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THE MORPHOLOGICAL RESEARCH OF THE BASALT AND LOESS COVERED PLATEAUS IN THE BAKONY MTS. (TRANSDANUBIAN MIDDLE MTS. – HUNGARY)

MORFOLOŠKE RAZISKAVE NA KRASU POKRITEM Z BAZALTOM IN PUHLICO V BAKONJSKEM GOZDU (TRANSDANUBIJSKO HRIBOVJE, MADŽARSKA)

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Abstract UDC: 911.2:551.44(439)

Móga János & Németh Róbert: The morphological research of the Basalt and Loess covered plateaus in the Bakony Mts. (Transdanubian Middle Mts. – Hungary)

We have conducted our morphological researches on the loess-covered Tési plateau and on the basalt covered karst area around Mt. Kab in the southern part of the Bakony Mts. The nearly 600 m high basalt covered Mt. Kab emerges high from the undulating mountains and hilly areas of the Southern Bakony Mts. Its surface, an area about 35-40 km^2 is covered by basaltic rocks of different thickness. Pseudokarstic landforms (depressions) developed on the basalt surface due to the karstic corrosion of the buried limestone layers. Grouping the objects of different morphology and evolution rate, and studying in corellation the genetic marks of the significant groups, a special karst process can be drawn, in which the depressions of various form can be understood as different stations of the same evolutionary series. The Mesosoic rocks building up the 60 km^2 Tési plateau emerge to the surface rarely above the loess cover. There is agricultural activity on most part of the plateau. Typical covered karstic landforms developed on the 3-5 m thick loess cover. Subsidence dolines or alluvial streamsink dolines with a small catchment area were formed on the summits. We studied the processes, forms and occurrence of recent covered karst of Mt. Bakony, and these studies shows that on the covered karst surface of the Tési-plateau the recent pit formation along with baticapture connected to hidden and real rock boundary, as well as the opening and activation of paleokarstic passages developed before loess formation also play a role in the evolution of the covered karst surface forms of the Tési-plateau.
Key words: basalt covered karst, development of pseudokarstic depressions, loess covered karst, hidden rock boundary, processes, landforms.

Izvleček UDK: 911.2:551.44(439)

Móga János & Németh Róbert: Morfološke raziskave na krasu pokritem z bazaltom in puhlico v Bakonjskem gozdu (Transdanubijsko hribovje, Madžarska)

V članku poročamo o morfoloških raziskavah na puhlični planoti Tési in z bazaltom prekritim kraškim območjem v okolici gore Kab na južnem delu gorovja Bakony. Skoraj 600 m visoka gora Kab, prekrita z bazaltom, izstopa iz hribovitega predela južnega dela gorovja Bakony. Površina gore, ki meri kakih 35-40 km^2, je prekrita z različno debelim bazaltom. Na bazaltnem površju so razvite psevdokraške oblike (depresije), ki so posledica zakrasevanja apnenca pod bazaltom. Z združevanjem glede na morfologijo in hitrost razvoja ter študijem korelacije genetskih značilnosti nastalih združb, smo izluščili nove kraške procese, kjer smo lahko depresije različnih oblik intepretirali kot različne stopnje iste razvojne poti. Mezozojske kamnine planote Tési le redko pogledajo na površje izpod pokrova puhlice. Blizu vrhov so nastajale udorne in ponorne vrtače z zelo omejenim območjem napajanja. Raziskave procesov, oblik in pojavnosti pokritega krasa gore Bakony so pokazale, da je nastanek recentnih jaškov povezan s skritimi litološkimi mejami. Pomembno vlogo pri razvoju površinskih oblik pokritega krasa imajo tudi paleokraški kanali, ki so se reaktivirali še pred nastankom puhlice..
Ključne besede: pokriti kras, razvoj pseudokraških depresij, skrite litološke meje, procesi, površinske oblike.

INTRODUCTION

We conducted our morphological study connected to covered karst on the loess covered surface of the Tési-plateau and the basalt covered Mt. Kab in the territory of the Bakony Mts.

All of the geographers making research in the Transdanubian Middle Mts. From the 1950-s (Láng 1958, Leél-Őssy 1959, Bulla 1964) have observed and have stressed those differences that can be shown between the allogenic type of karst of Gömör-Torna or A ggtelek and Mt. Bakony. All have mentioned that only a few forms of surface solution (karr, doline) can be detected on the karstifiable limestone and the dolomite surface of the Transdanubian Middle Mts. Jakucs referred to this phenomenon as "Transdanubian karst type" in contrary with the "Aggtelek karst type", and explained the variance by differing tectonism and temporarily differing coverage (Jakucs 1977).

With the study of paleokarsts 7 periods of possible karstification were collected from the beginning of the Mesozoic in the Transdanubian Middle Mts. – of this the existence of 2 phases can be proved on the Tési-plateau, but the number could be more. Preceding the covered karstification in formation even today, before the deposit of the most probably Upper-Pleistocene aged loess, in uncovered environment allogenic karstification occurred, which was accompanied by swallow hole and cave development. Today the loess covered sinkholes of the first phase are active.

