Misconceptions About Caves and Karst: Common Problems and Educational Solutions

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Abstract

Processes that have formed caves and karst and continue to operate in karst terranes are complex and not easily visualized by the public at large. This has resulted in several common and pervasive misconceptions about the intrinsic nature of karst. Unfortunately these misconceptions are all too often embraced by influential individuals, in both the public and private sectors, who have the authority and mandate to address and alleviate environmental and engineering problems occurring in karst terranes. An essential step in effective environmental management of karst regions is through education, whereby misconceptions are debunked and replaced with sound, clearly presented explanations of karst processes that address the origin of karstic landforms and networks of groundwater flow and that illuminate the interaction between natural processes and human activity. Eliminating misconceptions and teaching well established, modern concepts in a clear and concise manner could considerably reduce environmental problems in this fragile landscape.

Some common misconceptions about karst are: (1) Bedrock is solid, without voids; (2) Water enters sinkholes because they are there, rather than water creates sinkholes; (3) Pollutants put into the ground in karst remain where they are placed; (4) Water from karst springs is pure; (5) All sinkholes form catastrophically; (6) Karst is always well expressed on the surface; (7) Caves form by erosion; (8) Caves are as old as the rocks they are in; (9) Groundwater flow in karst is simple and direct; and (10) A lack of known caves suggests little or no development of karst. Each of these flawed views can be easily rectified through timely education.

Introduction

Karst terranes are inherently very sensitive to environmental stresses and far surpass many other landscapes and geologic settings in this regard. Environmental problems in regions of karst are increasing in both aerial extent and intensity, especially in localities where land use is rapidly changing as relatively undisturbed land is undergoing economic development. This is particularly evident in areas experiencing urbanization, an inevitable result of population growth and concomitant increases in residential, commercial, industrial, and agricultural activity. Progressive degradation of natural environments proceeds as increasing numbers of buildings, parking lots, and other structures are built and as various transportation and utility corridors are extended. The impact of this activity on karst is often severe

(Kastning, 1989, 1995, 1996). Environmental problems in karst typically include (1) instability and collapse of the ground surface, (2) erosion or sedimentation of sinkholes, (3) flooding of sinkholes, (4) contamination of groundwater, and (5) destruction or alteration of spelean environments. Because human activity in karst terranes may easily impact the subsurface in various ways, caves are particularly at risk. Problems include disruption of ecosystems or damage to the contents of caves, such as aesthetic deposits of minerals or archaeological and historic materials. The reader may readily find information on environmental impacts on caves and karst in various sources (Aley, 1972; Aley and others, 1972; Dougherty, 1983; Kastning and Kastning 1991, 1993; LeGrand, 1973; Slifer and Erchul, 1989; White, 1988; Zokaites, 1997).

Examples of environmental problems in karst are well documented in the literature, including proceedings volumes of the 13 preceding National Cave Management Symposia and proceedings of numerous geotechnical conferences on this subject (Kastning, 1994). As a means of alleviating environmental stress in karst lands, a trend in recent years is to produce informative booklets, brochures, maps, and posters on karst for distribution to schools, libraries, museums, and similar institutions (Hubbard, 1989; Kastning and Kastning, 1990, 1992, 1995; Zokaites, 1997). These are also being provided to landowners and governmental officials in communities underlain by soluble rock.

There is a pervasive lack of understanding among people living in karst regions about the intrinsic nature of this type of terrane and the characteristic processes that have formed it and continue to operate. Unfortunately, this unfamiliarity also extends to many individuals who have the authority and mandate to address and alleviate environmental and engineering problems that arise from changes in land use. Even more disconcerting than this large information gap is the prevalence of wrong information about caves and karst that is assumed by the public or is promulgated through spoken or written contact or through lay and media publications (newspapers, magazines, brochures, advertisements, and the like).

A Working Definition of Karst

Although the term "karst" is being used more and more by the press and is appearing in publications and documents from time to time, the meaning of the term is not always an easy one to convey to a lay person. The definition is somewhat convoluted and, when stated, usually needs to be embellished with examples. Specific wordings defining karst have been published in various speleological and geological lexicons (*see* listing of karst glossaries in Kastning, 1994). The glossary of karst terminology compiled by Monroe (1970) is recommended for those who desire a fairly complete guide to the many karst terms used by specialists.

