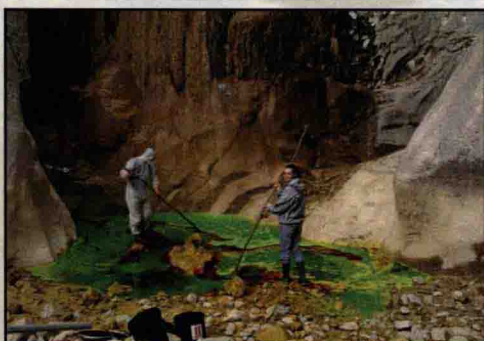
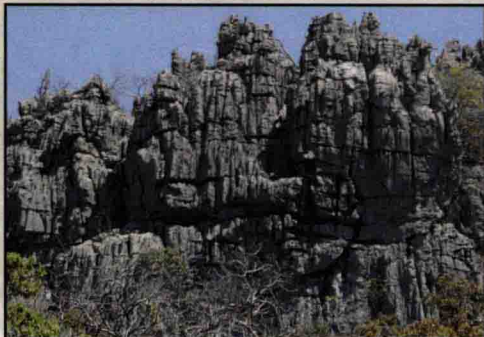


Karstology

Karsts, Caves and Springs

Elements of Fundamental and Applied Karstology



Éric Gilli

Translated from French by
Chloé Fandel



CRC Press
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KARSTOLOGY

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Preface

As I tagged along with a high school friend, one winter Sunday in 1974, to explore La Ratapignata, a small cave near Nice, France, I would never have imagined that our first foray into the subterranean world would be my first step into the realms of exploration, science, and university study. This textbook offers an explanation of the karst landscape built on more than three decades of firsthand scientific adventures. But many others had a hand in shaping my understanding, and here I thank them: Yves Créac'h for his scientific approach to caving and his appreciation for fine surveys; Claude Chabert for his philosophy of travel; Christian Mangan for his innate understanding of geology in the field; Jacques Mudry for his attentive listening and oft-renewed support; Jean Nicod, who set many people on the path to becoming karstologists and to whom I owe my decision to pursue a career in academia; Claude Rousset for his support during both of my theses; Robert Thérond, indefatigable geologist who welcomed me at EDF (Électricité de France) to write a speleology thesis. They share my passion for karst, and their presence can be felt written in between the lines of this book. I wish to give them credit here.

Time discloses the truth (Seneca)

to my son Paul

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1

Introduction and Definitions

1.1 Karst, Karstic, Karstology

The word karst, of Slovenian origin, indicates a particular type of landscape that occurs in carbonate rocks that have been shaped by water. Typical features in karst areas include closed depressions, caves and sinkholes, rivers that disappear into the ground, and large springs around the periphery of the area. Karst zones are present on approximately 50% of land in France, 20% in USA and make up almost 15% of rock outcrops in the world. These areas are home to 1.5 billion people.

In the French academic world, karstology is not taught as its own subject, and is instead traditionally studied as a sub discipline of geography, although it is relevant to other areas such as geology, hydrogeology, civil engineering, paleontology, archeology, and climate science. As a result, the word karst can have several meanings. It is a model for the geographer, an aquifer for the hydrogeologist, and a simple hole for the geotechnical engineer or the quarry-worker.

The goal of this book is to highlight the wide range of approaches to a subject defined in three different dimensions: the surface, the world below ground, and time. A few examples illustrate the importance of karst. Almost half of France relies on karst hydrogeology for its water supply. The majority of discoveries about prehistoric humans have been made in caves. The largest pools of petroleum lie in cavities in carbonate rocks. Changes in the climate have been recorded for millions of years in cave speleothems. In the field of geotechnical engineering, karstic cavities and groundwater are a source of great worry for development companies. Large-scale civil engineering projects (high-speed railways, dams, tunnels, etc.) often face difficulties related to karstology, and geotechnical engineers' lack of knowledge of the field is often surprising.

From a more recreational point of view, karst areas are known for their extraordinary scenery. In France, the Vercors, the Verdon, the Causses, the Cévennes, the Calanques.... Abroad, Ha Long Bay, the Yunnan Stone Forest, the towers of Guilin, and the Tsingy of Madagascar, among others. The numerous caves that have been made accessible to tourists draw millions of visitors every year.

