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# Towards defining, delimiting and classifying epikarst: Its origin, processes and variants of geomorphic evolution

Alexander Klimchouk

*Institute of Geological Sciences, National Academy of Science of Ukraine*
*P.O.Box 136, Kiev-30, 01030 Ukraine. E-mail: klim@speleogenesis.info*

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**Abstract**

Epikarst is the uppermost weathered zone of carbonate rocks with substantially enhanced and more homogeneously distributed porosity and permeability, as compared to the bulk rock mass below; a regulative subsystem that functions to store, split into several components and temporally distribute authogenic infiltration recharge to the vadose zone. Permeability organization in the epikarst dynamically develops to facilitate convergence of infiltrating water towards deeply penetrating collector structures such as prominent fissures that drain the epikarstic zone. This is manifested by epikarstic morphogenesis that tends to transform dispersed appearance of surface karst landforms into focused appearance adapted to the permeability structure at the base of epikarst.

Epikarst is the result of combined action of several agencies including stress release, weathering and dissolution. It is a dynamic system which main characteristics are time-variant, changing in a regular way during the epikarst evolution. This paper examines the main characteristics of epikarst in the light of its origin and evolution.

**Keywords:** Epikarst, Origin of epikarst, Karst Evolution, Karst hydrology, Karst morphogenesis

## Introduction

Appreciation of epikarst as a sub-system (structure) that bears specific functions in a karst system (Fig. 1) emerged during 1970s from various kinds of evidence independently obtained within different disciplines. Cave biologists found specific aquatic fauna in drips and seeps from the cave ceilings, suggesting the existence of saturated zones between the surface and caves. Karst hydrogeologists realized that the water budget of karst aquifers and spring hydrograph interpretation suggests the existence of an important storage at the top of vadose zone (Mangin, 1973, 1975). Moreover, such storage was also evidenced by hydrochemical and isotopic studies, which demonstrated strong reduction of the input signal variations, hence an efficient mixing of the infiltrated water with pre-storm water (Bakalowicz et al., 1974). Early finite element modeling of a karst system by Kiraly and Morel (1976) demonstrated the need to impose a high proportion of concentrated infiltration to generate the typical "karstic" storm hydrographs. It was supposed that concentration of originally diffuse infiltration would occur at shallow depth in a thin near-surface high conductivity layer. Speleological investigations in arid mountains of the Central Asia demonstrated a substantial shaft flow in the vadose zone after long periods without any precipitation and revealed the existence of numerous "hidden" shafts beneath karren fields (Klimchouk et al., 1979, 1981; Klimchouk, 1987, 1989). These works suggested that the near-surface weathered zone of exposed carbonates functions as a "recharge" zone for a karst system, and that concentration of originally diffuse infiltration within it accounts for the formation of hidden shafts at the base of such zone. Mangin (1973, 1975) introduced the term "epikarst" to denote this zone and a perched aquifer within it, at the top of vadose zone.

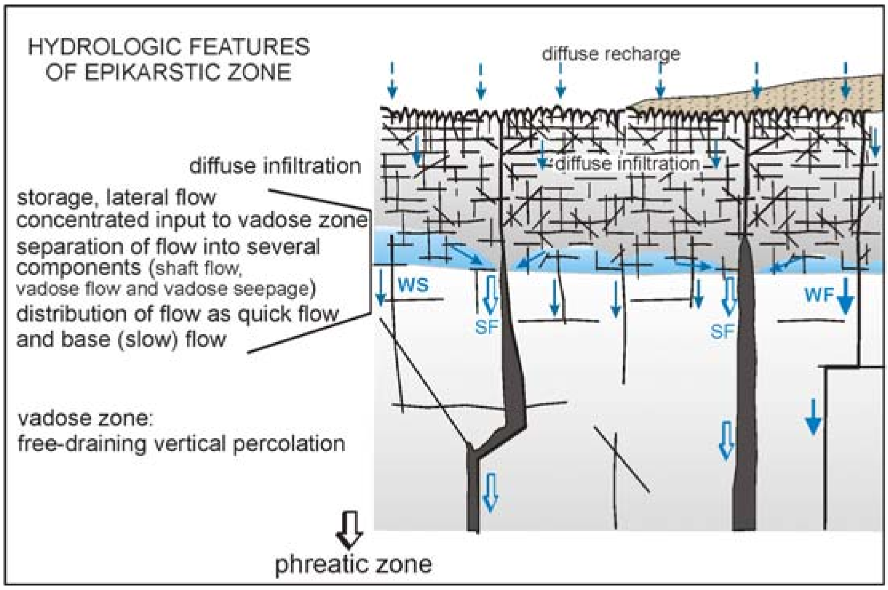


**Fig.1.** Diagram illustrating principal structural and hydrologic features of epikarst, and its relationship with the vadose zone. SF = shaft flow, VF = vadose flow, VS = vadose seepage.

However, it was the paper by Williams (1983) that brought the topic to international appreciation. During 20 years passed since that publication, hundreds of works were published, which highlighted enormous importance of the epikarst to karst hydrology and morphogenesis. In spite of the fact that many important aspects of the role of the epikarst are now widely acknowledged and well accepted, the scope of the concept is still debatable and numerous definitions vary considerably. This is partly the result of enormous spatial variability of the epikarst in local, regional and global scales, but also of its still poorly recognized evolutionary variability.

