“Ghost rocks”: a new way for speleogenesis, a new key for paleogeographies

Anne VERGARI (1)

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Introduction

During the extraction of limestone or during the big civil works in Belgium, the excavations often reveal a large amount of aged or weathered structures. More than their undeniable scientific interest, the study of these deficiencies is of the utmost importance for engineers in order to understand, detect and take preventive measures.

This paper describes a specific type of weathering, called « ghost rocks » for which the impact on human activities is not to be neglected. Not only does it shed new light on our understanding of karsts, but it also provides a valuable key to the explanation of succeeding paleographies.

The Ghost rock

A « ghost rock » (“Fantômes de roche” in French, Vergari, 1997; Vergari et Quinif, 1997) is the result of the *in situ* dissolution of limestone in a drowned environment that preserves the surrounding structure. Instead of the limestone layer, a generally pulverized structure is usually found (Fig. 1). The rock has lost its cohesion and sounds dull when hit with a hammer. The recognition of the limestone layers depends on the lithology and the duration of the dissolving process.

Different morphologies

The « ghost rock » (Fig. 2) presents itself as corridors, as pseudo-endokarsts or as weathered fringes of which the

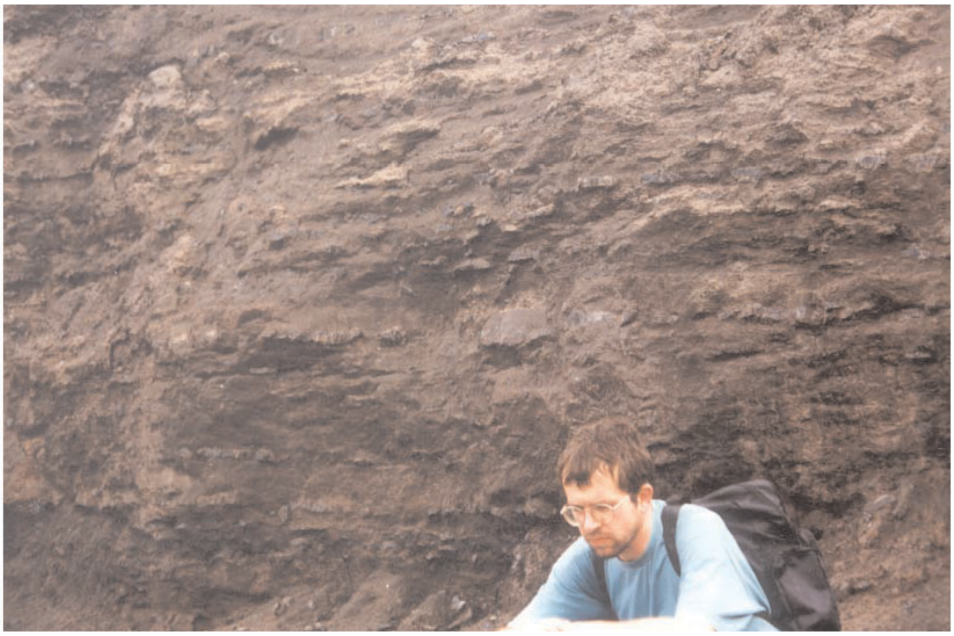

Fig. 1.- Example of ghost rock.

(1) Laboratoire Central de Gralex, 35 rue du faubourg, 1430 Quenast (Rebecq), Belgium. anne.vergari@gralex.be