Veress (1999, 2000, 2004) studied in detail the processes, forms and occurrence of recent covered karst of Mt. Bakony. He deduced the development of covered karst forms from the hidden karstification process under cover deposit connected to hidden rock boundary. He gave an argument in his article, that sinkholes defined by other researchers (Hevesi 1986, 2001) are in reality objects developed by baticapture.

He explains the baticapture of surface waters by pits forming only through solution. We studied the covered karst forms of the Tési-plateau in the recent years for providing a data base for the protection of the environment and some of the results we would like to elaborate in this article (Móga-Németh 2004).

At Mt. Kab the different aged limestone is covered by basalt and on its surface a number of smaller and larger depressions can be found. The development of the larger depressions (100-300 m in diameter) were explained in different forms – by the collapsing of earlier karstificated underlying dolomite bed (Jugovics 1954), with the surface evolution of material loss due to karstification forming under basalt layer (Győrffy 1957), with depressions developing before the lava flow (Leél-Őssy 1959). According to Vörös (1966) these forms were generated by the sinking of the surface of lava flow, which is due to the absence of reserves of flowing basalt penetrating under the edge. Eszterhás (1987) studied the smaller (6-50 m in diameter) basalt dolines as well. According to his opinion the depressions originated from the effect of underlying bed karstifying processes inherited into basalt producing pseudokarst phenomena, where the different types are determined by the actual fracture system of the covered rocks. Németh (1997), upon grouping the depressions through form came to the conclusion that the different morphological groups are links of the karstification process under coverage. The majority of the depressions that exceed a 100 m in diameter are volcanic, while the minority is karstic in origin (Németh 2000).

In our present paper after a short introduction of the territory, we would like to draw the effects of the structure of coverage and soil water flow on the origins of the basalt depressions and the process of genesis. Our ideas are based on many years of literary data collection and field work, statistical elaboration, mapping and laboratory research.

GENERAL REGIONAL AND MORPHOLOGICAL OVERVIEW OF THE KARST OF MT. KAB

The almost 600 m high Mt. Kab rises from the Southern Bakony mountainous and hilly region as the representative of Transdanubian basalt volcanism. Its surface of 35-40 km² is covered by basalt coverage of different depth. Under the steep peak region plateaus and smaller plateau fragments can be traced (Juhász 1988). The sides of the volcanic cone are cut by radial erosion valleys.

Most part of Mt. Kab is covered by rocks from the end of the Pliocene period. The carbonated rocks covering the bedrock appear only on lower areas. Dolomite occurs on the E, S and SW, Kössen layers and Dachstein limestone in NE and SW, Jurassic and Cretaceous formations in the N, Eocene limestone in the N and W, Pliocene sweet-water limestone in the S (Fig. 1). The territory is partially covered by Pleistocene loess (Csima-Mészáros 1979, Mészáros 1980).

Mt. Kab and its environment is a stump surface decayed by the end of the Cretaceous period and covered by sea sediment in the Eocene. After the withdrawal of the Eocene sea – connected to the