In attempting to refine the concept and definition of epikarst we should demarcate a respective natural system by addressing its origin and inherent characteristics, and reveal its place and functions in the context of a more general system (karst). It is also important to examine its characteristics from the evolutionary perspective. In particular, this paper attempts to elucidate how the epikarst evolve in the course of karst evolution.

## Essential characteristics of epikarst: criteria used to delineate the epikarst concept

The list below summarizes criteria used to delineate the epikarst concept, derived from twelve individual definitions and numerous relevant discussions found in the literature. They fall into the following groups:

- Structural features of the epikarstic zone
- Location of the epikarst
- Origin of the epikarst
- Hydrologic functions and roles in the overall karst system
- Morphogenetic role of the epikarst

Respective characteristics of the epikarst are briefly overviewed below.

## Structural features of the epikarstic zone

Structural characteristics are vital in delimiting the epikarst. Most of works stress on high and relatively homogeneously distributed fissure and solution porosity in the uppermost zone of exposed carbonates, with which epikarst is associated. This characteristic is comparative and scale-dependent; it holds true with reference to the underlying bulk rock mass which consist of low permeable blocks separated by much less densely packed prominent vertical fissures. Fissure networks in the shallow subsurface are commonly closely spaced (decimeters to a few meters) and continuous. The spacing of fissures increases with depth obeying a hyperbolic low (Chernyshev, 1983). The typical spacing of prominent vertical fractures with a significant penetration depth is estimated to be on the order of 30–50 m.

Estimates of overall epikarst porosity range between 1% (Smart and Friederich, 1986) and 10% (2-10% in Gouisset, 1981; 5-10% in Williams, 1985). They are one to four orders of magnitude more than fracture and solutional porosity in the bulk rock below (0.005 - 0.5%; Worthington et al., 2000).

The contrast in porosity and permeability in vertical direction between the epikarstic zone and the bulk rock mass below is of primary importance as it accounts for major hydrologic functions of epikarst. The lower boundary of the epikarstic zone is commonly highly irregular. It depends on relief, lithostratigraphy and geological structure. Fissure spacing thickening is more pronounced and penetrate to greater depths along prominent discontinuities. The boundary can be abrupt and very contrasting if coincides with sub-horizontal lithostratigraphic boundaries, or it can be gentle in homogenous sequences.

The thickness of the epikarstic zone varies considerably but it is most commonly estimated to be between few meters to 10-15 m.

## Location of epikarst

Most of definitions emphasize that epikarst is the uppermost zone of karstified rocks. Some of them refer to the direct exposure of the rock to the surface but others point out that epikarstic zone extends from the base of the soil. Strictly speaking, there is an apparent contradiction between these two criteria. There are many examples of epikarst without any soil, but in fact the epikarst/soil relationship is a special topic addressed in one of the following sections. These relationships should be viewed as genetic and stage-dependent. More generally, this issue is relevant to the problem of origin of epikarst.

## Origin of epikarst

Almost all definitions state that epikarst forms due to enhanced solution in the uppermost zone of the bedrock. This certainly is partly true, but the matter is not so straightforward. It appears to be more adequate to consider the combined effect of several agencies in the formation of epikarst, including stress release, weathering and dissolution.

### *Origin of epikarst in the context of general karst evolution*

Before discussing the origin of epikarst any further, it is necessary to look at various general evolutionary scenarios of the karst development in order to infer about starting points for the formation of epikarst. The evolutionary classification of karst (Klimchouk and Ford, 2000a; see Fig. 3.1-3, p.50), which views types of karst as variants and stages of general geological/hydrogeological evolution, provides a useful framework.

Epikarst can commence in young, diagenetically immature carbonates that have never been buried by other rocks. This is one of the variants of open karst, which evolves from syngenetic karst. Epikarst development and characteristics have pronounced specifics on eogenetic rocks not considered in this paper (for details see Mylroie and Carew, 1995, 2000).

The second variant of open karst can be envisaged when a soluble formation remained untouched by karstification during burial/re-emergence cycle, and karst commenced only after complete re-exposure (the "pure" line of open karst). In fact, this scenario does not seem quite realistic, as differential linear allogenic entrenchment and point breaching nearly always precedes substantial exposure of carbonate bedrock. This means that at least some input-output connections would establish and develop before complete exposure, which conforms to the subjacent or entrenched types of karst.

Most commonly, karst development commences beneath the cover at some stage *en route* to complete re-exposure. This is the evolutionary line of intrastratal karsts, which includes deep-seated, subjacent and entrenched karst types. *All of them cannot have epikarst*, although some hydrologic functions performed by an insoluble but permeable cover can be somewhat similar to that of epikarst.

Complete removal of the cover will bring the former intrastratal karst into the category of denuded karst, which belongs to the class of exposed karst types and is dominated by authogenic recharge. *Denuded karst is the most common situation to be considered as the starting point of epikarst evolution* (Fig. 2).

### *Origin of epikarst in denuded karst type*

Two aspects deserve particular attention in case of epikarst evolving in denuded karst type: the way of caprock retreat and the presence of the vadose zone.

