Geoheritage Information for Geoconservation and Geotourism Through the Categorization of Landforms in a Karstic Landscape. A Case Study from Covalagua and Las Tuerces (Palencia, Spain)

José F. Martín-Duque · Jesús Caballero García · Luis Carcavilla Urquí

Abstract This paper describes a methodological procedure for organizing geoheritage information, aimed at geoconservation and geotourism planning and management in protected areas. This method has been applied in a real-life process to declare the *Covalagua* and *Las Tuerces* sites as protected areas in the province of Palencia, in Northern Spain. Although the emphasis is on geoconservation, due to the predominantly karstic characteristics of the studied landscape, the process explains a course of action for the inventory, assessment and diagnosis of geological and geomorphological information for land use planning and management, including geotourism provision. The preparation of the regulations which derived from that information flow is also explained. The inventory included the classification, mapping and description of landforms. The assessment was based on the interpretation of the information in terms of geoconservation and geotourism capacities and limitations, and included a specific analysis of the singularity and representativeness of a *bogaz* (labyrinth karst) and a sinkhole field. The information which came from that evaluation led to the diagnosis, and to the setting of the planning, use and management goals for the geo-resources. These guidelines were finally articulated as regulations. The procedure described is innovative from a methodological point of view, as it attempts to correct the most common problems found in this type of surveys: (a) the accumulation of a large quantity of geo-information of little use for planning and management purposes and (b) the very limited relationship between the geo-information included in the inventory and that included in the evaluation, diagnosis and regulations phases.

Keywords Geoheritage · Geomorphology · Geotourism · Protected areas · Geosite · Karst · Categorization of landforms

J. F. Martín-Duque (✉)
Department of Geodynamics and Institute of Geosciences-IGEO (CSIC-UCM), Faculty of Geology, Complutense University of Madrid, C/José Antonio Novais 2, Madrid 28040, Spain
e-mail: josefco@geo.ucm.es

J. Caballero García
C/López de Hoyos 460, 28043 Madrid, Spain

L. Carcavilla Urquí
Research Area on Mining and Geological Heritage, Geological Survey of Spain (IGME), C/Ríos Rosas 23, 28003 Madrid, Spain

Introduction

This paper provides and explains a methodology which has been developed and used for the geotourism and geoconservation planning and management in a real-life project, to declare a protected area—*Covalagua* and *Las Tuerces*, Palencia province, Northern Spain. This study (Junta de Castilla y León and GAMA 2010) was intended to define specific measures which would ensure the conservation of two small karstic areas of considerable geological and geomorphological importance while developing their geotourism potential. Geoheritage, geoconservation and geoturism were examined together to devise a system of sustainable land management.

This study forms part of a project commissioned by the regional government of Spain in which the protected areas subject to planning are included (Castilla y León) and was produced by an inter-disciplinary team. At the end of the process, two land areas were planned. The main aim was the conservation and sustainable management of their natural values and resources. To do this, many guidelines and regulations were established to manage their geological, biotic and socioeconomic environment and were reflected in a specific and well defined legal framework. In all of the phases the geoheritage, geoconservation and geotourism played a leading role, and they are the central foci of this article.

Protected areas offer important advantages for the conservation of the geoheritage and the development of geotourism (Brilha 2002; Hose 2012) since they generally involve programmes for public use. What is meant by 'public use' of a protected area is the whole set of programmes, services, activities and facilities which are aimed at bringing visitors closer to the natural and cultural values of the area; this is all carried out in a secure, controlled way which guarantees the conservation, understanding and appreciation of these values (Gómez-Limón et al. 2000). Evidently, in natural areas where geo(morpho)logy is the main attraction, geotourism will be of special relevance along with its programmes for public use (Hose 2000), as in the case described here.

