave has a daily variation too, but in the *Vass Imre*-cave, even oscillations with a much shorter period could be detected. By means of the above mentioned remote-reading phototransistorized-anemometer we were able to observe during several hours quick bursts of wind with a period of 4–5 minutes and of a speed of a few tens of cm/sec. The cause of this phenomenon is not yet known. In any case the temperature variation of external air plays an important or even decisive role in forming the air-flow in the cave and the direction and speed of the air-flow in the cave exerts an important influence on the temperature and relative humidity of the air of the entrance sections (2) [21, 23].

Among the external meteorologic factors there are perhaps the pressure variations the influence of which is the strongest to the mircoclimate of the cave (2). The amplitude of the air-pressure variations can be observed to about 90% in the internal parts of the *Vass Imre*-cave too. Practically – with a delay of a few minutes – we have an immediate transfer of the effects, as even the quick-moving "thunderstorm-peaks" can be observed in the interior of the cave, though in a somewhat fainted form.

Investigations in connection with the composition of the gaseous phase were also carried out at the Station. Following the hypothesis of "aerosol-effect" in helictite-formation the question of developing and mean life of the Ca-aerosol was raised. The aerosol-droplets are essentially tiny, microscopical water-droplets floating in the air and containing dissolved limestone. Their presence in the air of the cave can be proved by the Tyndall-effect. Theoretical investigations carried out at the Stations have cleared that an aerosol droplet of 0.1 *mm* diameter can remain floating in an air of even 90% relative humidity for many minutes without evaporation. But, since the relative humidity of moderate-climate-caves generally surpasses 90%, the Ca-aerosol-droplets "survive" their time of subsidence. Their existence is a good example for the fact that the dropping waters being parts of the liquid-phase are able to exercise an important effect on the composition of the gaseous phase (7″). According to the supposition of the formation of the helictites from the Ca-aerosol, the electrostatic point effect on the top of needle-like helictites may also have its role in catching the aerosol-droplets (6′) [13].

Interesting new observations were made by the collaborators of the Station regarding the radioactivity of the gaseous phase. In several caves on the basis of measurements (made with GM-counters) has been shown that we get a radioactivity ( in form of $\beta$-radiation) above the level of background-radiation only in the side-niches free from air-flow. According to the experimental measurements the Ca-aerosol-droplets of the air of side-niches emit $\beta$-radiation (6″). It is not yet known whether the air of the niches – without the droplets – itself does contain a radiating component. On the observed spot the clay-layers of the ground did not show any radiation. So the origin of the $\beta$-radiation has not yet been cleared. Basing on the literature we may suppose that the observed radioactivity is the result of $\beta$-disintegration of the $^{14}C$ atoms of the carbonate-ion-content of the dropping waters. This seems to be probable owing to the fact that the aerosol-content of the cave-air originates from the dispersion of dropping waters.

In connection with the investigation of the gaseous phase the collaborators of the Station have elaborated new procedures for the use of psychrometers with Beckmann-thermometers and thermistors as well as for the application of phototransistors with frequency-signal to the telemetric investigation of air flow [19, 34, 36]. The results of the investigations concerning the gaseous phase were presented in 8 publications during the past 10 years.

## Perspectives of the further investigations

The results of the investigations of the past 10 years have justified the original assumptions and proved the correctness of the working hypothesis applied. Many — as yet unknown — karstic processes have been cleared up in course of ten years' work of the Research Station (6′, 6″, 7″, 8″, 9″, 11″, 12″, 13′).

The recent investigations are concentrated around the natural factors influencing the liquid phase (3, 7′, 8″, 10″, 12″). In this connection many interesting problems concerning the relations of hydrological and geophysical factors are open for resolution (e.g. the interaction of earthquakes and of the variations of the earth-magnetic field and the moving-conditions of karstic waters etc.). According to our present knowledge these basic research problems are in close connection with the requirements of everyday life too. (Protection against water in the mines, research of industrial- and drinking-waters etc).