In denuded karst type epikarst evolves in areas where bedrocks get exposed after retreating caprock. Hence, unloading effects apply. The rate and "completeness" of caprock retreat depends on the nature of denudation agency, the uplift rate and relief. One can envision two starting situations for the epikarst development:

1. Quick and complete removal of caprock; barren carbonate surface is directly exposed to weathering. Soil is originally absent, but it forms in paragenesis with the formation of epikarst as solution residual material.
2. Slow incomplete removal of the cover; regolith is present, providing the base for soil. The presence of regolith cushions the bedrock from physical weathering but may enhance considerably chemical weathering (dissolution).

The epikarst formation in these variants can differ substantially because of different effects of unloading and weathering, and different infiltration conditions.

Another aspect of utmost importance is that in denuded karst epikarst evolves above a ready made vadose zone, a free-draining percolation zone with predominant vertical percolation, where prominent conduits are inherited from an earlier stage of karstification (Fig.2). Separation of the epikarst from the phreatic zone by the established vadose zone is one of the primary points of the epikarst concept. Otherwise we would deal with a simple hydrographic profile with incipient vadose zone and a single phreatic aquifer body.

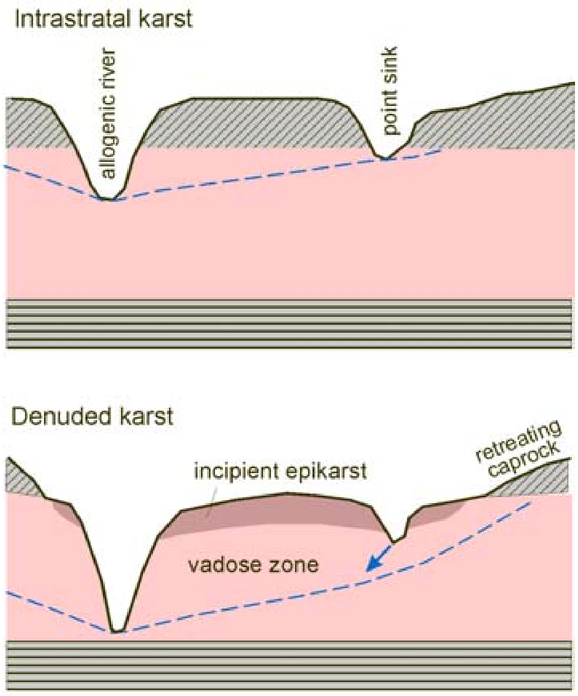


**Fig. 2.** Denuded karst that evolves from the intrastratal karst is the most common starting situation for epikarst development.

### *Role of stress release and weathering*

The relationship between the dissolution process on one hand, and stress release and weathering processes on the other hand is the key issue of the epikarst origin. Most researchers point to the primary role of dissolution in the formation of epikarst when explaining enhanced porosity in this zone. Although dissolution certainly contributes considerably to porosity enhancement in the epikarstic zone, it relies on availability of initial pathways for percolation and the surface area for reaction.

Structural prerequisites for the formation of epikarst evolve largely due to non-solutional processes such as stress release and physical weathering. These processes form the incipient epikarstic zone, a ready-made structure for diffuse infiltration and disperse solution in the uppermost zone of the bedrock. The role of solution increases on the farther stages of the epikarst development, and it is particularly important in bringing a specific organization to the epikarst structure.

That dissolution is not the primarily factor generating the porosity and permeability contrast between the top layer of the exposed rock and its bulk mass at depth is well illustrated by the fact that some kind of stress release and weathering profiles develop on most types of rocks, not only on soluble rocks. It is well appreciated in the geological engineering literature that stress release and weathering account for considerable near-surface porosity changes that occur when the rock is exposed in natural outcrops after burial. These effects include (Chernyshev, 1983; Klimchouk and Ford, 2000b):

- extension and opening of existing joints and formation of new joints;
- accentuation and opening of bedding planes and "micro-fissures", splitting of beds;
- enhancement of fissure frequency and connectivity of fissure networks.

On the other hand, weathering is also responsible for *in situ* deep chemical and mineralogical alteration of parent rocks, and for generation of fines that may choke fissure network and hence decrease permeability.

These effects depend primarily on:

- composition and structure of parent rocks
- climate
- unloading rate (which in turn depends on the balance between uplift rate and denudation rate)
- topography

*Karst vs. weathering; Epikarst vs. weathering profile*

Here we come to the important general problem concerning the origin of epikarst, which can be subdivided into two aspects:

- The relationship between the weathering concept and the karst concept.
- The distinction between "non-karstic" weathering profiles (weathering mantles) and epikarst.

One potential problem arises from the fact that the concept of weathering in its broadest form tends to embrace karstification, as well as many other individual exogenic processes. It is more reasonable to keep with the narrower notion of weathering, which stresses on the near-surface processes of in situ physical and chemical breakdown and alteration of parent rocks to products that are more in equilibrium with newly imposed physico-chemical conditions (Ollier, 1969).

In contrast, under karstification chemical alteration of parent rocks is minor, as is the amount of insoluble residue, and most of material is removed in the dissolved form through internal drainage system of conduits.

The non-karstic weathering profiles tend to develop into weathering mantles (or weathering crusts), which are mantles of chemically and mineralogically deeply altered weathering products containing much inert components. The net result is decreasing porosity and permeability of a weathering mantle in most cases.