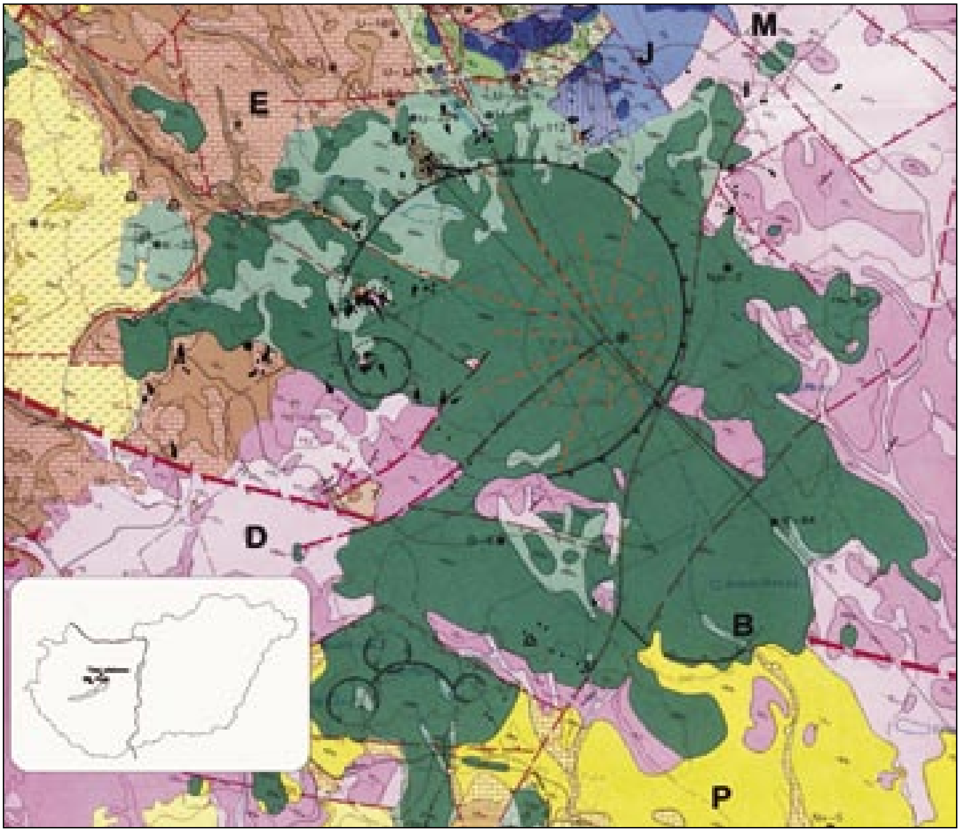

Figure 1: Basalt covered karst of Mt. Kab with the sinkoles.
Legend: B: Pliocene basalt, D: Maindolomite, E: Eocene nummulitic limestone, J: Jurassic limestone, M: Dachstein limestone, P: Pliocene limestone.

Photo 1: Typical pseudokarstic depression on the basaltkarst of the Mt. Kab.

Photo 2: The Macska-lik (Cat hole) is the most impressive sinkhole of Mt. Kab, it is opening in a limestone window.

structural movements of the Tertiary – the surface was broken up and with fault scarp block mountains were formed. At the end of the Pliocene volcanic action took place on the territory, which changed the aspect of the relief to a great extend, levelling the dissected surface and creating the typical volcanic formations (layer volcanic and parasite cones, crater lakes, lava covers) (Juhász 1988).

The surface water network of Mt. Kab is underdeveloped. A major permanent water flow did not develop on the territory, because the streams fed by springs infiltrate quickly on the karstic valley soles (Gyurman 1982). During heavy rainfall and snow melt in the dry valleys intensive, periodical water flows, while on the plateaus temporary springs and marshes are formed.

On Mt. Kab at present we know 132 depressions of karstic origin. The majority are sinkholes found on plateaus or valley soles, partly in the limestone windows of the coverage, partly in the karst territory encircling the basalt edge (Fig. 1, Photo 1). The closed, doline-like depressions developed in basalt are found only on plateaus. Their forms and dimensions show a great variety. They appear in smaller or larger groups in the company of developed sinkholes mainly on the basalt edge and near to limestone windows.

THE FUNCTION OF THE COVERAGE STRUCTURE IN THE FORMATION OF BASALT DEPRESSIONS

The volcanic layers of Mt. Kab is built up of the material of a number of activity phases (Vitális 1934, Csima–Mészáros 1979, Horváth-Peregi 1990). The lava benches, the underlying carbonated bed and the material of the first lava flow is dissected by the debris of basalt and its piroklasts, the so-called wethered basalt layers. Its colour is dark red and its substance clay-like, containing a large amount of basalt rocks. Its general thickness is 2-6 m, but at some places it can reach 20 m as well. Thinner wethered basalt layers can occur in lava benches – in the Pula basalt cave at 14 m level Eszterhás (1986) mentions a 25-30 cm layer, while Vörös (1966) – without giving the precise collecting place gives account of a 10-20 cm thick layer. We found a similar thick wethered basalt layer on the NE side of the given up basalt mine near to the sole. The presence of these thin layers however reflects, that outside the intervals between the major lava flows, smaller interfusion sections also took place, when the period was long enough for the beginning of debris processes. According to the lava benches of the N-ern plateau placed above each other and the levelling dissection of the periodical springs at the lava edges a number of thin wethered basalt layers can be suspected, each functioning as a regional impermeable.

In contrast to wethered basalt, basalt is permeable, as the decrease of mass due to solidifying, the earth movements and edge fractures caused cracks and fragmentation.

It becomes clear from the above mentioned that karst genetic basalt depressions can only develop where the impermeable layers are missing, meaning that the basalt and the underlying carbonated bed are in direct contact with each other. This can occur where the one-time peaks of the stub surface were covered only by the last lava flow.

THE ROLE OF THE SATURATED WATER IN THE DEVELOPMENT OF BASALT DEPRESSIONS

Precipitation falling on basalt surface can reach karstic underlying bedrocks in 3 ways:

A. The precipitation infiltrating into basalt flows along the fractures vertically and reaches the underlying rocks under the entrance point.

B. The infiltrating waters are force to flow horizontally, due to impermeable wethered basalt and reach the underlying rocks farther away.

C. Precipitation is not infiltrated into the basalt cover, but is collected along the sloping benches, and following a shorter or longer route reaches the underlying rocks on the surface.