Nontheless, it is an interesting problem to study the "white spots" in the table of speleological interactions (Fig. 1.), which are mainly connected with the interactions of physical radiations and fields with the individual karst-phases. It is a nearly open question, whether the entity of the radiations and fields in the interior of the karst has a special composition and distribution, which is characteristic to the karst (e.g. a cosmic radiation with selective absorption, a gravitational field connected with the form of the cavities etc.). The question also arises, which special interactions takes place between the individual radiation-zones and physical fields? (e.g. the influence of the $\beta$-radiation to the electrostatic field of aerosol-droplets etc.) (1). It is not uninteresting from the hydrological point of view, whether the karstic waters are a source of some electromagnetic radiation around them? (10″). It would be also interesting to know, which radiation-fields are brought about in the underground cavities by the thermal flow and telluric currents of the karstic rocks? (13″).

For the solution of all these questions one should create a special laboratory of karst-physics. It is the aim of the further investigations at the Jósvafő Station to clearing up the geological, hydrological and climatological karstic processes in this respect too.

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## A SZPELEOLÓGIAI KÖLCSÖNHATÁSOK RENDSZERE

A Jósvafői Karsztkutató Állomás
első 10 évének eredményei

**Összefoglalás**

MAUCHA L.

A Jósvafői Karsztkutató Állomás a budapesti Építőipari és Közlekedési Műszaki Egyetem Ásvány- és Földtani Tanszékének keretében 1957-ben kezdte meg munkáját. A Kutató Állomást műszaki-földtani alapkutatások céljából Dr. P a p p Ferenc professzor hívta életre, aki az Állomás fő feladatát a karsztban lejátszódó természeti folyamatok tanulmányozásában jelölte meg. A létesítmény pénzügyi fedezetének biztosításában Dr. C h o l n o k y Tibor rektor, az épület terveinek elkészítésével Dr. R e i s c h l Antal professzor jelentős segítséget nyújtott az új kutatóhely kialakításában.

Àz elmúlt 10 év alatt a Kutató Állomás munkatársai ismeretelméleti szempontból alapvetően fontos eredményt értek el a „szpeleológiai kölcsönhatások rendszerének" kidolgozásával. A táblázatba foglalt új ismeretelméleti szintézis összefoglaló áttekintést nyújt a karsztfolyamatok eredetéről. A táblázat segítségével előre lehet jelezni eddig ismeretlen karsztbeli kölcsönhatás-típusokat, tehát a modern szpeleológiai kutatások programját rejti magában.

Az elmúlt 10 év alatt a karszt szilárd fázisának (karbonátos kőzetek, barlangi ásványos kitöltések és üledékek) kutatása során az Állomás munkatársai 11 témakörben értek el új eredményeket. Különösen jelentősek voltak azok a vizsgálatok, melyek a karsztüledékek poligén eredetének, az aragoni-kalcit átalakulás részletes mechanizmusának, a tűszerű heliktitek aeroszólból való keletkezésének, a karszt reduktív zónájának és a karsztos litoklázisok fluktuációjának kimutatására vezettek.

A karszt folyékony fázisának (karsztvizek) tanulmányozása 7 különböző területen volt eredményes. Legfontosabb eredmények közé tartozik: a karsztos szivornyák létezésênek kísérleti bizonyítása és hidraulikai jelfogó szerepének kimutatása, a karsztvízszint árapály jelenségének és mechanizmusának kimutatása, a mélykarszt vízforgalmának kimutatása és a barlangi csepegővizek vízhozam- és összetételbeli változásainak meghatározása.

A karszt légnemű fázisának (barlangi mikroklima) vizsgálata 5 klimaelem esetében vezetett eredményre. Újszerűek voltak azok a vizsgálatok, melyek a felszíni és földalatti klíma kapcsolatára, a Ca-aeroszol keletkezésére, élettartamára és kicsapódására vonatkoztak.

Az elmúlt 10 év alatt az Állomás munkatársai 14 speciális vizsgálati módszert dolgoztak ki fenti eredmények eléréséhez, 10 év alatt 63 tudományos dolgozat látott napvilágot.

# SYSTEM DER SPELÄOLOGISCHEN WECHSELWIRKUNGEN

## Erfolge der Karstforschungsstation zu Jósvafő in der ersten zehn Jahren


**Zusammenfassung**

von

L. MAUCHA

Die Station für Karstforschung zu Jósvafő begann ihre Arbeit im 1957 im Rahmen des Lehrstuhls für Mineralogie und Geologie der Technischen Universität für Verkehrs- und Bauwesen in Budapest. Die Station wurde vom Prof. Dr. F. P a p p für technisch-geologische Grund-Untersuchungen ins Leben gerufen und als Hauptaufgabe der Station wurde von ihm die Untersuchung der sich im Karst abspielenden Naturvorgänge angegeben. Bei der Bereitstellung der Finanzmittel war der Rektor der Universität Prof. Dr. T. C h o l n o k y und mit der Vorbereitung der Pläne prof. Dr. A. R e i s c h l an der Gründung des Instituts geleistet.