In contrast, the development of weathering profiles on carbonates is characterized by increasing dominance of dissolutional removal of material and increasing capacity of the uppermost zone to transmit even the minor amount of residue that could form on carbonates. Such capacity evolves with the increasing organization of permeability in this zone towards major vertical drains in the underlying vadose zone. The net result is increasing porosity and permeability in the uppermost zone and the formation of epikarst.

The formation of a weathering mantle on insoluble rocks and the formation of the epikarstic zone on carbonates should be regarded as different types of hypergenesis, with largely opposite effects to the structure and hydrologic role of the uppermost zone of bedrocks exposed to weathering.

*Factors in the formation of epikarst*

The literature on weathering and karst provides an extensive discussion of major factors that exert important guidance on near-surface changes of structure and porosity of the rock. Although the factors in the following list are commonly recognized to guide dissolutional processes in karst, their effects on the epikarst should be viewed from the standpoint of the combined action of unloading, weathering and dissolution upon exposed rocks:

- <u>Parent rock composition.</u> Susceptibility to mechanical breakdown and dissolution.
- <u>Parent rock structure and texture.</u> Susceptibility to mechanical breakdown; effects on infiltration and solution processes, etc.
- <u>Tectonic structure, and lithostratigraphy in the upper section.</u> General arrangement of structural features, fissure permeability structure in the bulk rock, lateral and vertical variability of rock units within the near-surface zone.
- <u>Local topography.</u> Effects on drainage, shatter movement, stress-release fracturing, etc.
- <u>Presence and thickness of soil.</u> Biogenic effects including $CO_2$ and organic acids production; infiltration and hydrochemistry controls.
- <u>Climate.</u> Influences in a major way the character of weathering (physical/chemical weathering relationship) that will take place in any region, as well as solution rate. Chemical weathering is at a maximum in a warm moist tropical climate, while in polar and arid regions physical weathering predominates. Subsidiary factors are precipitation, temperature, vegetation and biological activity.
- <u>Microclimate.</u> Although the macroclimate determines the main character of the weathering in any given region, the

microclimate influences in many ways the soil and epikarst pattern in the local scale.

- Tectonic regime. Rate of uplift or subsidence with its effects on denudation and stress release.
- Nature of denudation agency that exposes the bedrock to the surface (high-rate/low-rate denudation).
- History of development (single-phase or multi-phase).
- Time

Most of these factors are variable in space and/or in time and are in the complex interplay. There are many feedback loops in their relationships. Fig. 3 is an attempt to visualize their influence and relationships in the formation of epikarst. Fracturing and dissolution are the main processes occurring in the uppermost zone of exposed bedrock to form epikarst, while *in situ* chemical transformations being of minor importance on carbonates. Fracturing is generated by weathering and stress release, and dissolution is driven by water circulation. The guiding factors can be subdivided into two sets, one being endogenic and the other being exogenic in nature.

Rocks in the near-surface zone vary in composition, texture and structure and therefore in their susceptibility to alteration by the epikarst-forming processes. On the other hand, the factors that guide these processes vary with position on the surface and with local conditions, so that these processes at any given locality vary in composition and intensity, and therefore in their capability to generate epikarst. These complex relationships, as well as evolutionary aspects, account for great variability of epikarst characteristics on local, regional and global scales.

## Hydrologic functions and roles of epikarst in the overall karst system

The structural and permeability distinctions between the uppermost zone and the bulk rock mass below account for specific hydrologic functions which this zone performs in the overall karst system. Epikarst hydrology received much attention during last 30 years and is generally well understood. Fig. 1 illustrates the main features.

Most of them arise from the fact that infiltration to the epikarstic zone is easier than drainage out of it. The relatively homogeneous hydraulic conductivity field at the top of the epikarst, which allows for diffuse infiltration, becomes increasingly heterogeneous towards its "bottom". Hydraulic conductivity in the epikarst is believed to be two to three orders of magnitude greater that in the underlying vadose zone but heterogeneity in its distribution is even more important. Drainage of the epikarst through prominent deeply penetrating fissures provides for flow concentration at its base. According to Kiraly (2002; see also Kiraly and Morel, 1976), more than 50% of the infiltration arrives to the vadose zone from the epikarst in "concentrated" form, directly into the high conductivity channels.

Epikarst is recognized as an important storage subsystem. Some studies (e.g. Perrin et al., 2003) suggest that storage in epikarst can be more significant than storage in the phreatic zone. Decrease in permeability with depth causes considerable lateral component in the flow within epikarst, which converges towards major deeply penetrating fissures.

In conveying water down to the vadose zone, the epikarst splits infiltration into several components: conduit or shaft flow, vadose flow and vadose seepage (Fig.1). Epikarst distributes recharge to the vadose zone as quick flow and slow flow. Both hydraulic and transport responses of epikarst to rainfall events depend on its maturity and links with the vadose zone, as well as on rainfall intensity and the pre-event precipitation history. Generally, epikarst accounts for retardation of through flow and considerable mixing, although it provides for quick hydraulic response at shaft flow (and hence at springs) in most cases.

The feedback of the flow field on the hydraulic conductivity field, a primary distinct feature of a karst system in general, produces it's effect in epikarst by developing an important organization in the epikarst structure. This organization evolves through dissolution in the course of the epikarst evolution to facilitate convergence of infiltrating water towards collector structures intercepting at the base of the zone. A well-developed epikarst differs from an initial stress release/weathering profile by a degree of such organization. Epikarst hydrologic mechanisms and organization manifests itself through karst morphogenesis.