In Spain, the main planning and management legal acts for natural resources are the so-called *Planes de Ordenación de los Recursos Naturales* (PORN; Natural Resources Management Plan). This act defines the land use zoning and regulation and must include the following sections: (1) delimitation of the land area included in the plan, (2) description and interpretation of its physical and biological characteristics, (3) analysis of the state of conservation of the natural resources, (4) identification of the general and specific limitations to be established with respect to land uses and activities and (5) application of one of the existing protection categories. The geoheritage, geoconservation and geotourism of the protected areas of *Covalagua* and *Las Tuerces* have been considered under this outline, and the essential content is described in this paper.

The methodological background to the explained procedure can be found in a series of 'classic' studies on 'land classification and evaluation on a geomorphological basis' (Arnot and Grant 1981; Moss 1985; Zonneveld 1989; Godfrey and Cleaves 1991; Mitchell 1991. The guidelines involved, used to date to establish capacities and limitations of the land areas in a wider sense, have been adapted here to geoconservation and geotourism (Hose 2000 and 2006; Dowling and Newsome 2006). With that, this paper contributes to other Spanish studies for incorporating geological and geomorphological information as an integral part of land use planning (Cendrero et al. 1992; Martín-Duque et al. 2003; Santos et al. 2006) or for protected areas (Serrano and González Trueba 2005; Carcavilla et al. 2005 and 2007).

Study Area

The *Covalagua* (2,321 ha) and *Las Tuerces* (2,019 ha) natural sites are located in the NE of the province of Palencia, in Northern Spain (Fig. 1). Both are found within the geological—geomorphological setting of *Las Loras*, which is formed by '*muela*' type reliefs (applicable to 'perched' synclines, or synclinal hills, between anticlinal valleys called 'combes'). *Las Loras* form a homogeneous physiographical domain of structural landforms culminating at c. 1,150–1,200 m in *Covalagua* and 1,000–1,100 m in *Las Tuerces*, while the main valley floors are located at a height of c. 900 m (Fig. 2).

The higher areas and slopes of *Las Loras* are predominantly underlain by carbonate rocks (limestone, sandy limestone and marls) while in the transition to the valley floors they are predominantly sand, gravel and conglomerates. Towards the centre of the valleys, and bordering the whole set of the perched synclines, Triassic shale and gypsum and Jurassic marls, limestone and dolostone outcrop. Finally, all these substrata are partly covered by superficial Quaternary formations, mainly alluvial materials.

The *Covalagua* and *Las Tuerces* sites have both outstanding geological and geomorphologic value, because of their structural configuration, but mostly because of their well and diverse development of karstic landforms, which have important landscape and ecological repercussions. In *Las Tuerces,* different types of *karren* at various stages of development can be found, along with unique karst corridors. Also, an outstanding fluvio-karstic gorge at *La Horadada* (which includes a remarkable castle-type relief) and a platea-like valley (*Recuevas Valley*). In *Covalagua*, there is an impressive sinkhole field, a spectacular cave (called *Los Franceses* cave, prepared for tourist visits), and an exceptional karstic spring with tufa deposits, among other important features. See Figs. 3 and 4. The value of this rich natural capital has been pointed out in various inventories of the geoheritage, geological and geomorphological, in this region (Sánchez Fabián 2005; Basconcillos et al. 2006; Ortega et al. 2008; Fernández-Martínez and Fuertes-Gutiérrez 2008; Fuertes-Gutiérrez and Fernández-Martínez 2010). Outstanding selected examples of the relationships between those karstic landforms and singular associated ecosystems are: high biodiverse nemoral vegetal species and communities colonise the interior of the karst corridors; the bottom of the sinkholes of the Covalagua sinkhole field are filled with clayey deposits—residua of the limestone weathering—which hold the only truly soils of the area, which in turn support high biodiverse grassland communities, and the limestone cliffs which edge the residual platforms of *Las Loras* are the habitat of valuable birds of prey, among others.

Fig. 1 Location of the natural areas of *Covalagua* and *Las Tuerces*, at the Northeast of the Palencia province (Castille and Leon Autonomous Community, Northern Spain). The *small quadrangle* represents the area of Fig. 2

A preliminary analysis of the areas under study was carried out by the GAMA environmental consultants (see the *Acknowledgements* section for details) in 2008 (but was not published), allowed a series of essential factors to be identified when designing a management system to encourage the development of geotourism. In fact, both *Covalagua* and *Las Tuerces* already offer interesting development opportunities for this type of tourism:

Both landscapes are visited by a significant number of people, because of their geomorphological values, with *Los Franceses* cave (Fig. 4 (4.2)) currently receiving around 15,000 visitors/year.