In den vergangenen zehn Jahren konnten die Mitarbeiter der Station durch die Ausarbeitung des „Systems der speläologischen Wechselwirkungen“ aus dem Gesichtspunkte der Erkenntnistheorie grundlegende wichtige Erfolge aufweisen. Die neue erkenntnistheoretische Synthese – zusammengefasst in einer Tabelle – gibt eine Übersicht über den Ursprung der Karstvorgänge: mit ihrer Hilfe kann man bisher unbekannte Karstvorgangs-Wechselwirkungs-Typen im voraus erkennen, d. h. man kann gewissermassen ein Program moderner späleologischer Forschung aufstellen.

Die Mitarbeiter der Station konnten in den vergangenen zehn Jahren in der Untersuchung der festen Karstphase (karbonatische Gesteine, mineralische Ausfüllung von Höhlen und Sedimente) in elf Themenkreisen neue Resultate erreichen. Besonders bedeutend waren: die Untersuchung des polygenen Ursprungs der Karst-Sedimente, des detaillierten Mechanismus der Transformation Aragonit-Kalzit, des Entstehens der Nadel-Heliktiten aus Aerosol, die Erweisung der reduktiven Zone des Karstes sowie der Fluktuation der Karst-Lithoklasen.

Die Erforschung der flüssigen Phase des Karstes (Karstwasser) zeitige Erfolge in sieben verschiedenen Gebieten. Zu den wichtigsten Resultaten gehören: experimenteller Nachweis der Existenz von karstigen Siphons und derer Rolle als hydraulischer Relais, Nachweis der Ebbe-Flut-Erscheinung des Karstwasserniveaus und dessen Mechanismus, Feststellung des Wasserkreislaufs des tiefen Karstes und die Bestimmung der Änderungen in Wasserergiebigkeit und chemischer Zusammensetzung der tropfenden Wässer der Höhlen.

Die Untersuchung der Gas Phase des Karstes (Höhlen-Klimatologie) lieferte Erfolge für fünf Klimaelemente. Neuartig waren die Forschungen betreffend den Zusammenhang des Klimas an der Oberfläche und Höhle, die Entstehung des Ca-Aerosols sowie sein Lebensdauer und seine Kondensation.

Gleichfalls wurden in den letzten zehn Jahren von den Mitarbeitern der Station 14 Spezial-Methoden für die Forschung ausgearbeitet. Die Anzahl der wissenschaftlichen Publikationen in dieser Periode beläuft sich auf 63.

# СИСТЕМА СПЕЛЕОЛОГИЧЕСКИХ ВЗАИМОДЕЙСТВИЙ ПЕРВОЕ ДЕСЯТИЛЕТИЕ СТАНЦИИ ПО ИССЛЕДОВАНИЮ КАРСТА В ЙОШВАФЕ

**Резюме**

ЛАСЛО МАУХА

Станция по Исследованию Карста в Йошвафе начало совю работу в 1957 году в рамках геолого-минералогической кафедры Будапештского Строительного и Транспортного Политехнического Университета. Станцию организовал д-р Ференц Папп для целей теоретических инженерно-геологических исследований, главной задачей станции он поставил исследование природных процессов, протекающих в карстах. Значительную помощь в создании нового исследовательского центра оказали ректор д-р Тибор Ч о л н о к и, обеспечивший финансовые средства, и профессор д-р Антал Р е й ш л, составивший план здания.

За прошедшие 10 лет сотрудники исследовательской станции, с точки зрения теории познания, добились фундаментально важных результатов разработкой „системы взаимных спелеологических воздействий". Новый синтез знаний, собранный в таблицу, дает суммарную картину происхождения карстовых явлений. С помощью тэтой аблицы можно предсказать до сих пор неизвестные типы карстовых взаимодействий, т.е. она заключает в себе программу современных спелеологических исследований.

