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A review on natural and human-induced geohazards and impacts in karst

F. Gutiérrez [a], M. Parise [b,*], J. De Waele [c], H. Jourde [d]

[a] University of Zaragoza, Zaragoza, Spain
[b] National Research Council, IRPI, Bari, Italy
[c] Department of Biological, Geological and Environmental Sciences, Italian Institute of Speleology, University of Bologna, Italy
[d] University of Montpellier II, France

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ABSTRACT

Karst environments are characterized by distinctive landforms related to dissolution and a dominant subsurface drainage. The direct connection between the surface and the underlying high permeability aquifers makes karst aquifers extremely vulnerable to pollution. A high percentage of the world population depends on these water resources. Moreover, karst terrains, frequently underlain by cavernous carbonate and/or evaporite rocks, may be affected by severe ground instability problems. Impacts and hazards associated with karst are rapidly increasing as development expands upon these areas without proper planning taking into account the peculiarities of these environments. This has led to an escalation of karst-related environmental and engineering problems such as sinkholes, floods involving highly transmissive aquifers, and landslides developed on rocks weakened by karstification. The environmental fragility of karst settings, together with their endemic hazardous processes, have received an increasing attention from the scientific community in the last decades. Concurrently, the interest of planners and decision-makers on a safe and sustainable management of karst lands is also growing. This work reviews the main natural and human-induced hazards characteristic of karst environments, with specific focus on sinkholes, floods and slope movements, and summarizes the main outcomes reached by karst scientists regarding the assessment of environmental impacts and their mitigation.

Contents

* Corresponding author.
E-mail addresses: fgutier@unizar.es (F. Gutiérrez), m.parise@ba.irpi.cnr.it (M. Parise), jo.dewaele@unibo.it (J. De Waele), herve.jourde@um2.fr (H. Jourde).

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1. Introduction

In the past two centuries the world's population has increased exponentially, reaching over 7 billion people in 2011. The larger number of people has resulted in rapid urban expansion and increasing occupation of land, together with a rising demand of primary resources (water, building materials, food, electricity, etc.), with the consequent increasing anthropogenic impact on the environment (industries, wastes, pollution, traffic, etc.) (Goudie, 2013).

Humans are slowly learning how to deal with environmental issues, trying to find a sustainable balance between the use of resources and the need of preserving and recovering the natural assets (Middleton, 2013). Humans are also learning how to live in a changing environment, understanding the response of natural systems to both human and natural modifications (e.g. floods, landslides, and climate change), and building a societal resilience to natural disasters (Djalante, 2012).

Some areas in the world are intrinsically more vulnerable than others, depending on a series of factors like geology, geomorphology, hydrogeology, biodiversity, climate and so forth. If we only consider surface and subsurface geological factors, the most vulnerable areas are those with a direct relationship between surface morphology and subsurface hydrology, widely known as “karst”. The increase in population and resource demand is resulting in a progressive occupation of karst terrains. In order to minimize the impacts and hazards on these vulnerable and complex areas, man is head for learning how to “live with karst”.

This paper presents a review on hazards and impacts typical of karst, including sinkholes, floods, and slope failures, as well as anthropogenic impacts like pollution of karst aquifers. It deals with their genesis and controlling factors, their inventorying, investigation and assessment, as well as alternatives for their possible mitigation and remediation.

2. The karst environment

The shape of the Earth's surface is the result of a wide set of physical and chemical processes that have acted over thousands or millions of years. The karst landscape takes its name from a region comprised between NE Italy and Slovenia dominated by outcrops of carbonate rocks. Karst refers to an ensemble of morphological and hydrological features and the dominant process responsible for them: dissolution of soluble rocks (mostly carbonates and evaporites). In karst landscapes (Fig. 1), surface and subsurface rock dissolution largely overrules mechanical erosion, leading to a distinctive morphology and hydrology (Ford and Williams, 2007). It may also occur in other carbonate rocks, such as dolostones. In less pure carbonate rocks or in limestone sequences with interbedded insoluble lithologies (Fig. 2), the typical karst features are less developed or even subordinate with respect to other types of landforms.

