COBISS: 1.01

# PHYSICAL STRUCTURE OF THE EPIKARST

# FIZIČNA STRUKTURA EPIKRASA

William K. JONES[1]

**Abstract** UDC 551.44:556.3
***William K. Jones: Physical Structure of the Epikarst***
Epikarst is a weathered zone of enhanced porosity on or near the surface or at the soil/bedrock contact of many karst landscapes. The epikarst is essentially the upper boundary of a karst system but is also a reaction chamber where many organics accumulate and react with the percolating water. The epikarst stores and directs percolating recharge waters to the underlying karst aquifers. Epikarst permeability decreases with depth below the surface. The epikarst may function as a perched aquifer with a saturated zone that transmits water laterally for some distance until it drains slowly through fractures or rapidly at shaft drains or dolines. Stress-release and physical weathering as well as chemical dissolution play a role in epikarst development. Epikarst may be found on freshly exposed carbonates although epikarst that develops below a soil cover should form at a faster rate due to increased carbon dioxide produced by vegetation. The accumulation of soil within the fractures may create plugs that retard the downward movement of percolating water and creates a reservoir rich in organic material. The thickness of the epikarst zone typically ranges from a few meters to 15 meters, but vertical weathering of joints may be much deeper and lead to a "stone forest" type of landscape. Some dolines are hydrologically connected directly to the epikarst while other dolines may drain more directly to the deeper conduit aquifer and represent a "hole" in the epikarst. Water stored in the epikarst may be lost to evapotranspiration, move rapidly down vertical shafts or larger joints, or drain out slowly through the soil infillings and small fractures. Much of the water pushed from the epikarst during storms is older water from storage that is displaced by the new event water.
**Keywords**: epikarst, recharge, vadose zone, karst.

**Izvleček** UDK 551.44:556.3
***William K. Jones: Fizična struktura epikrasa***
Epikras je preperela vrhnja cona krasa s povečano poroznostjo, značilna za številne kraške pokrajine. Je zgornja meja krasa in hkrati prostor v katerem se kopičijo organske snovi, ki reagirajo s pronicajočo vodo. Epikras skladišči in usmerja preniklo vodo v kraški sistem. Hidravlična prepustnost epikrasa pada z globino. Epikras lahko deluje kot viseči vodonosnik, v katerem voda lateralno potuje do vertikalnih struktur (razpoke,brezna), skozi katere hitro ali počasi odteka v globino. Epikras nastaja zaradi razbremenilnih napetosti v tleh ter fizičnega in kemičnega preperevanje. Epikras se razvije tudi na sveže izdanjenih karbonatih, vendar je razvoj zaradi dodatnega $CO_2$ hitrejši na območjih, pokritih s prstjo. Nakopičena prst v razpokah je lahko skladišče organskih snovi in povzroča zastajanje pronicajoče vode. Debelina epikrasa je navadno do 15 m, čeprav lahko, npr. v kamnitih gozdovih, vertikalno preperevanje razpok seže precej globlje. Vrtače so hidrološko lahko del epikrasa, lahko pa predstavljajo vrzeli, skozi katere voda neposredno odteka v kras. Voda iz epikrasa hitro (skozi brezna in razširjene razpoke) ali počasi (skozi sisteme ozkih razpok) odteka v kras, podvržena pa je tudi evapotranpiraciji. Večji del vode, ki ga padavinski dogodki iztisnejo iz epikrasa, je stara skladiščena voda, ki jo nadomesti sveža voda padavinskega dogodka.
**Ključne besede:** epikras, polnjenje vodonosnika, vadozna cona, kras.

[1] Karst Waters Institute, PO Box 356, Warm Springs, Virginia 24484, USA, e-mail: Wkj30@hotmail.com
Received/Prejeto: 23.2.2013

## INTRODUCTION

Epikarst is studied by biologists, hydrologists and geomorphologists. The presence of a near-surface habitat that retained at least some water year round has long been recognized by biospeleologists (Rouch 1968). A brief paper by Mangin (1973) proposed the term "epikarst" for the perched aquifer in the upper part of the vadose zone. Williams (1983) called this the "subcutaneous zone" and described the structure based on geomorpological obersvations. Williams viewed the epikarst as a zone with many open fractures that facilitates rapid infiltration of precipitation but creates a bottleneck for water movement at some depth as the frequency and size of the fractures decrease. An introduction to epikarst is presented in Ford and Williams (2007). A definition of the epikarst from a 2003 Karst Waters Institute conference and workshop on the subject (Jones *et al.* 2004) is:

*"Epikarst is located within the vadose zone and is defined as the heterogeneous interface between unconsolidated material, including soil, regolith, sediment and vegetative debris, and solutionally altered carbonate carbonate rock that is partially saturated with water and capable of delaying or storing and locally rerouting vertical infiltration to the deeper regional, phreatic zone of the underlying karst aquifer."*

A number of interesting studies have been published since the 2003 conference and this paper presents a brief review. The literature now contains more quantitative studies based on multiple year data collections and some old questions have been addressed but some new questions have arisen. A few books directly deal with the epikarst and a number of edited collections have sections on the subject.