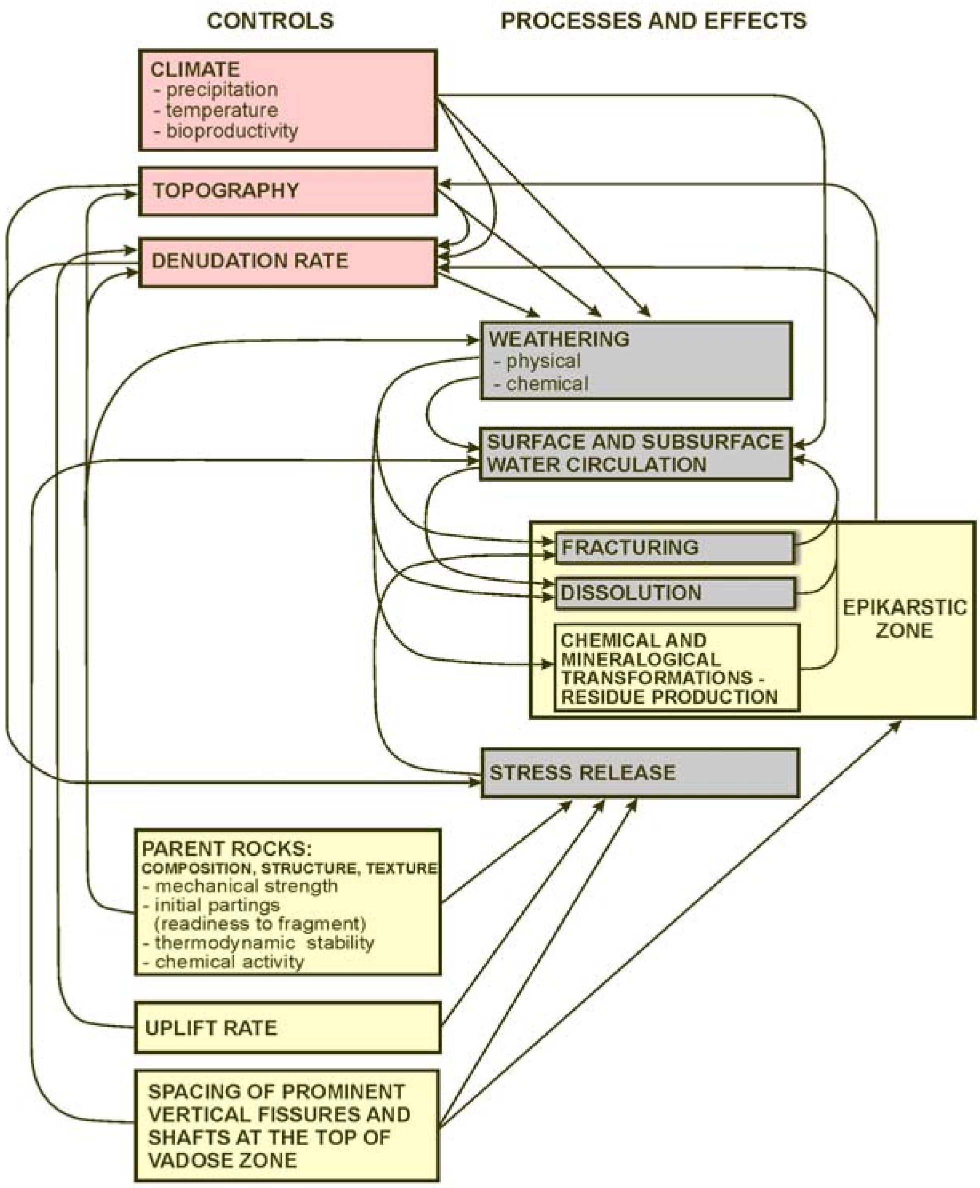


**Fig.3.** Principal factors of the epikarst formation, and their relationships.

## The role of epikarst in karst morphogenesis

Specific hydrological processes operating in the epikarst, coupled with solution effects, account for important morphogenetic effects. The role of epikarst in karst morphogenesis was specifically addressed in Williams (1983, 1985), Ford and Williams (1989) and Klimchouk (1987, 1989, 1995, 2000).

There were two conceptual models proposed for epikarstic morphogenesis. The Williams' model emphasizes the focused dissolution within drawdown cones in the epikarstic water table to generate solution dolines by gradual lowering of the surface above such foci. The Klimchouk model, while appreciating focused dissolution within a 3D volume of drawdown cones, stresses on the enlarging of vertical leakage paths to form "hidden" shafts at the base of epikarst. This model implies collapsing of the partly discontinued "plug" above a growing shaft, and subsequent rapid mass wasting and enlargement at the shaft mouth prepared by focused dissolution within the epikarst drawdown cone, to form a doline (see Klimchouk, 2000 and Fig.4). Both models rely on recognition of specific hydrologic processes in the epikarst, acknowledge specific morphogenetic mechanisms in this zone and envisage doline-dominated landscape as the result of the epikarst evolution.

**Fig.4.** A "plug" of discontinued boulders (karren field) above a 3 m wide shaft, Kyrktau plateau, Tien-Shan (Uzbekistan). Photo by A.Klimchouk.

