



Available online at  
**ScienceDirect**  
www.sciencedirect.com

Elsevier Masson France  
**EM|consulte**  
www.em-consulte.com/en



Original article

## Geological risk assessment for rock art protection in karstic caves (Alkerdi Caves, Navarre, Spain)

Irantzu Álvarez<sup>a,\*</sup>, Arantxa Bodego<sup>b,d</sup>, Arantza Aranburu<sup>c,d</sup>, Martin Arriolabengoa<sup>c,d</sup>, Miren del Val<sup>c,d</sup>, Eneko Iriarte<sup>d,e</sup>, Víctor Abendaño<sup>f</sup>, José Ignacio Calvo<sup>f</sup>, Diego Garate Maidagan<sup>g</sup>, Arturo Hermoso de Mendoza<sup>f</sup>, Fernando Ibarra<sup>f</sup>, Jaime Legarrea<sup>f</sup>, Jesus Tapia Sagarna<sup>d</sup>, Juantxo Agirre Mauleon<sup>d</sup>

<sup>a</sup> Department of Graphic Expression and Engineering Projects, UPV/EHU, Rafael Moreno "Pitxitxi" n° 2, 48013 Bilbao, Spain

<sup>b</sup> Department of Stratigraphy and Palaeontology, Faculty of Science and Technology, UPV/EHU, Sarriena s/n 48940, Leioa, Spain

<sup>c</sup> Department of Mineralogy and Petrology, Faculty of Science and Technology, UPV/EHU, Sarriena s/n 48940, Leioa, Spain

<sup>d</sup> Aranzadi Zientzia Elkartea, Zorroagaina, 11, 20014 Donostia-San Sebastián, Spain

<sup>e</sup> Laboratorio de Evolución Humana, Universidad de Burgos, Pl. Misael Bañuelos s/n, 09001 Burgos, Spain

<sup>f</sup> Grupo de Espeleología Satorrak, calle Descalzos 37 bajo bis, 31001 Iruña-Pamplona, Spain

<sup>g</sup> Instituto Internacional de Investigaciones Prehistóricas de Cantabria, Universidad de Cantabria, Avda. de los Castros s/n, Santander 39005, Spain

### ARTICLE INFO

#### Article history:

Received 28 September 2017

Accepted 23 January 2018

Available online xxx

#### Keywords:

Geological risk assessment

Protection area

Karst

Rock art

Geographical Information Systems (GIS)

### ABSTRACT

This paper sets out a methodology for calculating the potential zone of damage to which an Item of Cultural Interest (ICI) located in a karst environment is exposed. An itemised study of the geological characteristics of the cave environment is proposed: lithological cartography, endokarst and exokarst geomorphology and the study of fracturing of the limestone massif. Based on these data and using a Geographical Information System (GIS), it was possible to calculate the degree of the geological threats on a susceptibility map, according to the vulnerability of the heritage item to be protected and its exposure to the identified hazardous geological processes. By combining these parameters, the existing geological risk was calculated and mapped and the necessary protection area for conservation of the cultural heritage was defined. This methodology was applied in the Alkerdi caves located in the municipal area of Urdazubi/Urdax (Navarre, northern Spain).

© 2018 Elsevier Masson SAS. All rights reserved.

## 1. Introduction

Any discovery of rock art always poses a challenge for the researchers but also for authorities responsible for its management and protection. When artistic items are found in natural surroundings with no specific legal protection, it becomes necessary to modify the list of activities permitted in the area. Before any conservation or restoration work begins, it is necessary to analyse the natural and man-made dangers in the area and the vulnerability of the item or site, in order to decide where the protection area should be drawn to prevent any possible impact [1,2].