They already have some existing tourist infrastructure, including viewpoints, paths, parking areas, information panels and signposted trails.

Both areas have good road access.

Some recreational facilities are already located there, being specially popular for speleologists and climbers because of the many karstic caves and rock cliffs, although the number of visitors is still relatively small (non-mass tourism, specific and complementary).

The area has other elements of cultural interest, which complement the eco-tourism. These include a pilgrimage at *Las Tuerces* site and some of the best Romanesque churches in Spain around both places.

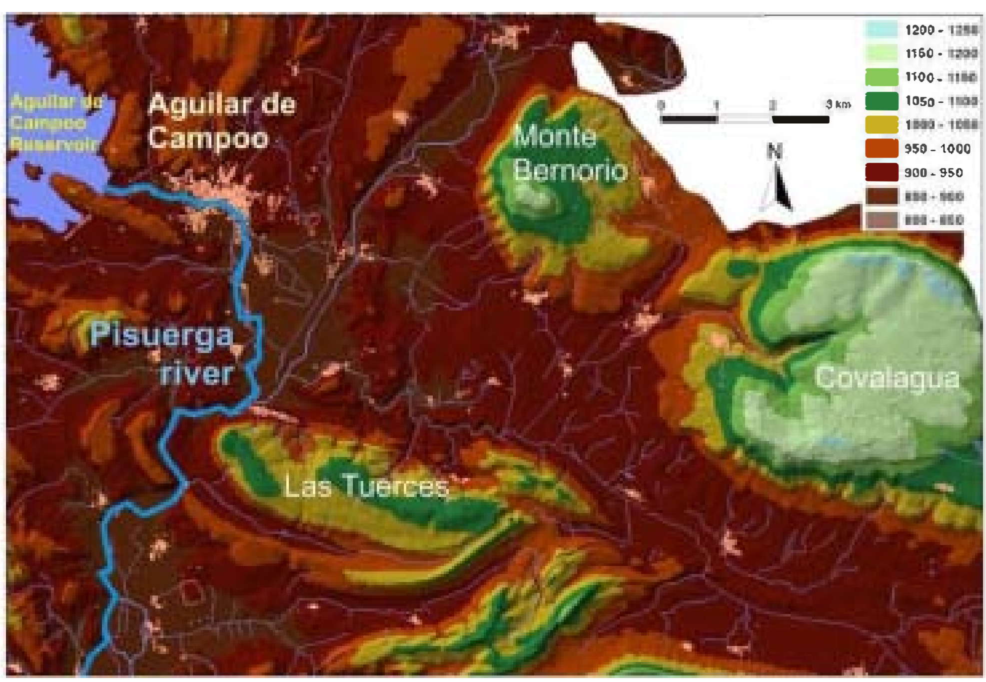


Fig. 2 Digital elevations model of the *Covalagua* and *Las Tuerces* area, showing the topographic framework of the study area. Heights in meters above sea level

Fig. 3 Pictures of some of the most outstanding sites of the study area. *3.1*, ***Las Tuerces*** labyrinthic karst; note, between the two rock masses, a former phreatic tube-like cave, with roughly circular cross-section, evolved to a superficial corridor. *3.2*, Spring and tufa deposit of ***Covalagua***; although it can be barely seen, the centre of the image is a large tufa barrier. *3.3*, ***La Horadada*** fluvio-karstic canyon, a relevant example of a limestone canyon cut into a cuesta (limestone platform with a general dip slope to the East, to the right of the image); the canyon scarps hold many karstic cavities and are subject to significant rock falls. *3.4*, ***La Horadada*** castle-like karst, also called ruiniform karst, because of its similarity with a ruined building. *3.5*, A sinkhole of the ***Covalagua*** sinkhole field; note how the sinkhole bottom holds a grassland community; this community fits precisely with soils which conform exactly with the clayey deposits—residual of the limestone weathering—that fill the bottom of the sinkhole. *3.6*, the ***Valcabado*** viewpoint, located at the Northern edge of the Lora de Valdivia (Covalagua); outstandingly, this edge is a sharp boundary between the Eurosiberian and Mediterranean phytogeographic regions of the Iberian peninsula. The trees below the viewpoint form a beech forest, belonging to the former region. See Fig. 4 for the location of this pictures