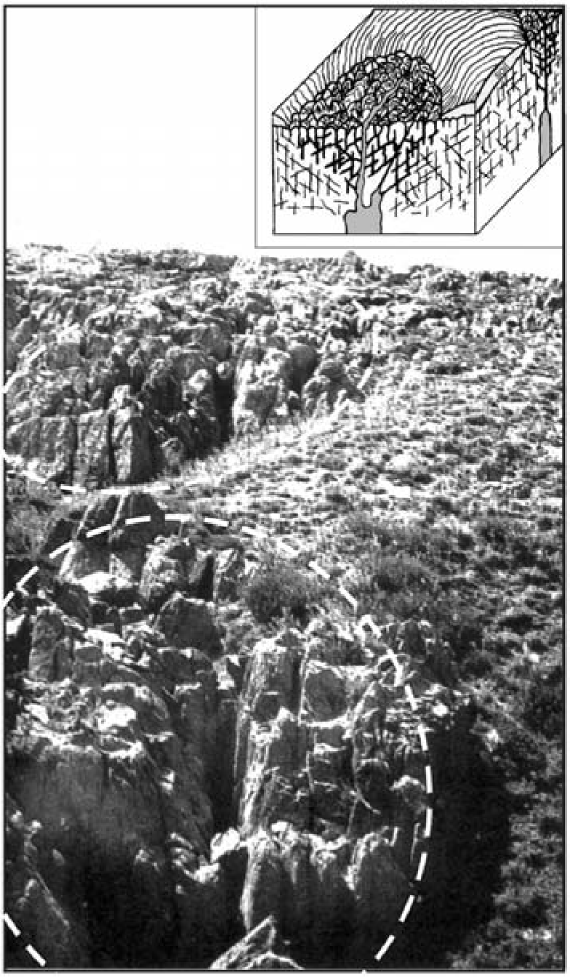

**Fig.5 (right).** The photograph illustrating the soil loss in the mature epikarst, the Kyrktau plateau, Tien-Shan (Uzbekistan). The soil loss is most intense above karren fields (encircled with dashed lines), which are projections to the surface of epikarst "catchment" structures of shafts at the base of the epikarst, as shown in the inset. Photo by A.Klimchouk.

There is a view that dolines do not represent epikarst because they are landforms penetrating into it (Bakalowicz, 2004). In contrast, I do consider dolines to be a part of epikarst because they are the morphogenetic result of the epikarstic hydrologic processes, manifested at a certain stage of the epikarst evolution. However, it should be acknowledged that some types of dolines have nothing to do with epikarst morphogenesis (point recharge dolines, true collapse sinkholes, etc.) and hence they can be considered as "holes" in the epikarst.

More generally, epikarstic morphogenetic mechanisms act to adjust authogenic surface karstic morphology to the permeability structure at depth, at the level in the base of the epikarstic zone. Hence, they act to transform predominately diffuse appearance of karst landforms in relatively young karst landscapes (karren-dominated) into predominantly focused appearance in mature karst landscapes (doline-dominated). This adaptation function of epikarst continues in mature karsts as denudation continuously lowers the surface and brings still deeper sections of a massif under the action of these mechanisms. In this sense, the epikarst is a kind of a "reaction zone" for karst morphogenesis, which works until complete "consumption" of an exposed carbonate massif.

This suggests that the general problem of karst morphogenesis and its variability (with respect to the type of exposed authogenic karst) should be approached from the standpoint of epikarstic morphogenesis. In the view of the discussion in previous sections about the origin of epikarst and factors in its formation, such an approach seems to be broader and more adequate than traditional consideration of superficial solution processes alone.

## The soil-epikarst relationship

Whether the epikarst develops with or without the soil (regolith) cover depends on a coverbeds composition and a mode of its removal (the nature of a denudation agency which exposes the bedrock). However, the presence of the soil is also a function of the development of the epikarst itself. Where the complete exposure is a starting point for the epikarst development, the soil forms during the incipient and young stages of the epikarst development which are characterized by poor links of this zone with the drainage structures at the vadose zone below. Where the soil is present, it enhances solutional enlargement of fissures in the epikarst. With the development of effective drainage organization in the epikarst and collector structures below, the improved conditions for transport of fines through the epikarst bring about damage of the soil cover, and the soil loss will progressively increase. The soil loss occurs first above drawdown cones expressed as distinct karren fields (Fig. 5) and progresses through the area with further maturation of the epikarst and improvement of its links with the vadose zone below.

The main natural reason for the soil loss is believed to be ecological crisis, as that produced by climatic changes. The above consideration suggests that the soil loss can also be related to the particular (mature) stage of the epikarst development.

## Evolution of epikarst

*Continuous evolution*

Epikarst is a dynamic system which main characteristics are time-variant, changing in a regular way during the epikarst evolution. Several distinct stages can be envisaged in the continuous epikarst evolution. Fig. 6 illustrates this evolution, and the bar chart in the left side indicates relative changes in the intensity of the main characteristics of the epikarst. Epikarst icons depicting particular stages, and the stage names, correspond to the evolution starting from the complete exposure of the bedrock (without regolith). However, as stated above, the epikarst evolution can also commence under the regolith cover. In this case the epikarst will go through the incipient and young stages being the soil-covered, with respective effects on some characteristics.