An essential first step in effective management of karst terrane is to define karst. In very simple terms, the following working, one-sentence definition has been found to suffice: *Karst is a landscape that is principally formed by the dissolving of bedrock.* For clarity, it is useful to add that karst is characterized by sinkholes, caves, dry valleys (little or no surficial drainage), sinking streams, springs and seeps, solution valleys, and various forms that are sculpted on the bedrock surface (collectively known as *karren*). Hydrologically, groundwater in karst terranes flows efficiently through openings in the bedrock that have been enlarged by the dissolution process. Surface water is rapidly conveyed underground at zones of *recharge* (typically where water enters sinkholes, soil, and vertical fractures in the bedrock) and then passes through a network of conduits (fractures, partings between beds of rock, and caves). The water eventually emerges at the surface in zones of *discharge* (springs, seeps, and wells). Karst forms in rocks that are soluble to various degrees when in contact with slightly acidic natural water. Commonly, the rocks that are most easily dissolved, and hence become karsted, are carbonate units, such as limestone and dolostone (sedimentary) and marble (metamorphic), and sulfate units such as gypsum (sedimentary). Nearly all rocks may be dissolved to some degree. Only minor solutional features develop in materials with very low solubility in water, such as granite, gneiss, and other silicate materials. In most cases, these features are insignificant in terms of hydrologic and environmental impact. Most significant areas of karst in the United States are found within outcrops of limestone, dolostone, marble, and gypsum.

The study of karst is a relatively new science that draws largely on the principles of geology and physical geography. A thorough professional understanding of the processes that occur both at the surface and in the underground and an appreciation for the total hydrologic system necessitates a familiarity with scientific karst studies. The level and scope of modern karst studies are demonstrated by the recent proliferation of textbooks on the subject (*see* *listing in* Kastning, 1994). Recent texts on karst and caves include those of Ford and Williams (1989), White (1988), and Klimchouk and others (2000). Additionally, the number of scientific journal articles and graduate theses on karst is expanding at a phenomenal rate.

Misconceptions About Karst

There are many common misconceptions regarding caves and karst. Over the years we have addressed several that have been particularly troublesome in the regions and local communities where we have worked on environmental problems. Moreover, misconceptions are innocently conveyed to visitors on tours at some show caves, although this problem is lessening as owners and managers of these attractions are themselves becoming more aware of the processes of karst and speleogenesis. We have previously addressed four of the most common misconceptions (Kastning and Kastning, 1994, 1997). In this paper we revisit these and include six others. The misconceptions discussed here are among the most prevalent and many of these are potentially troublesome in cave and karst management.

Misconception No. 1: Bedrock is solid, without voids. Rocks are viewed as strong, unyielding, and relatively inert materials that provide a stable foundation at the surface of the earth. This may be true of crystalline materials such as igneous and metamorphic rocks and hard, dense, insoluble sedimentary rocks. However, soluble rocks (such as limestone, dolostone, marble, and gypsum) may easily have been hollowed through dissolution by acidic groundwater. Pore spaces and fractures (representing primary and secondary porosity, respectively) may be enlarged in this way, resulting in conduits that become interconnected into extensive, well-integrated flow networks (Figure 1). Cavities excavated in this manner may vary greatly in size and extent, with some attaining large dimensions. Dissolutionally enlarged openings, in turn, may cause structural instability of the bedrock and provide avenues for rapid circulation of groundwater. *The presence of karst features on the surface is nearly always indicative of subsurficial openings and integrated groundwater flow paths.*