Some interesting interpretative initiatives have been installed, with various geological itineraries, explanatory panels and a geological field guide (Basconcillos et al. 2006).

As a result of the flow of visitors to both areas since the mid-1990s, a limited tourist infrastructure has been the development in the nearby villages. Nowadays, the ten nearest villages offer a total of 16 registered accommodation

Fig. 4 Identification and location of some of the geosites referred within the text at *Las Tuerces* (**a**) and *Covalagua* (**b**) natural areas. The boundary of the studied area, shown by the line, was delineated by the regional government. **a** *1*, *Las Tuerces* karst corridor (see picture 3.1 in Fig. 3); *2*, *Recuevas* valley; *3*, *La Horadada* fluvio-karstic canyon (see picture 3.3 in Fig. 3); *4*, *La Horadada* castle-like karst (see picture 3.4 in Fig. 3). **b** *1*, good examples of collapse sinkholes; *2*, spring and tufa deposits of *Covalagua* (see picture 3.2 in Fig. 3); *3*, entrance to the *Los Franceses* cave; *4*, good examples of solution sinkholes (see picture 3.5 in Fig. 3); *5*, *Valcabado* viewpoint; *6*, Ebro valley. Picture 3.6 in Fig. 3 shows both the *Valcabado* viewpoint and the Ebro valley, with the beech forest in its valley slopes at this location. Specifically, this overlay of the orthophoto with the Digital Elevation Model allows the visualization of the sharp boundary between the Eurosiberian and Mediterranean phytogeographic regions of the Iberian peninsula, being this large ecosystem limit the upper boundary of the forest (*dark green colour around 6*)

venues with 115 beds and four restaurants seating 203 diners. Although this is currently the most significant economic activity in the area, and the only sector which is expanding, the fact is that it is scattered and the occupation is irregular, being very seasonal. Therefore other sectors of the local economy are not significantly affected by these activities at present.

Methodology

The geoheritage, geoconservation and geotourism studies described below were part of a natural resource planning study aimed to declare a protected area including the two sites (*Covalagua* and *Las Tuerces*, Northern Spain). But rather than merely one part of the whole, the geomorphologic traits and significant geological heritage were the main focus of the geoheritage interest in the PORN. The whole process was focused by the geological and geomorphological information, as reflected in the land zoning and assessment, primarily based on the geomorphology (Santos and Herrera 2010). Even the catalogue of habitats and landscapes and the land use structure was based on the geomorphology. A study of the geological heritage of the area was cardinal because identifying the geosites and geomorphosites of significant scientific, cultural, educational and geotourism value was a key factor in the final design of the land management system.

The first methodological phase was a geological and geomorphological inventory. The primal objective was to summarise the geomorphological data and to provide initial cartography for planning purposes, in acordance with the planning objectives (with geoconservation and geotourism being essential within them), over a detailed conventional catalog of geological elements. The assesment and diagnostic phases were developed then, in accordance with similar objectives. As a result, legal planning and management regulations, including geoconservation and public use measures were written.

Certain recurrent issues, often detected in Natural Resources Management Plans and other similar documents, were avoided, e.g. (a) larga amount of useless information for planning and management purposes included in the final document and (b) the absence of relationship between the information included in the inventory and that included in the evaluation, diagnosis and regulation phases, which does not shows any causal relationship (see Figs. 5 and 6).