За прошедшие 10 лет сотрудники станции при исследовании твердой фазы (карбонатные породы, пещерные минеральные заполнения и осадки) в 11-и темах добились новых результатов. Особенно важными представляются те исследования, которые выявили полигенное образование карстовых осадков, детальных механизм преобразования арагонит-кальцита, образование игольчатых геликтиков из аэрозоли, наличие редуктивной зоны карста и флюктуацию карстовых литоклавов.

Исследование жидкой фазы карстов (карстовых вод) успешно проведено в 7-и различных областях. К самым важным результатам относятся экспериментальное доказательство существования карстовых сифонов и выявление их роль в качестве гидравлического реле, выявление наличия карстовых приливов и отливов выяснение их механизмов, выявление водообмена глубокого карста и определение изменения дебита и состава „капающих" пещерных вод.

При исследовании воздушной фазы карстов (микроклимат пещер) получены результаты в случае 5 климатических типов. Новыми явились исследования, касающиеся взаимоотношение поверхностного и подземного климата,

образования кальциевого аэросоля, длительность его жизни и условия выпадения.

За прошедшие 10 лет сотрудники станции было разработано 14 специальных методов для достижения вышеупомянутых результатов. За 10 лет были опубликованы 63 научные работы.

## SISTEMO DE LA SPELEOLOGIAJ INTEREFIKOJ

Rezultoj de la Karstesplora Stacio ĉe Jósvafő en al una jarde ko de ilia laboro

**Resumo**

L. MAUCHA

La Karstesplora Stacio ĉe Jósvafő komencis funkcii en 1957, en la kadro de la Mineralogia kaj Geologia Katedro de la Budapeŝta Konstruindustria kaj Trafika Universitato. La Stacion fondis d-ro profesoro Ferenc P a p p por teknika-geologiaj bazesploroj; kiel la ĉefan taskon de la Stacio li determinis esplori la naturprocezojn disvolviĝantajn en la karsto. Grave helpis la establon de la nova esplorejo rektoro d-ro professoro Tibor C h o l n o k y, per la certigo de la financa bazo, kaj d-ro professoro Antal R e i s c h l, per la pretigo de la planoj de la konstruaĵo.

Dum la pasintaj 10 jaroj la kunlaborantoj de la Karstesplora Stacio atingis baze signifan rezulton prilaborinte la „sistemon de la speleologiaj interefikoj". La tabelita nova gnoseologia sintezo donas resuman superrigardon pri la origino de la karstprocezoj. Helpe de la tabelo estas prognozeblaj la ĝis nun nekonataj tipoj de la karstaj interefikoj, la tabelo enhavas do la programon de la moderna speleologia esplorado.

En la esploro de la solida karstfazo (karbonataj stonoj, grota minerala plenigaĵo kaj sedimento) dum la pasintaj 10 jaroj la kunlaborantoj de la Karstesplora Stacio atingis en 11 temoj novajn rezultojn. Precipe gravaj estis la esploroj, per kiu oni demonstris: la poligenan originon de la karstaj sedimentoj, la detalan meĥanismon de la aragonito-kalcito transformiĝo, la el-aerosolan originon de la nadlosimilaj heliktitoj, la reduktivan zonon de la karsto kaj la fluktuadon de la karstaj litoklazoj.

La esploro de la fluida karstfazo (karstakvoj) alportis sukceson en 7 diversaj temoj. Al la plej signifaj rezultoj apartenas la pereksperimenta demonstro de la ekzisto de la karstaj sifonoj kaj la demonstro de ilia rolo keil hidraulika relajso, la demonstro de la fenomeno kaj meĥanismo de la tajdo en la karstakvonivelo, la demonstro de la akvotrafiko en la karsto profunda kaj la observo pri la ŝanĝoj en la debito kaj kemia enhavo de la groto glutakvo.

La esploro de la gasa karstfazo (grota klimato) rezultis novajn konojn pri 5 klimaelementoj. Novtipaj esploroj okazis pri la interrilato inter la surtera kaj subtera klimato, kaj pri la genezo, vivdaŭro kaj precipitado de la Ca-aerosolo.

Dum la pasinta jardeko la kunlaborantoj de la Stacio prilaboris 14 specialajn esplormetodojn por atingi la rezultojn suprajn, kaj 63 sciencaj studoj aperis.