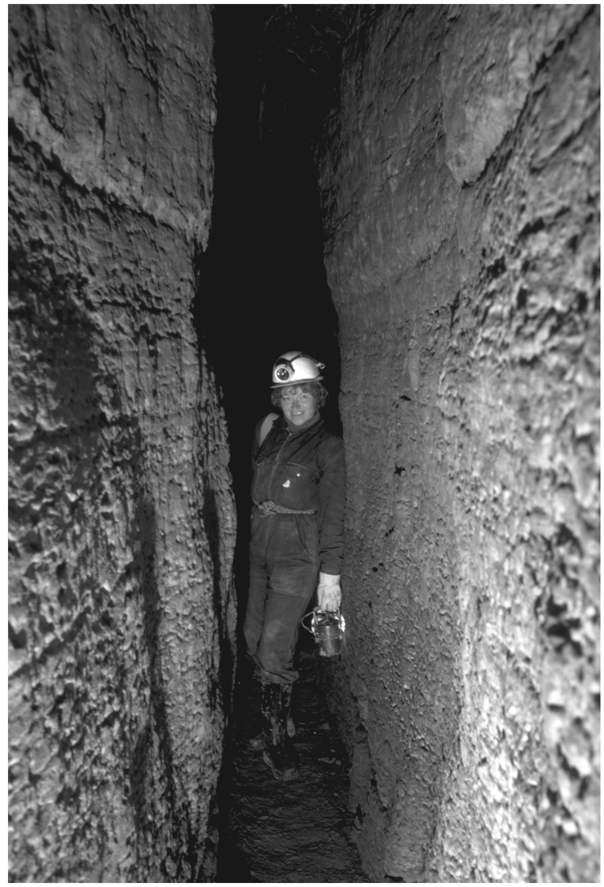

Figure 1. Cave passage in Mystery Cave, Mystery Cave State Park, Fillmore County, Minnesota. This passage has developed along one of many parallel joints. Note the prevalence of pore spaces and bedding-plane partings on the walls of this passage. The pores represent much of the porosity present at the time of deposition of the sediments (primary porosity). The joints were tectonically produced at a much later date and are part of the secondary porosity available to groundwater flow. Even later, groundwater flowing through both types of openings (primary and secondary) have dissolved the bedrock on the walls of the joints, enlarging the width of the joint and thereby allowing for more space for groundwater flow (tertiary porosity).

Misconception No. 2: Water enters sinkholes because they are there, rather than water creates sinkholes. Most people recognize that water enters sinkholes. After all, if a sinkhole is a closed depression on the surface, it will collect water from precipitation and runoff. This water has nowhere to go except into the ground. Sinkholes are all too often viewed as pre-existing funnels that happen to channel and concentrate water that impinges on them. However, the relationship between surficial waters and sinkholes is generally the converse (Kastning, 1999): *sinkholes form and enlarge at places where surficial water can easily enter the ground, such as along enlarged fractures in soluble bedrock.* Infiltrating water has

Figure 2. Sinkhole and vertical-shaft entrance to Purgatory Pit, Rutland County, Vermont. This entrance consists of a series of offset shafts in marble that have formed along joint planes. The sinkhole-shaft complex formed in response to recharge entering fractures that extend downward from the surface. Even though many sinkholes presently receive surficial water from precipitation, most were created as water slowly percolated downward along enlarging openings.

formed the sinkholes, rather than pre-existing sinkholes merely providing convenient sites for recharge (Figure 2). Of course, once established, sinkholes may then concentrate water flow and continue to enlarge.

Misconception No. 3: Pollutants put into the ground in karst remain where they are placed. When compared with most other types of rock (sandstone, shale, and crystalline rocks, such as granite, gneiss, and the like), carbonate rocks and gypsum are highly porous and permeable. *Karsted rocks will not naturally filter contaminants to any appreciable extent.* Moreover, contaminants are easily and very rapidly transmitted to points of discharge, principally springs and wells. The residence time of chemical ingredients in karstic groundwater is relatively short in comparison to that in other rock terranes. Water issuing from the subsurface through springs and wells may easily be contaminated by toxic substances that are introduced in recharge zones. Waste placed in sinkhole dumps or "solid" landfill wastes will leach from these deposits and migrate with the groundwater (Figure 3). One of the most effective attention getters when explaining this phenomenon and its consequences to the public is to comment on how leachate from dead farm animals placed in sinkholes may appear in tap water in nearby homes. In karst, what goes into the ground may soon come out of the ground with little chemical change.