Many books and movies pull their characters into the mysterious depths of a cave. Lastly, caves, springs, and underground rivers, populated by fairies, dragons, elves, djinns, or other fantastical beings are the center of many myths, legends, and religions.

This book is therefore intended for a wide audience, including both professionals and well-informed amateurs, who wish to understand how karst landscapes and caves come into being. It may also be relevant to engineers responsible for development projects in karst areas.

The scope of the concepts addressed extends far beyond the French border, but the examples used here come primarily from France.

1.2 The Karst Region in Slovenia

The Karst, or Kras, region after which karst is named lies to the north of Trieste. It is a landscape of wooded plateaus, with complex topography and many closed depressions, caves, and sinkholes. The bedrock, when visible, is often sculpted into



Figure 1. Map of the Slovenian Karst (or Kras).

picturesque shapes. Streams are uncommon, and quickly disappear into the ground. Large underground rivers have been found there, such as the Reka in the Skocjan caves, or the Pivka in the Postojna caves. The latter are a popular tourist attraction, drawing several hundred thousand visitors each year to see the grottoes or the Predjama castle, built into the mouth of a vast limestone cave.



Figure 2. Predjama castle in classic Karst (Slovenia). The castle is partially built into the entrance of a cave.

1.3 Definitions

1.3.1 Geomorphology

The strict definition of karst is as follows:

A surface and subsurface landscape created by water dissolving carbonate rocks (limestone and dolomite).

A wider definition includes all soluble rock types that water can infiltrate into, dissolve below ground, and create durable cavities in. This requires on the one hand that the rock have a mechanical resistance great enough to prevent the immediate collapse of cavities, and on the other hand that there be a path for the dissolved minerals to exit the system. These concepts are important, as they differentiate karst from other landscapes. Some forms of surface dissolution can in fact be observed in most rock types, particularly in intertropical zones where basalt and granite weather easily. In these cases, however, the effects of water do not extend to great depth, because the products of collapse or alteration quickly fill any cavities as they are created.

Non-carbonate rocks such as gypsum, salts, and certain sandstones are soluble and can therefore form comparable landscapes. The word karst is then sometimes used, but the term parakarst is preferable. Finally, the action of warm water in periglacial regions can open cavities and create thermokarsts. Chapter 9 is dedicated to these types of landscapes.

1.3.2 Hydrogeology

Karst being a result of water's effects at the surface and below ground, it can also be approached from a hydrogeological standpoint. Karst, from this angle, is a limestone unit where the surface hydrographic system is partially or completely sunk below ground, and travels through the limestone, forming aquifers that feed springs. Together, the zone of infiltration, the aquifers, and the springs make up a karst system.

1.3.3 Thermodynamics

Karst can also be approached from a thermodynamic angle, by considering the energy required for its creation. Water sculpts rock at the surface, infiltrates below ground, shapes the bedrock, and then emerges in springs. Karst is therefore a dynamic system, to which thermodynamic laws apply. Fluids transfer mechanical and chemical energy in a resistant environment, where this energy is dissipated. The system is driven by the kinetic energy of water due to its hydraulic gradient, and the chemical energy associated with the dissolution of limestone (Mangin, 1975). At the most basic level, the whole system depends on the sun, which drives the water cycle: caves, a key part of the karst landscape, are therefore indirectly created by the sun!

1.3.4 Civil Engineering

Finally, it is common practice among civil engineers to label as karst any cavities encountered on construction sites or in boreholes. This is a terminological error and is to be avoided. Civil engineering nevertheless holds significant economic value, and part of this book is dedicated to "karst" as defined by geotechnical engineers.

1.4 Components of the Karst Landscape

The shapes that can form in karstic topography are immensely varied, but the characteristic components of Slovenian karst are generally as follows:

- Picturesque water-sculpted rock formations, karren or lapies.
- Closed depressions (dolines, sinkholes, poljes).
- Presence of caves and caverns.
- Streams frequently disappearing below ground.
- Few springs, but often with very high discharge.