Inventory Phase

The first step was to identify the geological characteristics and features of the area, to be able to analyze their value and potential in terms of geotourism and so plan their management appropriately. The inventory was based on the classification, mapping and description of homogeneous land areas. At this stage the landforms (including lithology, topography and geomorphological processes) were considered to provide the best synthesis of the land. This meant that rather than using a geomorphological classification and mapping organised by genetic criteria (i.e. attempting to explain the origin of the different landforms), the classification was based on ecological and landscape criteria: i.e. prioritising the shape of the landforms, independently of how they were formed, and the characteristics of these which dictate how they should be 'managed'. In this case, the land classification was intended to guarantee a homogeneous response to the landforms in terms of planning, public use and management as a protected natural area.

To do this, a three-level classification was designed. The basic mapping element was the geomorphological *unit* (35 units), represented by land polygons covering the total 'planning area' (Table 1; Fig. 7). The geomorphological *groups* include a certain number of related geomorphological units to provide a landscape context. Three geomorphological groups were identified: I, uplands of *Las Loras*; II, slopes and valleys; and III, alluvial plains (Table 2; Fig. 8). Finally, the geomorphological *features of interest* (16 features) characterise the units where they are found, providing an additional level of information (Table 3; Fig. 9). These features are not unit-specific, and any element (e.g. a sinkhole) may be found in different units. Some microlandforms were also defined, being a fourth (non-mappable) level, which refer to the most characteristic features of karstic micromorphologies i.e. the types of *karren* (Table 4).

The criterion for identifying and defining the geomorphological units and features of interest was based on a classification of exokarstic landforms, although the representation method varied. In a conventional geomorphological approach, the landforms are represented by symbols and colours, of limited use for planning (e.g. many land areas are left 'blank'). The approach used in *Covalagua* and *Las Tuerces* represents groups and units by polygons and features of interest by polygons and points. This means that the map is directly intended for planning and management purposes and it is also compatible with the spatial data structure of a vector based Geographical Information System.

In accordance with the main objective of these maps and the inherent difficulties of any landform classification (since some landforms tend to evolve gradually into others), the limits and criteria for unit differentiation were set precisely fiom a planning viewpoint for public use and essentially geotourism, being each unit homogeneous in terms of its behaviour and response. The distinction, for example, between geomorphological units 2 and 3 uses 'walkability or non-walkability ofkarst corridors' as a criterion. This example is very interesting in methodological terms, because a strictly geomorphological classification would not differentiate