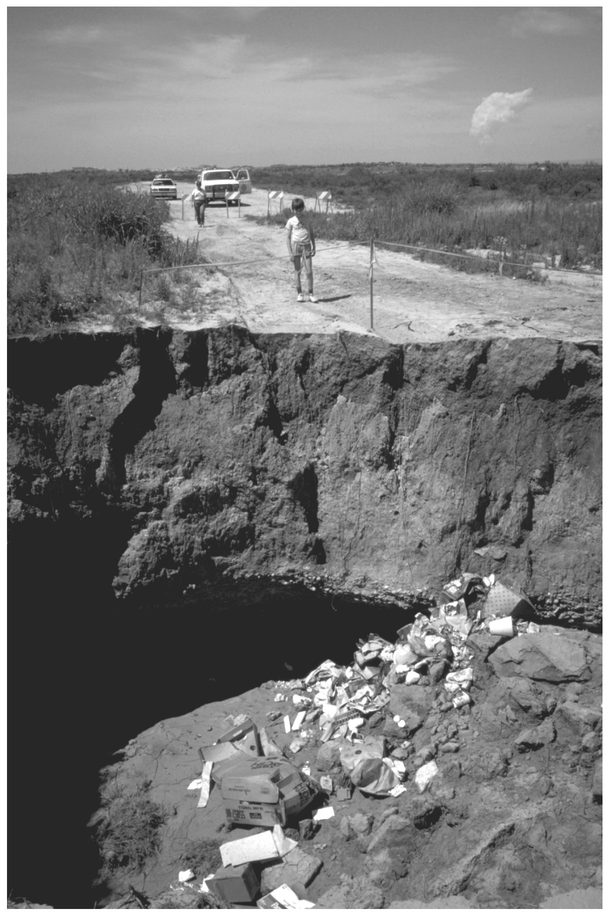

Figure 3. Household trash dumped into a sinkhole in gypsite terrane, near Carlsbad, Eddy County, New Mexico. This sinkhole formed just three days before this photograph was taken. In that short time, an individual found this sinkhole and disposed of trash. Chemical contaminants in trash are quickly transmitted into underlying aquifers and to local water supplies such as springs and wells.

Figure 4. Entrance to Donaldsons Cave, Spring Mill State Park, Lawrence County, Indiana. This a moderately large karst spring. Many springs in karst are used as water supplies. Despite public opinion that spring water is inherently pure, water issuing from karst springs has moved quickly through the aquifer, with little or no chemical change or filtration.

Misconception No. 4: Water from karst springs is pure. There is a general belief that water issuing from natural springs has been naturally purified and is thereby healthy to drink and use (Figure 4). This is exemplified by the popularity of bottled spring water. There are hundreds of brands of bottled spring water being sold in the United States today. Additionally, many people, including those living in karst areas, routinely obtain "potable" water from springs, assuming that water emanating from the ground must be clean. The fallacy that spring waters are inherently pure is obvious from the explanation in Misconception 3 above. *Groundwater in karst moves rapidly from points of recharge to points of discharge, with relatively little chemical change.*

Misconception No. 5: All sinkholes form catastrophically. Most people living on well developed karst may be able to recognize a sinkhole and be able to describe a sinkhole based on its geometric form and know that water enters the ground through sinkholes. *However,* most consider sinkholes to have formed through sudden collapse of the ground into pre-existing voids (caves) in the subsurface. In fact, one of the chief concerns of landowners who have sinkholes on their property (especially where they are close to buildings) is that the land may collapse catastrophically, perhaps taking a building with it. Careful inventory and analysis of sinkholes in a particular area, however, would most likely show that relatively few have formed by outright collapse. Instead, *most sinkholes form gradually, keeping pace with dissolutional removal of bedrock in the subsurface.* This type of sinkhole, commonly referred to as a solution-subsidence sinkhole, is characterized by a bowl shape with gentle slopes (Figure 5). Conversely, solution-collapse sinkholes, formed by catastrophic failure of the bedrock in will typically have steep (often vertical) walls with exposed bedrock.

Figure 5. Typical sinkhole on the Pennyroyal Plain, east of Mammoth Cave National Park, Barren County, Kentucky. Most sinkholes form as bowl-shaped depressions with gently sloping sides and little exposed bedrock. Termed "solution subsidence sinkholes," these form gradually as dissolution slowly modifies the upper surface of the bedrock above fractures through which dissolved material is carried into the subsurface. These sinkholes are unlikely to result in sudden collapse. Most observed sudden collapses result as soil particles are slowly plucked and moved downward by percolating groundwater (a process termed piping or suffosion) followed by catastrophic collapse of the thinning roof of the developing cavity.

Misconception No. 6: Karst is always well expressed on the surface. All too often land is considered to be non-karsted even though it is underlain by soluble rock. Typically the basis for this conclusion is that there are no obvious karst features on the surface, especially well-defined sinkholes. In the course of our personal geotechnical investigations, the authors have seen several cases where large sections of land have been designated as non-karstic simply because surficial depressions appear to be absent (Kastning, 1995, 1996). Yet, we found that some depressions may exist that are very subtle and have little topographic relief. They would certainly not show up on topographic maps that have a 20-foot or greater contour interval (Hubbard, 1991). For example, a thicker than typical soil layer (such as in valleys at the base of steep mountains) might "hide" or mute karstic features. Moreover, some of these lands exhibit other, less obvious karst features, such as dry valleys (Figure 6) and springs or seeps. *In some cases, there may be little or no surficial expression of karst even though well established, karsted, groundwater-flow networks may exist in the subsurface.*

Figure 6. Dry streambed, Schoharie County, New York. Karst is not always well expressed on the surface. One clue that a terrane is karstic is that surficial stream channels have little or no flow. Small stream channels in karst are often dry except immediately following significant precipitation.