*Discontinuous evolution*

Buried epikarst presents a specific type of paleokarst. Preserved paleo-epikarst horizons are frequently recognized within carbonate sequences (Osborn, 2002). Re-exposure of paleo-epikarst horizons can result in their exhumation and re-establishment of their hydrologic functions (Table 1).

Interruption of epikarst evolution by glacial stripping is the most common, especially in mountain regions. Glaciers can strip away completely the epikarstic zone. The result is the loss of functional relationship of conduit systems with the newly formed relief (Fig.7). The removal of epikarst changes drastically hydrological behavior of the post-glacial karst system. The epikarstic zone tends to re-establish after glaciations, and its evolution follows largely the same pattern as discussed above. However, some differences on the stages of incipient and young epikarst can be imposed by:

(i) differences in stress release effects imposed by glacial unloading and those from the original post-burial unloading;

(ii) peculiarities of weathering processes in the periglacial zone; (iii) presence of well developed although hydrologically functionless conduits (shafts) in the vadose zone.

Most of alpine karst massifs that experienced glaciations during the last glacial maximum (25-14 ka) have the epikarst re-establishing, presently on incipient or young stages.

The Table 1 presents the evolutionary classification of epikarst, in which the principal categories (in bold) are distinguished on the basis of the evolution continuity and actuality. The types of epikarst (in italic) correspond to main starting scenarios that differ by the principal factors of the epikarst formation. The types in the continuous epikarst evolution can be further subdivided according to their relative age (maturity) as discussed above (see Fig.6.)

## Definition of epikarst and final remarks

Conceptually, epikarst was viewed as either an aquifer, or as a zone in the vertical section of a karst massif. The latter notion seems to be more appropriate for karstology as it allows considering various functions and properties of the epikarst subsystem in the overall karst system. The epikarstic zone can be defined from various perspectives, although a general karstological definition should attempt to emphasize several principal characteristics, namely: origin, structural distinction, hydrologic functions and the morphogenetic role.