The major part of infiltrating precipitation gets into contact with one of the wethered basalt layers and this changes the direction of the vertical soil water flow to horizontal. In accordance the water reaches the potential karstifying places not only from above, but from the sides as well. The output of soil waters flowing above wethered basalt layers which run to the underlying karstic bed sideways exceed many times the output infiltrating from above (Fig. 2).

At snowmelt or heavy rainfalls soil water reaches surface either areally (marshy territory) or in one point (spring). These temporary water emerging places enlarge the hydrological activity period of the underlying karstic bed, as marshy places are capable of providing water after 1-3 weeks, while springs after 1-4 months following precipitation or snow melt (Gyurman 1979).

THE ORIGIN AND DEVELOPMENT OF BASALT DEPRESSION

Karstification under volcanic cover is due to the corrosion of soil waters. The role of precipitation infiltrating directly in this process is not important. For the deterioration of underlying bed, mainly the water flows on wethered basalt layers are responsible. All of the karstifying zones have a separate sub surface catchment area and their expansion is determined by the extension of impermeable formations. The water flows arriving from the catchment areas can flow slowly within the coverage, and are not capable of causing enlargement in depressions. During karstic decay in the carbonated rocks under coverage material absence is created, which causes collapsing mass movements. In the cavities thus formed basalt breaks in, creating newer and newer fractures. The surface appearance of the material absence is determined by the thickness and fracture lines of the basalt. According to our observation the basalt depressions occur near to limestone windows or basalt edges. This refers to the fact that the general thickness of basalt (20-40 m) is not ideal from the point of view of inheritance, which means that depressions can only be formed where coverage thins. If the fractures of basalt cohere below the subsurface hollows remain vaulted, as only the lower rock layers can cut off, while the upper are jammed. In cases of parallel or upward coherent fractures the material loss can be inherited to the surface (Eszterhás 1987). Above the open hollows shallow depressions are formed, which help the intensification of karstifying processes from the surface.

If the depressions in their development baticapture surface water flows, or with the devastation of their environment a catchment area is formed, erosion is also effective. Due to the quickness of the denudational processes the underlying bed and also the overlying cover starts to decay in increasing extend (Fig. 2). Thus the surface depression deepens further and slowly gains the form of a cornet. The nadir of the swallow cornet points towards the water drain gallery more and more. If the depression is connected to a larger catchment area the water flow deepens a regression ditch into its side.

Through the water conducting galleries of the basalt depression morphologically resembling to swallow holes, the fractured coverage is totally destroyed, thus enabling the underlying bedrocks to emerge and form limestone windows on the uninterrupted volcanic cover (Photo 2)(Jugovics 1971).

It is necessary to state that the depressions formed with the above drawn development method, cannot be regarded as real sinkholes even after the formation of the rock boundary, though functionally they act as sinkholes. The reason is that the depressions are not formed alike with allogenic

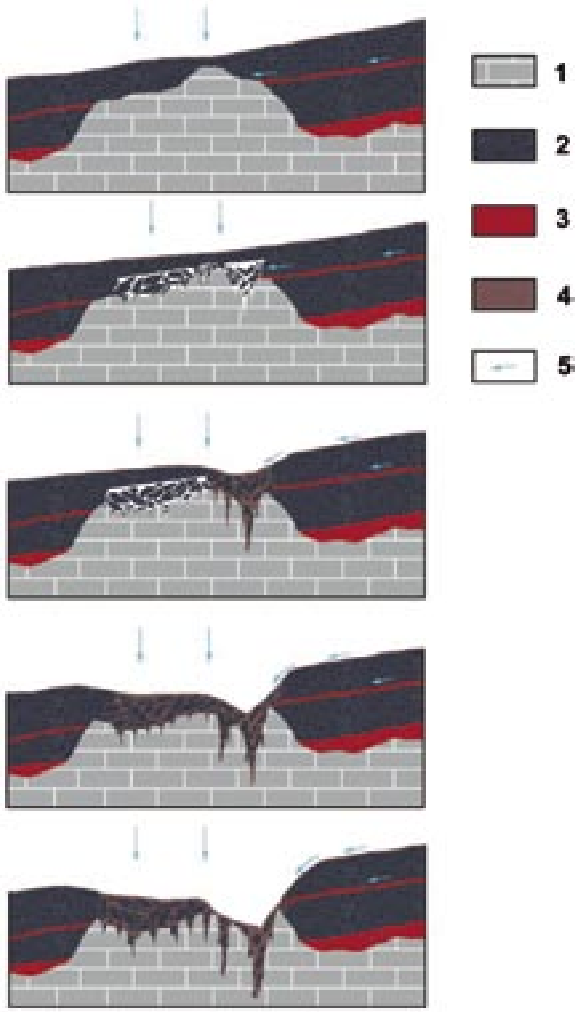

Fig. 2: The morphogenetic phases of the pseudokarstic depressions. Legend: 1. limestone, 2. basalt layers, 3. weathered basalt layers (sometimes red clay), 4. sediments, 5. percolating and flowing water.

karst, and do not account to the major criteria of sinkholes (Jakucs 1971), e. g.