Misconception No. 7: Caves form by erosion. Nearly every caver or karst scientist who has visited a number of show caves has heard an explanation of how that particular cave had been "carved" by a swiftly running underground stream. Everyone is familiar with the erosive power of surficial streams, so it seems natural to extend this process to the subsurface. Besides, it gives the impression of the awesome power of nature. Yet, careful measurement of flow in cave conduits through timed dye-tracing studies, along with analysis of dissolution scallops in the bedrock walls and floors of caves (Figure 7), shows that water traveling through even the largest conduits is generally too slow for significant erosional removal or rock. *Most caves form through dissolution of the bedrock by slowly circulating groundwater.*

Misconception No. 8: Caves are as old as the rocks they are in. Again, this is a common mistake that one hears time and again on tours in show caves. It is an easy mistake to make, after all the bedrock is usually very old, often in the range of hundreds of millions of years. It is awe-inspiring to think that the cave you are visiting is that old. However, *caves are relatively young landforms, formed in rock that is typically ancient.* The age of most caves in karst regions is not older than one or two million years (Figure 8). This has been determined through use of radioisotopes and paleomagnetism in cave sediments and through correlation of caves with the known surficial erosional history of the region.

Figure 7. The Sump in McFails Cave, Schoharie County, New York. Scallops visible above the water level indicate the slow velocity of flow present under phreatic conditions when the passage was enlarging by dissolution of the bedrock. Scalloping is not a product of erosional excavation.

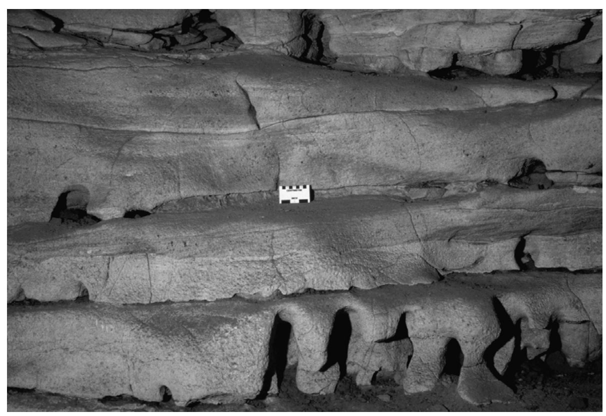

Figure 8. Bedding-plane anastomoses in Wyandotte Cave, Crawford County, Indiana. These small openings are typically characteristic of early stages of excavation of cave passages within favorable beds of soluble rock. Clearly, even these immature openings are considerably younger than the sedimentary rocks that surround them. Certainly mature caves are even younger, typically having formed during the last million or so years.

Misconception No. 9: Groundwater flow in karst is simple and direct. It is a simple matter to note where water may enter the ground in karst regions, namely through sinkholes or where streams disappear into swallet holes or cave entrances. Similarly, it is easy to identify discharge points such as springs or seeps. It follows then that, in many cases, observers would assume that water would likely take a relatively direct route from the observed points of recharge to points of discharge. This route is often conceived as the shortest route between two points. Whereas the inferred route may be the correct one, it is inadvisable to make that conclusion in karst. There are many documented cases, based on well designed dye-tracing studies, where water takes a devious path and emerges at a distant point and not at the nearest spring (Figure 9). Paths of groundwater flow in karst also may converge or diverge in the subsurface, resulting in fewer or more possible routes. Additionally, conduit flow systems are flashy in character and respond in unpredictable ways to storm events or other rapid changes in surface-water conditions. For example, overflow pathways to springs may be used only during flood events. Therefore, *networks of groundwater flow in karst are usually complex, and flow paths and discharge points may be difficult to predict.*

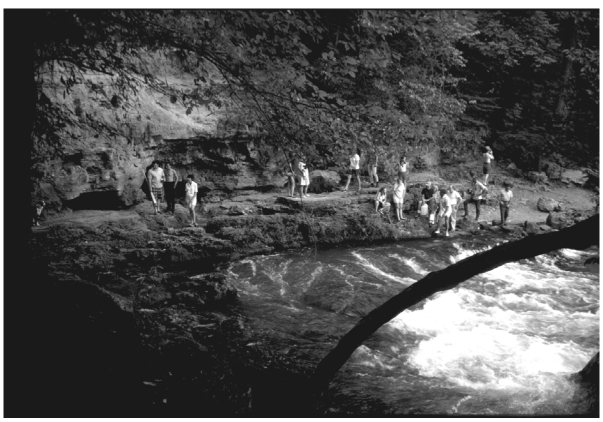

Figure 9. Big Spring, Ozark National Scenic River, Carter County, Missouri. This spring is the largest in the United States in terms of discharge. Tracer dyes injected at many recharge points, up to tens of miles distant, have been detected at this spring, indicating an extensive and complex contributing groundwater drainage basin. Flowpaths of groundwater in karst may be indirect and complex. Dye tracing is the only reliable way of determining such flowpaths.