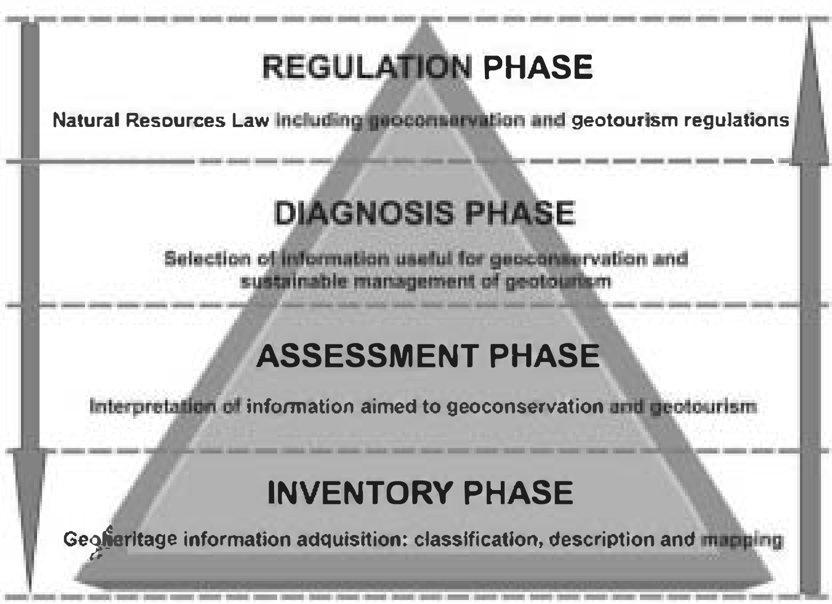
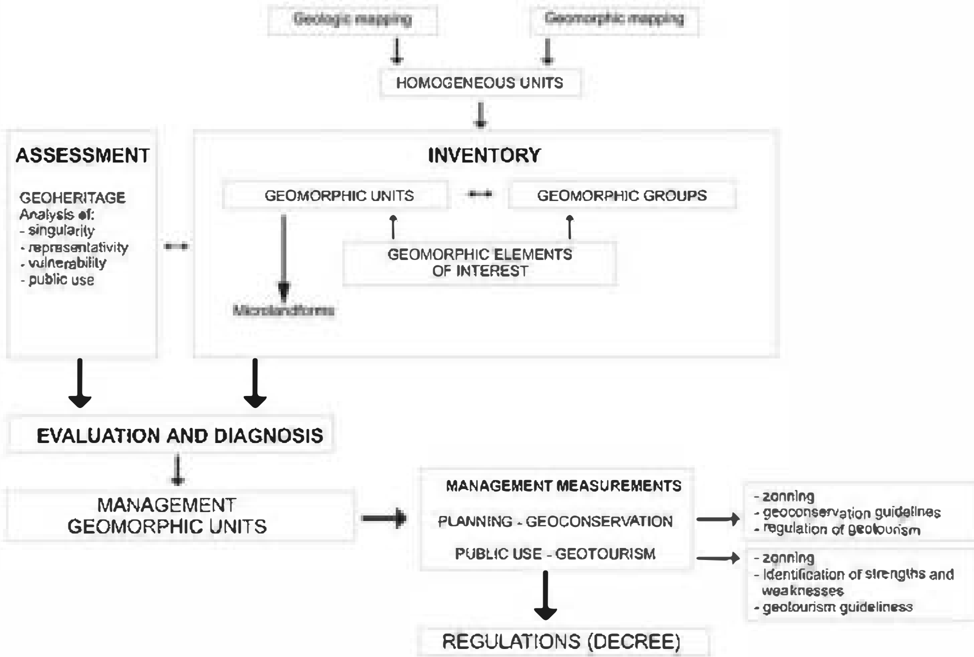


Fig. 5 Organising of the geological and geomorphological information aimed at the planning of natural resources in protected areas. Modified from Warrington (2004)

Fig. 6 Integration of the geologic and geomorphological studies in the Plan of *Covalagua* and *Las Tuerces*



between these two units. The inventory approach is therefore 'dictated' by the main goals of planning, conservation and geotourism, which was a requisite and objective of this Natural Resources Management Plan (Fig. 10).

Finally, a brief description of the geological groups, units and features was included. It was considered necessary to highlight those remarkable characteristics including geoconservation useful for planning; for example, weathering of the limestone at this site produces collapse sinks when exposed near the surface.

Assessment Phase

The geomorphological groups, units and features were later interpreted and assessed in the following terms: (1) their *potential* within the context of a protected area (special characteristics, scientific, educational, visual, recreational or geotourism interest) and (2) their *limitations* (risks inherent in the active geomorphological processes, e.g. subsidence or rock falls), or geo-ecological process vulnerability. Their level of preservation was also assessed, as this factor significantly affected their planning and management.

The study included a specific analysis on the *singularity* and *representativeness* (Wolfert 1995; Carcavilla et al. 2007) of the most characteristic landscapes of both areas; these are the labyrinth karst (bogaz) of *Las Tuerces* and the sinkhole field of *Covalagua*. This analysis was based on a compilation of other examples of karstic landscapes in Spain (Fig. 11), drawn up from a bibliographic analysis and through direct consultation with specialists in karstic geomorphology in Spain. This consultation was carried out through an ad hoc survey that asked to identify *bogaces* and sinkhole fields through Spain and Castilla y Leon. For that, there were included descriptions of *Covalagua* and *Las Tuerces* sites for comparative porpuses. Seventeen specialists were consulted, and everyone responded to the survey. The specialist selection was based on their recent research on Spanish karstic sites.

The analysis of the information showed that there were few samples of laberinth karst in Spain, making *Las Tuerces* a significant feature in the national listing. *Las Tuerces* is also a very good sample of one of the most typical karst landscapes. This makes it both *singular* and *representative*.