A. Were not formed through baticapture, but baticapture took place after their development

B. Were not formed on rock boundary, but reached this status following their origin.

C. Were not formed through erosion, but erosion effects took part in their formation afterwards.

THE GEOGRAPHICAL AND GEOLOGICAL DESCRIPTION OF THE TÉSI-PLATEAU

The Tési-plateau situated on the territory of the E Bakony is the widest in extension (59 km^2) and the most levelled plateau. The Tési-plateau and the edge plateau remnants are bordered on all sides by valleys and basins along fractures and ditch-like depressions. With its steep slopes it is divided morphologically and hydrologically from its neighbourhood. On the plateau level differences are small, but the flat watershed backs hard to recognize, and the shallow, broad soled erosional-derosional valley systems cutting in from the edges dissect it to plateau sections.

The Tési-plateau is built up of Triassic, Jurassic and Cretaceous deposits, mainly limestones and dolomites which are covered by loess of different thickness which does not exceed a few m in depth. It is a typical covered karst with 200 periodically active and inactive sinkholes, with caves and shafts. Its main cave is the Alba Regia cave, which is at present 3600 m long and 200 m deep (Szolga 2003).

The Gaja stream cut in the N edge of the Tési-plateau a deep gorge where those karst springs (Siska- and Szent-kút, Vadalmás and Kőbánya springs) issue, which are fed by the sinkholes of the N-ern, Jurassic and Cretaceous limestone territory of the plateau.

In the E-ern and S-ern edge of the Tési-plateau dry valleys (ancient vadis) deepen (Burok, Hideg, Vár and Bükkös valleys). On these S-ern slopes built from dolomite (around Várpalota and Inota cities) the abbrasional wawe-cut bench and the pediment surfaces can be recognized. The Várpalota basin trapped the bigger S-ern, mainly Triassic limestone territory of the plateau, but the so-called main karst water springs connected with the mining in Várpalota's environment dried up (Futó 2003, Juhász 1988).

THE MORPHOGENESIS OF THE COVERED KARST SURFACE FORMS OF THE TÉSI-PLATEAU

The centre of the loess covered plateau is to some extend hollow. In this depression the main inner valley system of the karst plateau was formed, which due to strong NW-SE directed and diagonal tectonic preformation is sharply bent a number of times. (Fig.) The valley and ditch system is partly inherited from coverage deposits (superimposed valley) formed in an epigenetic way, partly by the backward cut of valley heads through repression – which process continues even today. Following the eastbound slope direction of the shallow hollow, the ditch system leads the periodically occurring waters eastwards towards the Tábla-, or Burok-valley. The flowing waters however seldom cross the edge of the plateau, they are in most cases swallowed in the numerous sinkholes opening in the stream bed.

The bedrocks emerges from under the loess cover only in few occasions, so karren are scarcely

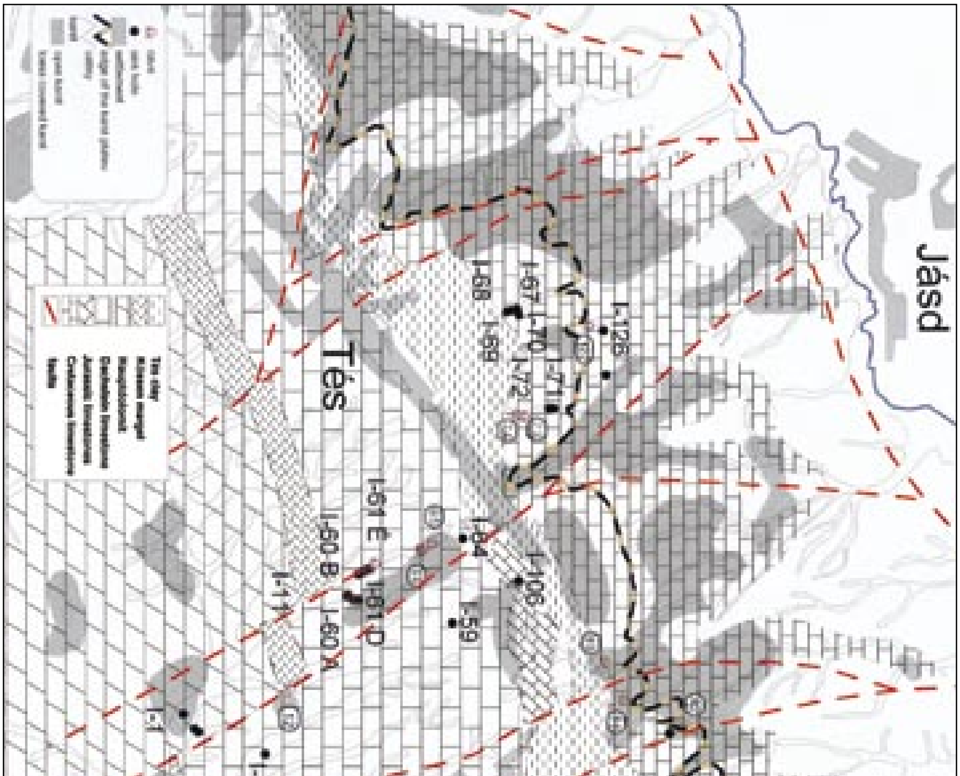

Fig. 3: Map of the loess covered Tési plateau with the underlying bedrocks, the exhumed areas and the sinkholes.