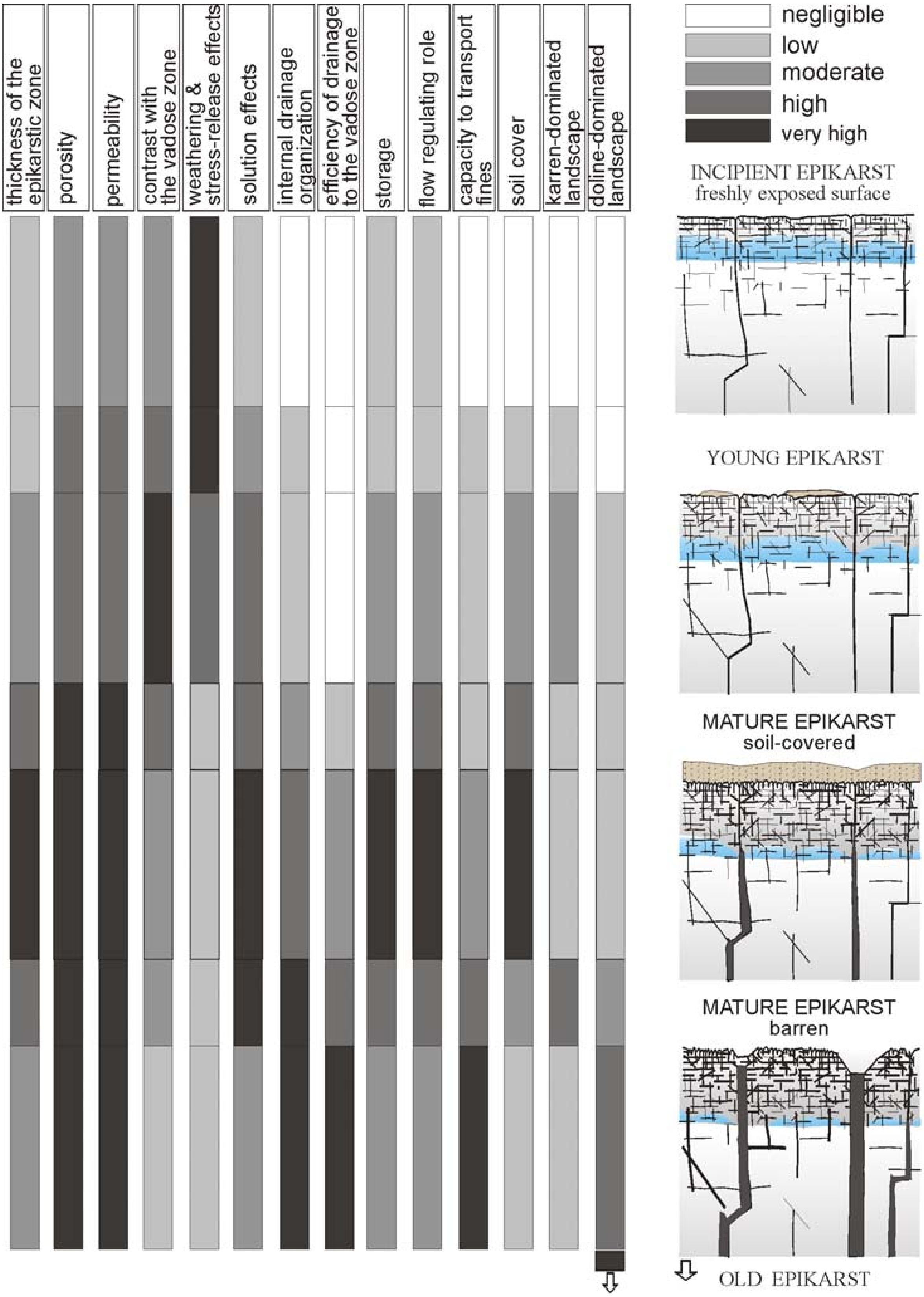


**Fig.6.** The continuous evolution of epikarst and changes in its characteristics.

TABLE 1

Evolutionary classification of epikarst

| **Continuous epikarst evolution** | |
|---|---|
| **Epikarst in open karst** (evolved on young carbonate platforms which have never been buried) | **Epikarst in denuded karst** (evolved after denudational removal of the cover, in paragenetic relationships with the draining structures in the vadose zone) |
| Incipient | Incipient |
| Young | Young |
| Mature | Mature |
| Old | Old |
| **Discontinuous epikarst evolution** | |
| *Epikarst re-**established** after mechanical removal of the original epikarst* (i.e. by glacial scour) | |
| **Epikarst exhumed after burial** | |
| **Terminated epikarst evolution** | |
| *Paleo-epikarst (buried)* | |

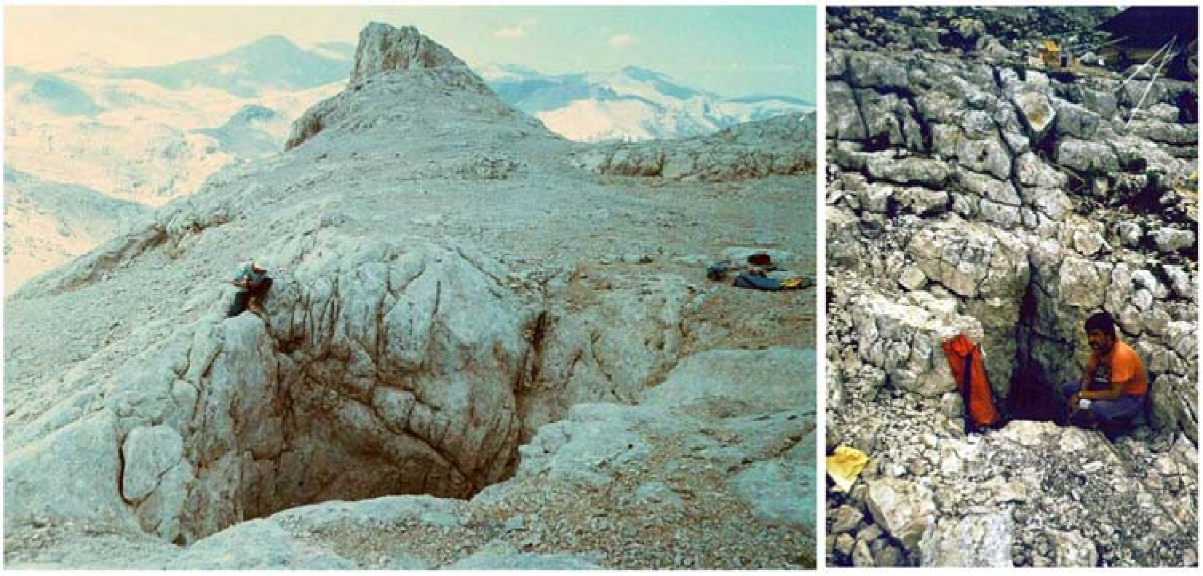

**Fig.7.** Shafts opened to the surface by glacial scour of the epikarstic zone. Left photo: A shaft on the top of the ridge at the elevation of about 3100m, which was shaped by the last glaciation occurred during Holocene (9.1-7.5 ka), Aladaglar massif, Eastern Taurus, Turkey; note that the epikarstic zone is virtually absent. Right photo: A narrow neck of a large (90m deep, 3m wide) entrance shaft of the Arabikskaja System (-1110m) at the elevation of 2180m, Arabika massif, Western Caucasus. Note that the incipient epikarstic zone is already present, formed since the last glaciation that occurred supposedly during the Last Glacial Maximum (25-14 ka).

Epikarst is defined as:

The uppermost weathered zone of carbonate rocks with substantially enhanced and more homogeneously distributed porosity and permeability, as compared to the bulk rock mass below; a regulative subsystem that functions to store, split into several components and temporally distribute authogenic infiltration recharge to the vadose zone. Permeability organization in the epikarst dynamically develops to facilitate convergence of infiltrating water towards deeply penetrating collector structures such as prominent fissures that drain the epikarstic zone. This is manifested by epikarstic morphogenesis that tends to transform disperse appearance of surface karst landforms into focused appearance adapted to the permeability structure at the base of epikarst.

Further studies of epikarst should help to develop its more adequate typology. Efforts toward detailed characterization of the hydrologic and transport behavior of the epikarst, as well as its morphogenetic role, should be placed in the context of the typological variability of epikarst. Recognition of the complex nature of the epikarst and of different starting conditions for its development allows more comprehensive approach to the general problem of karst morphogenesis.

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