Biological work on epikarst fauna (especially Copepods) includes a book by Pipan (2005) and numerous papers. A summary of research on epikarst communities was presented by Culver *et al.* (2012). A paper on "Copepod distribution as an indicator of epikarst system connectivity" should be of interest to hydrogeologists as well as biologists (Pipan & Culver 2007). An introduction to the hydrology of the epikarst zone was presented by Bakalowicz (2012). A book by Kogovsek (2010) offers a very detailed study of several sites in Slovenia with data collected over several years. Another study from Slovenia by Trcek (2003) presents an interesting analysis of spring hydrographs.

## THE NATURE OF THE EPIKARST ZONE

The epikarst typically extends from exposed carbonate bedrock on the land surface or from the soil/bedrock contact downward for several to tens of meters. The epikarst may contain a perched aquifer but is situated in the vadose zone (Fig. 1). The permeability of the epikarst decreases with depth and creates a sort of bottleneck for vertically percolating water. The epikarst has very fast and very slow flow routes so water infiltrating from a given storm event may be partitioned along paths of widely ranging permeabilities. Flow routes through the epikarst may be very fast by flow directly down shaft drains to underlying stream conduits and essentially bypass the smaller fractures with little mixing or storage within the epikarst. Some of the infiltrating water may be stored for a period of several years and may also migrate some distance horizontally within the epikarst zone.

Water emerging from a karst spring is generally a mixture of autogenic and allogenic recharge to the karst aquifer system. Several studies have attempted to identify the proportion of epikarst water to total spring discharge. This is obviously very site specific for a karst basin that receives a high percentage of recharge from sinking streams may have a much lower percentage of epikarst water in the water discharging through a cave stream or spring. Trcek (2003) and Trcek and Krothe (2004) studied the Hubelj Spring (Slovenia) and the Orangeville Rise (USA) using oxygen isotopes as a tracer to aid in separating the components of storm hydrographs. The studies found that there was a significant "piston flow" effect with new event water moving into storage and displacing older stored water from the epikarst. The average event water was about 22% of the storm discharge at the springs and the epiflow component was 41% at the Hubelj Sping and 59% and the Orangeville Rise.

A more direct sampling of epikarst water involves collecting water at ceiling drips or rimstone pools within a cave. A multiyear study of the epikarst above Postojna Cave in Slovenia involved sampling several ceiling drips (trickles) in the roof of the cave to collect flow rates, chemical characteristics and sampling for injected fluorescent tracers (Kogovsek 2010). The vadose zone is 100 meters (depth of cave passage) beneath the surface at the