Photo 3: The most frequently occurring surface forms of the Tési-plateau are the covered karst dolines, which function as periodical sinkholes (I-36).

Photo 4: Alluvial streamsink dolines on the loess covered plateau.

seen on the surface. Mainly on the surface rocks of the plateau edge, exhumed from under the coverage, can scattered karren be recognized, formed under soil and root karren, which are small in size and fractured on the surface, due to the mining activities of the surrounding population through many hundred years. The solution dolines characteristic to autogenic and allogenic karsts are missing from these territories of exhumed surface.

During our field work conducted on the Tési-plateau we identified 200 covered karst depressions, which in the data base of speleologists and environment protection are referred to as sinkholes (Alba Regia BGK. Csop. 1977). The different sized and variously positioned covered karst depressions were described upon morphological and genetic features as different forms, but the researchers agreed upon the fact that these forms are functionally sinkholes.

The forms are not present in a uniform way on the plateau's surface – there are sections, patches, lines where these features appear intensively in a group. There are a large number of sinkholes where underlying rocks cannot be traced underneath the covering or carried in loess deposit – in these cases it is difficult to determine what period rocks do waters flow into. Upon placing geological and morphological maps on each other, it becomes clear that hidden rock boundaries play an important role in the situation of sinkholes, which notwithstanding the veil like loess cover, lead to the development of well traceable rows of sinkholes following these lines (Rónai-Szentes 1972). (Fig. 3). Nearly half of the sinkholes of the Tési-plateau can be found on the borders of Dachstein limestone and Main dolomite, the Kössen marl and Dachstein limestone, Dachstein limestone and Tési clay marl (Cretaceous munierical clay), Tési clay marl and Zirc limestone (requineal, orbitolinal Cretaceous limestone), Tési clay marl and Dachstein type Lower Lias, so-called Kardosrét limestone.

The most frequently occurring surface forms of the Tési-plateau are the covered karst dolines, which function as periodical sinkholes. These are formed where a gallery or pit is presenting the rocks of the underlying bed. These galleries can be recently formed, developing today, or can be older, paleokarst hollows. The cover deposit (loess, loess-containing deposit) are carried into these underlying passages with the inflowing waters. The material transport most probably takes place in sequences, it occurs faster with high precipitation, while in dry conditions can even cease, though with the solidifying and sinking of deposits these subsidence dolines can still deepen.

Veress (1999) in the development of these forms mainly takes into account kripto karstification, what takes place if the partly or completely permeable cover deposits thin to such an extend that the waters arriving from the partially impermeable cover deposits can infiltrate through them and reach the karstifiable rocks in solutionable condition (kripto rock boundary). The loess is dekalcificated near the surface. In this case at the thinning of these rocks there is less of $CaCO_3$ or none at all, so the infiltrating water remains solutionable in the limestone lying underneath. Veress upon his research on the covered karst territories of the Bakony, mainly the Hárskút-plateau, demonstrated virtually the development of all covered karst depressions from the solution of pit in direction towards the surface. The gradually decreasing rocks above the pits collapse. The process reaches the cover deposits by the collapse and on the surface an aeric steep depression is formed. If the pit broadening continues in the karst rocks, then the surface forms also broaden sideways. The surface depression helps to intensify the pit development because precipitation flows towards the depression and increases the amount of the soluting material. The pit and the covered karst depression is mutually conditioned, the formation of one generates the development of the other. If the pit, opening on the surface, reaches the valley sole, the subsurface capture of the water conducting ditch takes place. Veress (1999, 2000)

Photo 5: On the N-ern edge of the plateau, where loess cover is to such an extent thinned by washing away and erosion, allogenic subsurface capture is present (I-41 Kín cave).

Photo 6: Some caves (I-44 Alba Regia cave) and depressions were formed through allogenic karstification before the loess accumulation at the end of the Pleistocene.