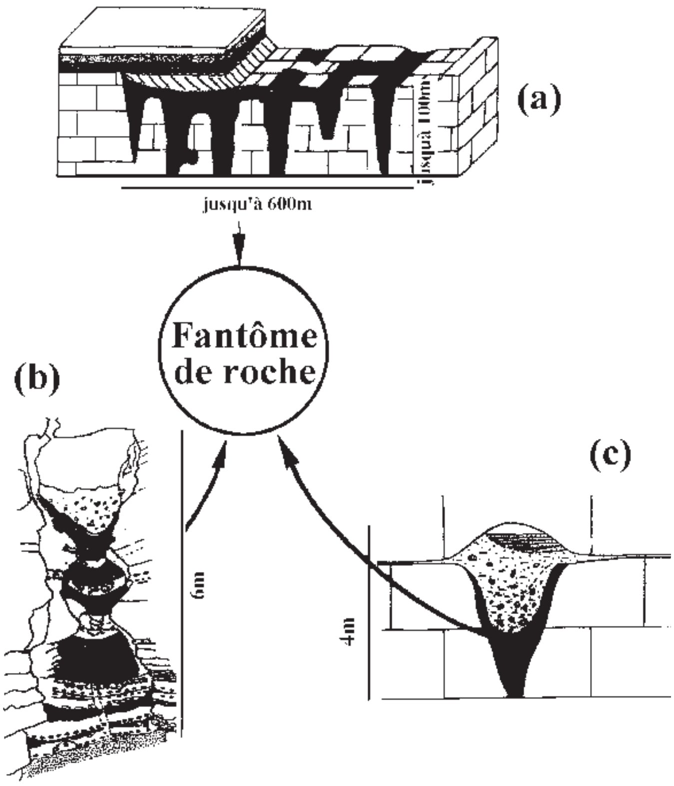

Fig. 2.- Morphologies of "ghost rocks".

the weathered layers. In the bulk of the limestone, these galleries and pseudokarsts are interconnected.

The « filling » of the different morphologies consists of weathering of the layers. Dark and pulverised, it sometimes takes brighter colours, sometimes due to oxidation. In all cases, the original signature of the rock is preserved. On a macroscopic level, one can find back the stratification joints, the cutting of the blocks, the alignment of the cherts, the extension of the calcite veins or even the presence of fossils. The gradual passing over from sound rock into weathered rock can be seen over a few decimetres up to a few meters.

The ghost rock process can start from other morphologies, giving birth to an edge of weathered product on the wall of endokarsts (caves) or the weathered fringe edging of cryptodolines.

size may vary from several tenths of meters to a few decimetres. By drilling, some have been found to be up to 100 m of depth as measured from the current surface of the limestone.

A first morphology consists of hectometre large areas where the « pockets » are plurimetric corridors, starting from the roof of the limestone and which repeat themselves along interconnected directions. In-between these corridors, mounts of rock are found, of which the core has not been attacked by the weathering. Observation on smaller scale shows that the aggressive solutions against the limestone are sideways dispersed, using the smallest flows to propagate: joints of different scales but also the porosity of the surrounding material. The ghost rock is the result of a real gangrene that affected the solid limestone.

The pseudo-endokarst presents itself in another remarkable morphology (Vergari, 1998). First, it shows the existence of endokarst morphology, formed by an *in situ* weathering of the limestone, and not due to any underground river. Next, it proves the presence of potential holes in the rock, that result of the cumulative packing of

The fitting-up in space

Besides their particular « filling » nature, the ghost rocks are easily identifiable by the repetition of an equal step in space and by the fact that they appear in two conjugated orientations. Such a fitting-up proves the initiation of the phenomena on a web of subvertical joints, in relaxation at the moment of weathering (Quinif *et al.*, 1996) and that repeats itself with a frequency depending on the depth at which they appear (Souffaché & Angelier, 1989).

A survey of the fractures (weathered or not) in a quarry that is crossed by a fault reveals that particular tectonic blocks show different behaviour towards weathering. The constraint level of the tectonic block during the development of ghost rocks determines its involvement. A block, captured between two nearby faults, and in relaxation when soaked with potentially aggressive water, will be highly affected. In the same way, crossing faults will propagate the development.

The current investigation of star-like forms indicate that these may be attributed to the intervention of bacteria. (Quinif, 2002, verbal communication).

The geochemistry

The geochemical balance between a sound rock and a weathered rock indicates that the diffusion that lead to a ghost rock proceeds by the dissolution of $CaCO_3$ leading to a gain in porosity, sometimes with local concentration modifications of certain elements, but without external additions (Fig. 3).

The presence of more or less important impression of the encasing is explained by the lithology and more particularly by the tree-dimensional arrangement of the insoluble and the less soluble elements. As such, one goes