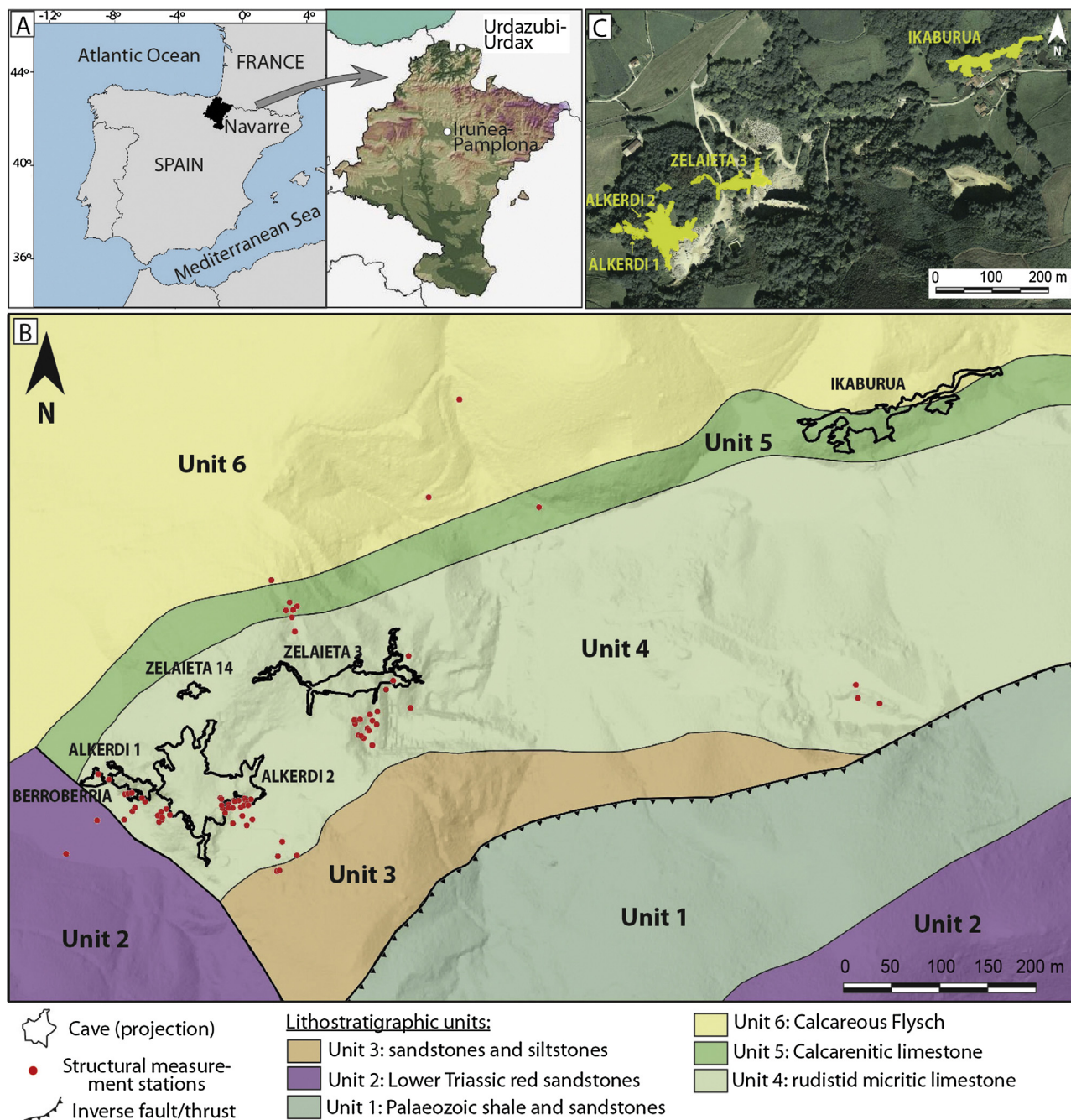
Nowadays, there is no tested and globally accepted methodology for calculating geological risks in karst environments. Several proposals have been made, for instance, those by Carrasco et al. [3] (PROTEKARST), Angulo et al. [4] and Iriarte et al. [5], all of them based on overlapping different layers containing values of differ-

ent factors and creating a zoning map. Similarly, when it comes to establishing the protection area for conserving an Item of Cultural Interest (ICI) located in a karst environment, there is no tested, objective, hierarchical model [5]. In the specific case of karst environments, where the natural and cultural heritage is closely related [6], any calculation of the possible risks entails complex studies. It is very difficult to devise universal methods that can be applied to all cases [2], although it is recommended to apply flexible methods, adaptable to the specific conditions of each region [6].

## 2. Research aim

The aims of this paper are to establish the methodology used to calculate geological risk indexes throughout karstic massifs, and to define the potential zone of damage and therefore, determine the protection area required for conserving the new rock art found in the Alkerdi 1 and 2 caves. This index was calculated based on the detected geological dangers, the vulnerability of the item to be conserved and its exposure to the identified geological threats. Due

\* Corresponding author.



**Fig. 1.** Location of the Alkerdi karstic massif. A. Geographical location of Urdazubi/Urdax in the Navarre province and in the Iberian Peninsula. B. Simplified geological map of the study area, with indication of the Alkerdi-Zelaieta-Ikaburua karstic system (projected caves) and stations of structural measurements. C. Aerial view of the study area (with the quarry fronts) and the projection of the caves.

to its flexibility, this methodology is apt to be applied in any karst environment.

### 3. Case study: the Alkerdi karst system

The Alkerdi massif is located in the north of the province of Navarre (Spain), in the municipal area of Urdazubi/Urdax, adjacent to the French border (Fig. 1A). The massif is composed of Cretaceous reefal limestones that extend discontinuously in a SW-NE direction and overlie Lower Cretaceous sandstones, and are overlaid by calcareous Upper Cretaceous Flysch deposits (Fig. 1B). The SW limit of the massif is a Cretaceous fault, that puts it in contact with Lower Triassic sandstones and to the SE, Palaeozoic and

Triassic rocks overlap the Cretaceous succession by an Alpine thrust (Fig. 1B).

The massif contains an extensive karst system, the Alkerdi-Zelaieta-Ikaburua system (Fig. 1B and C), developed from 200 m to 120 m a.s.l., which is still under speleological/archaeological exploration. To date, 53 cave entrances, sinkholes and springs have been located in the study area (Fig. 1B). The karst system, structured into four cave levels running in a SW-NE direction (multi-level karst system), extends for more than 1 km and is composed of six main caves (Fig. 1B). One of these caves, Alkerdi 1, contain important items of rock art, including an ICI (engravings) [7,8], and new artistic manifestations were recently found (more than a dozen of paintings and engravings, archaeological hearths and material scatters) in

Download English Version:

<https://daneshyari.com/en/article/8965284>

Download Persian Version:

<https://daneshyari.com/article/8965284>

[Daneshyari.com](https://daneshyari.com)