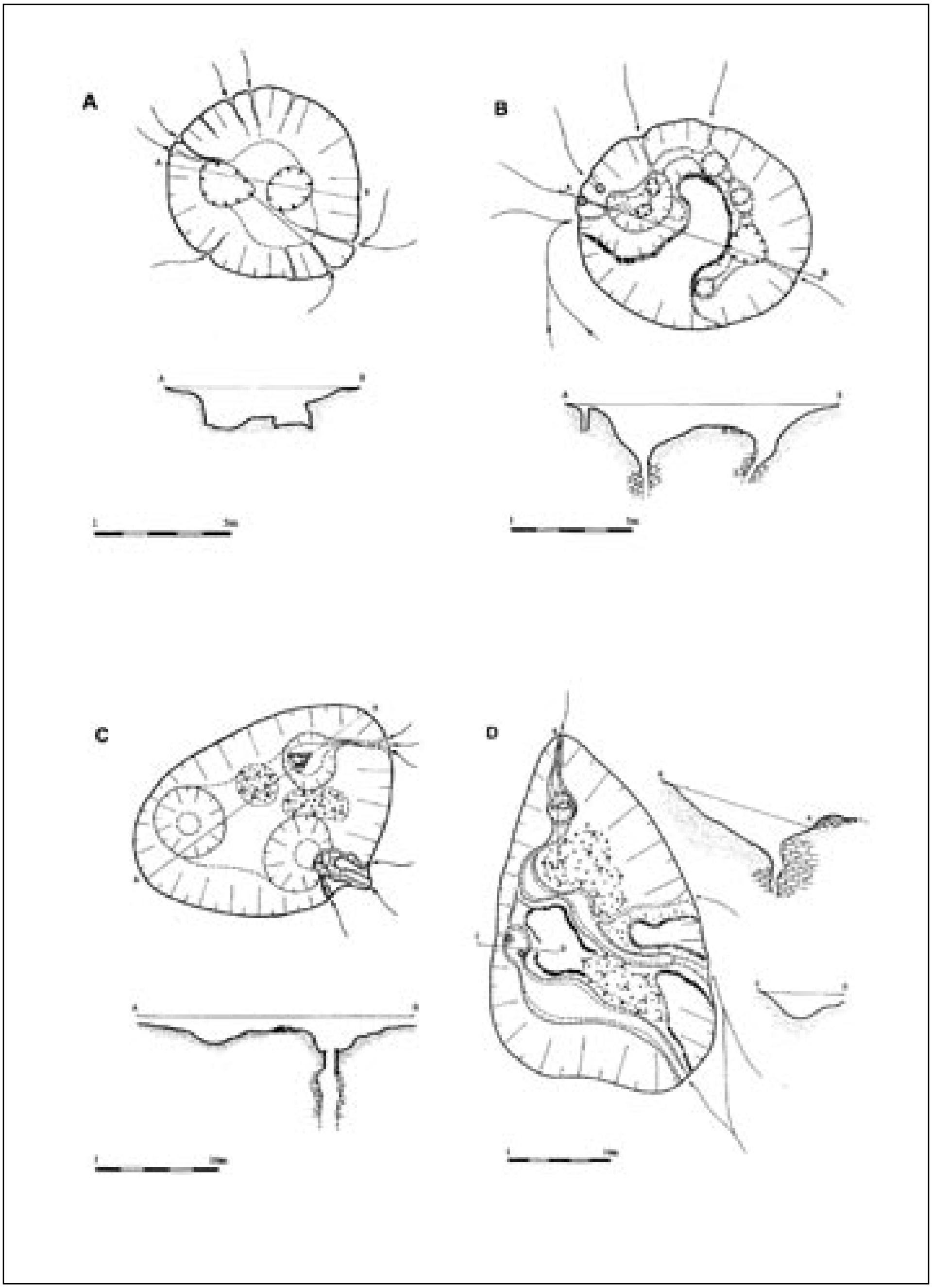

Fig. 4: Different covered karst surface forms developed on the Tési-plateau. A= I-36, B= I-82, C= I-73, D= I-46 sinkhole.

refers to this phenomenon as pseudo-surface capture, which develops on hidden rock boundary, due to the thinning of cover deposits, and is differentiated from real subsurface capture.

On the Tési-plateau a number of covered karst surface forms – from the simple, cornet-shaped to the bigger and more complicated forms build up a number of pits, with numerous water conducting ditches - can be placed into this genetic system. If many pits are formed near to each other, on the surface twin forms growing into each other develop. (Fig. 4, 5) If it is a joined pit, the pits opening onto the surface appear as a line of depression. The side slopes generating from the cover deposit of surface karst forms can even by washing away or can be dissected by watershed ditches. The creeping land mass also causes the shelving of side slopes. The clay depositing in the temporary lakes forming in depressions generate flat depression bottoms. On filled in bottoms secondary surface forms, young depressions are formed (Veress 1999, Móga-Németh 2004).