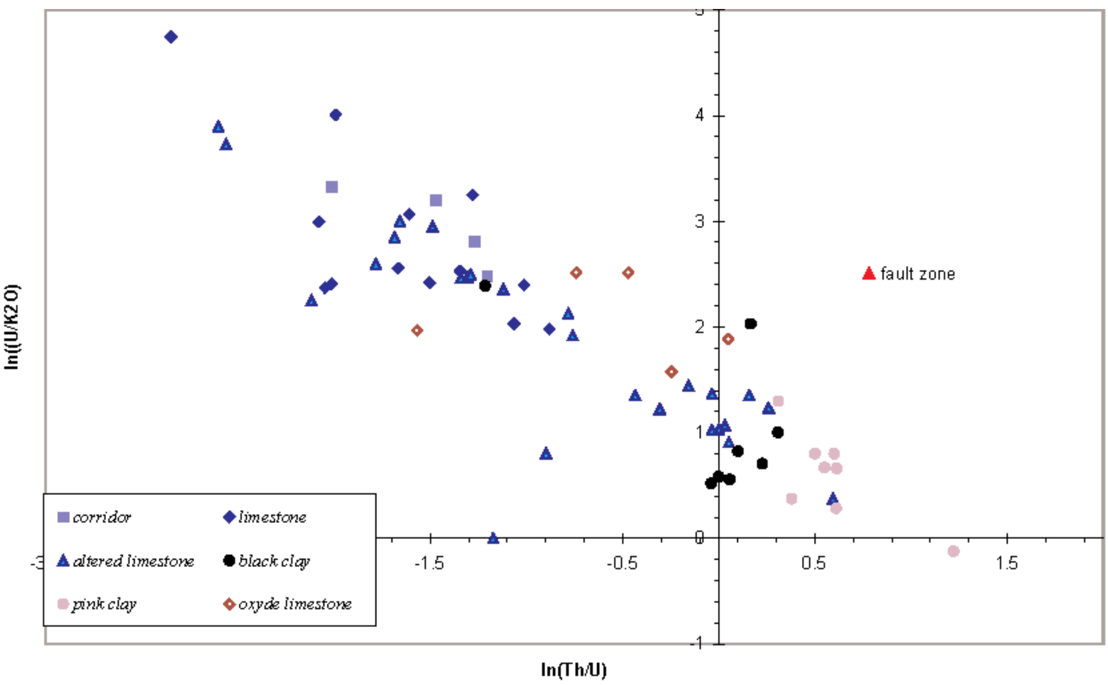

Fig. 3.- U-Th-K diagram. Evolution between limestone and ghost rocks.

from a sound rock to a real « pumice-stone » that has kept the original volume of the rock, or to a clay, which is more difficult to recognise as an *in situ* weathering of limestone. As can be seen on the Figure 2, the presence of the black clay may correspond to an *in situ* weathering of the limestone.

Note that the gain in porosity of blocks that are close to the surface allows in some cases the rock to play a role as a reservoir for external additions, leading for example to iron minerals.

A key for paleogeographies

From a paleogeographic point of view, the existence of ghost rock implies a raised water level, drowning the massif, while the tectonics present joints are mechanically relaxed.

The different presentation of a « classical » karst and a ghost rock leads to a new explanation of the speleogenesis. Whether cryptodoline or endokarst, the karst will develop on a particular fault, the most open to start from, whilst the water will flow from a high to a low point using the most preferred way. On the opposite, the indifferent use of a group of cracks, implies that the water must immerse the limestone in order to use a group of stress opened joints. The rock ghost consists of a « protokarst » (native karst) of which the draining of the fillings by a posterior water flow generate underground networks where the surficial landscape presents a chessboard design or a regular pattern.

In fact, the physical examination of weathered rock shows that the « fillings » are easily mobilised after the renewal of the energy of the transport of discharges. This is visible on an anthropic level through the evacuation of the limestone residues in the quarry as mudflows and blocks through the pseudoendokarsts. The reactivation may locally cause surface sinkholes. On a geological scale, the evacuation of these fillings may be due to the tectonic of blocks or the sinking of a valley.

In addition, the ghost rocks may digest foreign sediments such as river sands and pebbles. On the other hand, thanks to the settling of weathered limestone layers, of which the effect can be seen up to the surface, the trapping of continental or marine sediments may give us valuable recordings.

As such, the concept of « ghosts rocks » gives us a paleogeographic precise reconstitution from west to east of Belgium. From the limestone barrier on the northern boundary of the synclinorium of Namur which was back to back with the Brabant Massif in the Cretaceous up to the depression of a palaeo-Maas river in the Lower Miocene, the « ghost rocks » provide us a better understanding (Fig. 4). Even of our actual dynamic aquifers system, which can respect Darcy Law on a large scale (Rorive, Squerens, 1994).

Fig. 4.- Ghost rocks on the right side of the Maas river.

These various aspects will be developed during the presentation.

Conclusions

More than in the case of the bedrock deterioration, the "ghost rocks" can be recognised by remarkable geometric standards:

- repetition with a given step of weathering,

- figures opposite of racking due to the compressing and collapse,

- digestion of immigrant fillings.

It can play the native part of protokarst for the development of an endokarst or a current landscape.

The origins and processes involved in this paleoweathering, coupled with immigrant sediments records, give us some remarkable tools in order to reconstruct the paleogeographies.

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