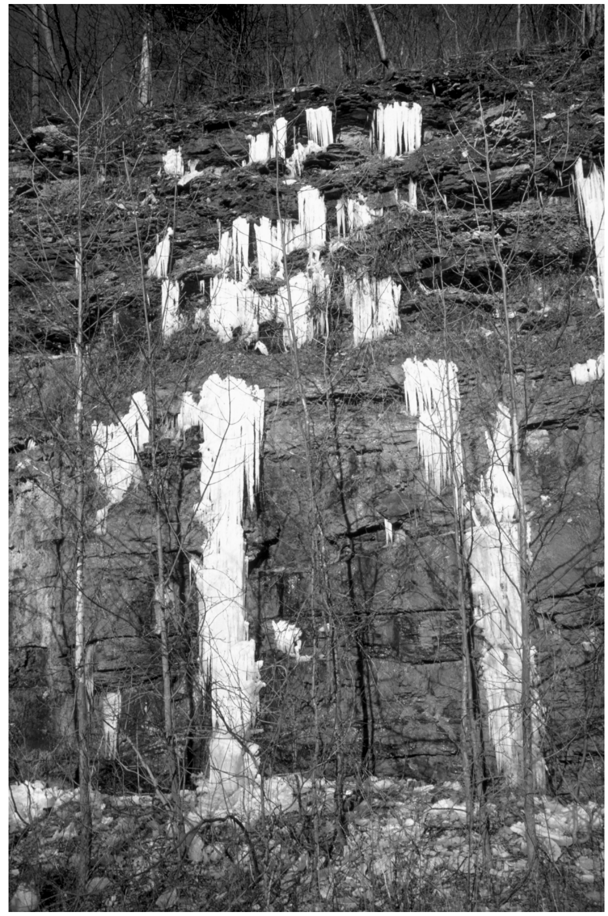

Figure 10. Seepage from bedding-plane partings along a wall of an abandoned quarry, Radford, Virginia. Groundwater flow is highlighted in this example by freezing of discharging water in winter. Many karst areas have significant flow along partings and fractures, yet enterable caves may not present or yet discovered. Nonetheless, groundwater discharge may be considerable along numerous small conduits. The absence of known caves does not in itself indicate the absence of karst.

Misconception No. 10: A lack of known caves suggests little or no development of karst. Not all areas of karst have known caves. The absence of known caves is often used as a reason to classify a terrane as non-karstic, especially if the surface is also devoid of obvious karstic landforms (see Misconception No. 6, above). However, there are many examples of karst terranes where recharge zones and discharge zones are easily identified and mapped (Figure 10). Timed dye-tracing studies may show that groundwater travels at velocities commensurate with conduit flow, proving that these particular terranes are karstic in the subsurface, even though few or no enterable caves are known. There are many documented situations where caves were eventually found in terranes thought to have a low potential for the discovery of caves. Furthermore, conduits do not need to be large enough for human exploration in order for well-integrated flow systems to exist. *Groundwater in karst may easily flow in openings too small to be termed "caves," yet this flow may be hydrogeologically significant.*

Conclusions

Through no fault of their own, many people living in karst regions (and many who make crucial environmental and management decisions related to those areas) are misinformed about the geomorphic and hydrogeologic processes that operate in karst and form caves. Misconceptions about caves and karst, including the ten enumerated above, are relatively easy to debunk and clarify through education. The speleological community has an obligation to do what it can to protect cave and karst resources. It has the data and knowledge that is required to manage karstlands properly. Educational outreach to the population at large and to those whose mandate it is to properly manage and protect the environment goes a long way toward encouraging responsible behavior and decision making. Explanations should be clear and concise, keeping in mind that members of the lay public may be learning about karst for the first time. Graphical aids, such as maps, drawings, and photographs, go a long way in making the points necessary. Progress is being made in this regard and should continue.

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