There are depressions in which a number of swallow places, sinkhole mouths are found. These are such, presumably older alluvial streamsink dolines, where the place of swallowing is temporarily changed (Photo 4). By the formation of new sinkholes older ones become inactive, or are linked off from the main water conducting ditches. Sinkholes can open on different heights, but are related to one object. It can occur that they obtain the water from the same ditch, but the water conducting system of many ditches can also be connected to such a sinkhole network, and their water collecting area can also differ. (Fig. 5)

In contrary with the pseudo karstifying model (Veress 1999), which does not allow any effect of baticapture, in the development of surface forms in the covered karst area of Mt. Bakony, we presume that the baticapture characteristic to allogenic karsts could have, and is taking place on the territory of the Tési-plateau as well, because on one hand the above described pit formation process can also be a form of baticapture, on the other hand, on the N-ern edge of the plateau, where loess cover is to such an extend thinned by washing away and erosion that Cretaceous and Jurassic limestone appears in patches, thus in the temporary ditch banks running towards the Gaja gorge, allogenic subsurface capture is present. (Fig. 3, 5, Photo 5).

On this exhumed territory there are a number of transitional forms which bear both the characteristics of covered karst and allogenic karst. Longer or shorter cave shafts and karst springs belong to these sinkholes. The galleries belonging to the sinkholes are underdeveloped, and rich in tectonic and corrosion forms, but it is not in favour for the development of erosion forms that the water collecting territory is covered only by loess deposit, which often fills in the passages. The more developed gallery network of some caves (Alba Regia cave, Háromkürtő and Csengő shafts) were formed through allogenic karstification before the loess accumulation at the end of the Pleistocene. In these cases the erosion forms are richer, because they were formed by the assistance of the pebbled deposits of rocks covering the surface before the loess (Photo 6). Below the loess buried surface the development of cave galleries stopped, or at least its space slowed, which later, due to exhumation and the thinning of cover deposits renewed, mainly by the development of corrosion forms (Szolga 2003).

This example shows that on the covered karst surface of the Tési-plateau the recent pit formation along with baticapture connected to hidden and real rock boundary, as well as the opening and activation of depressions developed before loess formation also play a role in the evolution of the covered karst surface forms of the Tési-plateau.

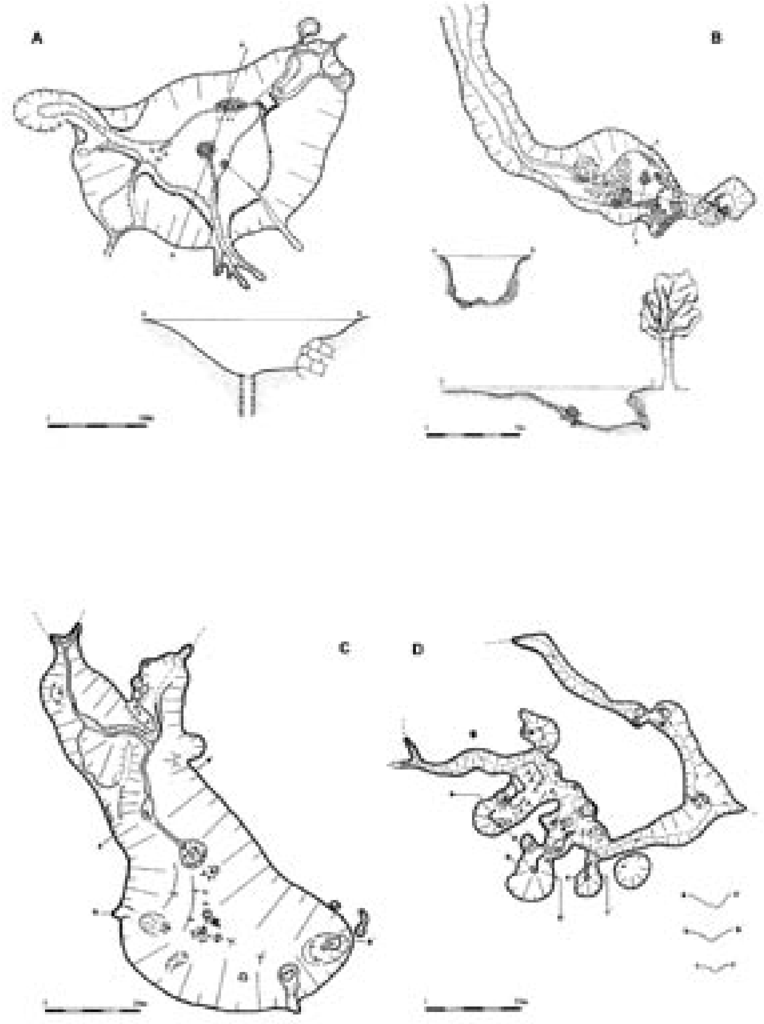

Fig. 5: Bigger and more complicated loess covered karst surface forms build up a number of pits, with numerous water conducting ditches. A= I-44 (sink hole of the Alba Regia cave), B=I-41 (sink hole of the Kín cave), C= I-12, D= I-1 sink hole.

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