In most cases, carbonate rocks are dissolved by slightly acidic waters infiltrating into the rock. Acidity primarily derives from CO_2 present in the air and in the soil, which slowly dissolves into the meteoric waters reducing their pH and increasing their corrosion capability. Other sources of acidity can be organic acids or oxidation processes occurring in aerate conditions. These aggressive waters percolate downwards and flow down-gradient in the phreatic (saturated) zone towards the discharge points (i.e. springs). In carbonate karst areas, most of the dissolution occurs in the epikarst, close to the surface (Williams, 2008), and rapidly decreases downwards as the saturation degree increases. A large number of papers address the problem of dissolution kinetics of carbonate systems interacting with meteoric waters (see for example Dreybrodt et al., 1996; Kaufmann and Dreybrodt, 2007; Palmer, 2007). Many factors influence the chemical reactions involved in the dissolution of carbonate rocks, which ultimately lead to a wide

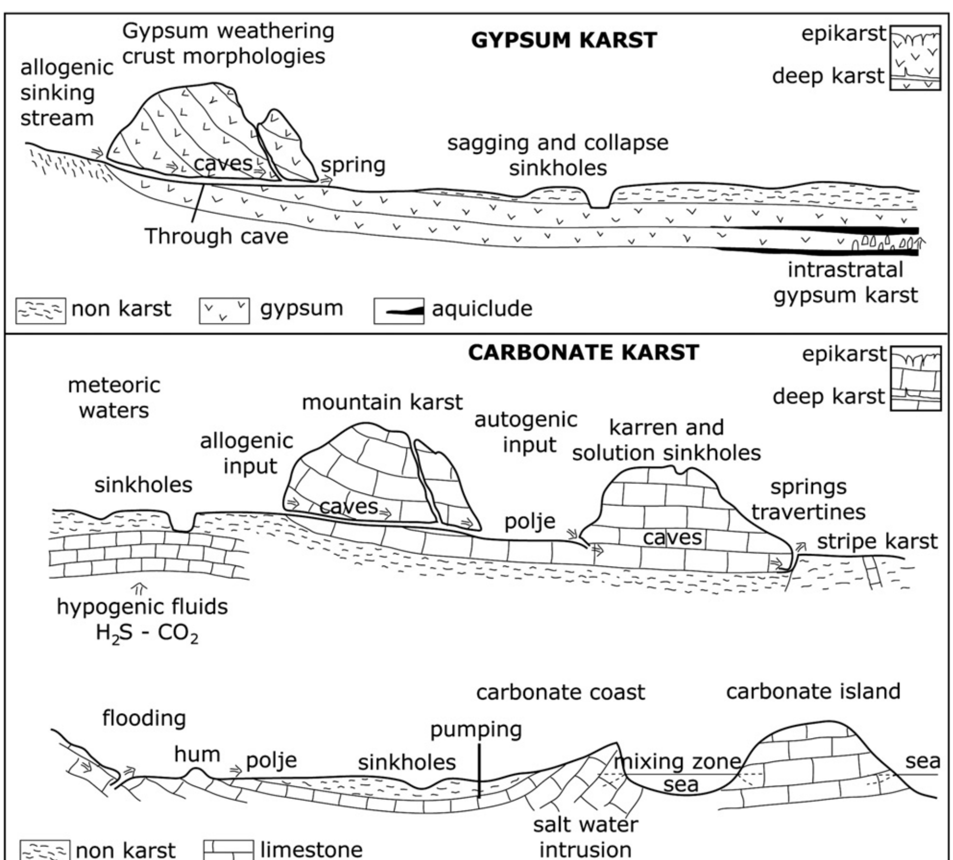

Fig. 1. Simplified sketch of karst in gypsum and carbonate settings.