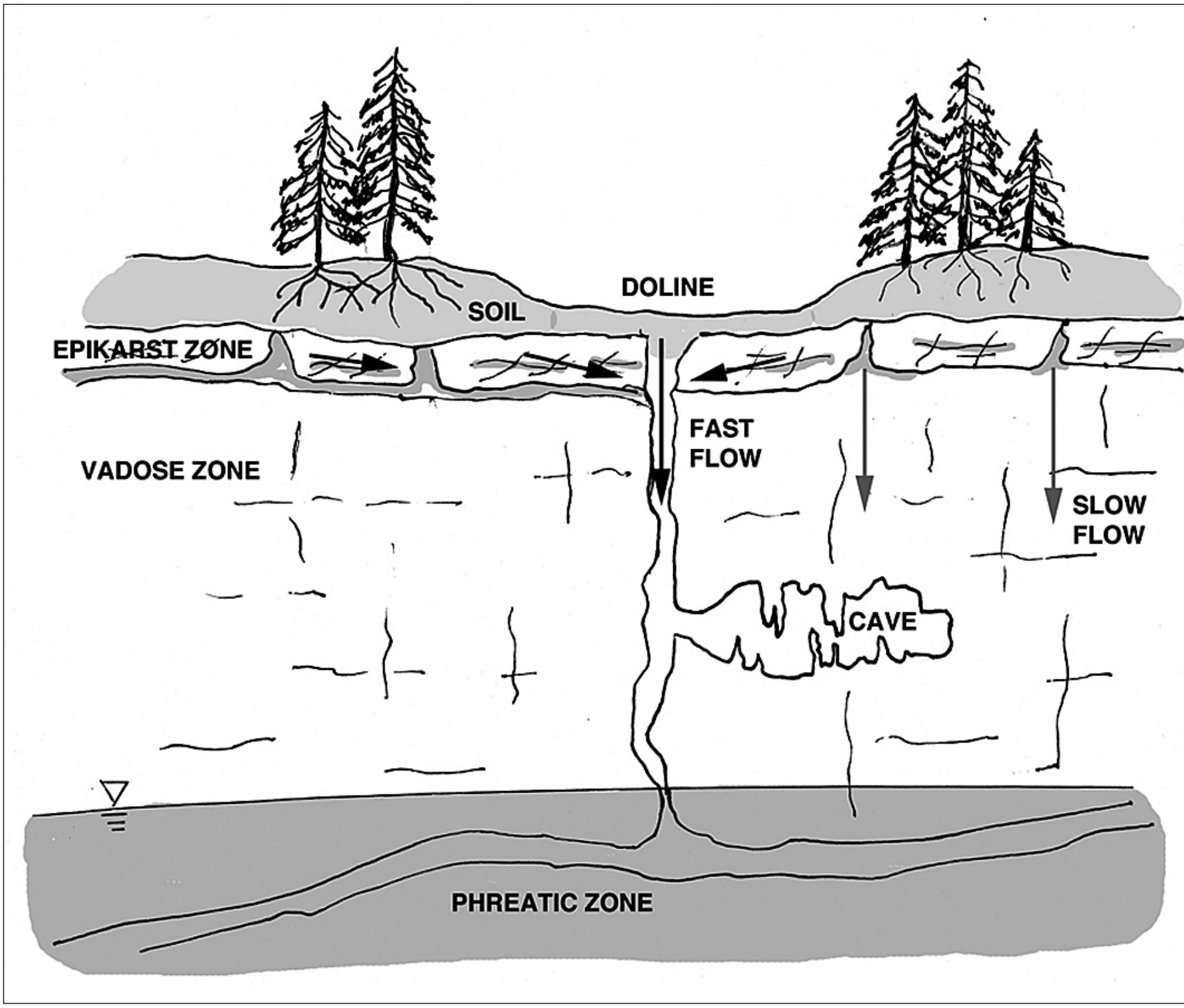


*Fig. 1: Sketch illustrating water movement through the vadose zone. Infiltrating water enters the epikarst at the soil/bedrock contact and may be stored in fractures and transmitted horizontal for some distance to vertical drains. Water may remain in storage in this zone for several years and be pushed out (displaced) by new storm event water. Some of the vertical drains or shafts may essentially bypass the epikarst and rapidly deliver event water to the phreatic zone.*

sampling sites. Kogovsek found that the trickles were very responsive to individual storm events with 72% of the annual precipitation infiltrating through the epikarst zone. Storage of event water was very high at this study site and most of the storm response water pushed out at the trickles was older water being displaced by the event water. When the antecedent moisture was low prior to a storm event the response at the trickles was delayed until sufficient water had moved into the epikarst fractures to flush old water from storage. Monitoring of the trickles following injection of dye on the land surface above the sampling sites resulted in a general pattern of one to three days for the first appearance of the tracer (depending on flow response at the trickle) but suggested that 98% of the injected mass of the tracer was stored in the poorly saturated catchment area within the epikarst. Tracers injected by spreading on the soil took much longer (over three years) to reach a maximum concentration at the trickles compared to about five months for the tracer injected onto bedrock. Dye was still being recovered seven years after injection for one of the tracer tests.

Epikarst probably develops to some extent on most karst landscapes except perhaps in very arid regions. However, Kresic (2013) argues that epikarst, at least the usual description as presented here, is actually the exception and true epikarst is relatively rare. Epikarst developed on very young (eogenetic) carbonates are influenced by the high primary porosity (Taborosi *et al.* 2004), but the karren forms become more like classical continental epikarst as the limestone matures (Mylroie *et al.* 2012). A study of the partitioning of percolation water on Guam (Jocson *et al.* 2002) showed a similar range of travel times (hours to months as found in older karst settings. A study of the Edwards aquifer in Texas (USA) suggests a potential of significant storage within the bedrock matrix (Stinson *et al.* 2012) as well as the fractures.

Epikarst studies are certainly still in fashion and questions remain concerning the nature of the epikarst in different settings. Is there epikarst in regions where caves are formed primarily by hypogenic processes? How does glaciation affect the epikarst? Epikarst will be an important part of future research on the transport of carbon through the vadose zone.

## ACKNOWLEDGEMENTS

Dr. Lee F. Elliott prepared the figure. Thanks are due to reviewers Drs. Branka Trcek and John Mylroie for suggestions that improved the manuscript and added several important references.

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