Sinkhole fields are more commonly found than labyrinth karsts, both in Spain and worldwide. *Covalagua* has a total 387 sinkholes over an area of 10.1 km^2, which means a density of 38.3 sinkholes/km^2, which in certain sectors is even higher (53.1 sinkholes/km^2). This sinkhole concentration, one of the highest in Spain, makes this an area of considerable natural value.

Diagnostic Phase

According to the previous interpretation and assessment phases, the relevant information was selected for natural resource and public use planning, including geotourism. In other words, in this phase the generic and specific geoconservation and geotourism management measures were developed.

The first conclusion of the diagnosis was that both *Covalagua* and *Las Tuerces* should be declared protected areas, because they represent two of the best examples of karstic landforms at the North-Central region of Spain. In point of fact, new environmental legislation in Spain advocates the protection of 'Karstic systems in carbonates and

Table 1 Geomorphological classification of the inventory

Code	Name	Geomorphological terminology		Local name
		International	Spanish	
1	Rocky pavements with karren surfaces	Limestone, pavement, karrenfeld and kluftkarren	Pavimentos Lapiaz estructural	
2	Narrow corridor karst (non-walkable)	Kluftkarren, giant grikelands, bogaz, corridors karst, labyrinth karst and box valleys	Callejones, corredores and zanjones (Iberoam.) megalapiaces macrolapiaces lapiaces gigantes ciudades encantadas	
3	Walkable corridor karst			
4	Walkable slope corridor karst			
5	Oval corridor karst and closed depressions			
6	Castle-like karst with corridors	Ruiniform karst and castle-like karst	Karst ruiniforme	
7	Flat surfaces with karst towers	Karst towers		*Torres*
8	Aligned cavern (collapse) sinkhole fields with angular karren	Aligned sinkhole field	Campos de dolinas alineadas	*Torcas*
9	Aligned funnel (solution) sinkhole field			*Hoyas*, *Hoyos*, *Hogas* and *Hoyal*
10	Slope valleys and small alluvial plains on uplands			
11	Small razorbacks on uplands	Razorback	Crestas	
12	Karren and soils on cuestas backs	Holhkarren Kavernosekarren	Campos de lapiaz tubular and dorsos de cuesta	*Lanchar Lastras*
13	Soils developed on cuesta fronts	Cuesta fronts	Frentes de cuesta	
14	Rocky scarps on cuesta fronts			
15	Karstic platea	Platea	Depresiones cerradas, con paredes verticales	*Recuevas*
16	Valley bottoms on marls	Subsequent valleys	Valles ortoclinales (subsecuentes)	
17	Small knobs on limestone uplands	Hill and knob	Pequeñas mesas	
18	Tilled fields on marls on uplands			
19	Dry valleys	Dry valley	Valle seco	*Valseca* and *Callejo Valseca*
20	Tilled dry valleys			
21	Small valleys		Valles cataclinales (consecuentes)	*Vallejo* and *Vallejuelo*
22	Hillslopes on marls	Hillslopes on marls	Laderas sobre margas	*Cuestas*
23	Limestone cliffs	Cliff and alcoves	Cantiles and cortados	*Rompizones*
24	Hogbacks and razorbacks	Hogback and razorbacks	Crestas and crestones	
25	Fall headwalls	Headwall (fall)	Cicatrices de arranque de desprendimientos	
26	Scree slopes	Talus slope and scree slope	Canchales	
27	Debris on slopes	Colluvium	Coluvión	*Cuestas*
28	Floodplains	Floodplain	Llanura de inundación	*La Vega*
29	Fluvial terraces	Terraces		
30	Tilled karren and soil surfaces on uplands			
31	Terraced slopes on marls	Terraced slopes	Laderas aterrazadas	
32	Small quarries on colluvium	Quarry		
33	Spoil heaps of old lignite mines	Spoil heaps and waste dumps		
34	Limestone quarries	Quarry		
35	Silica sand quarries			

Geomorphological units

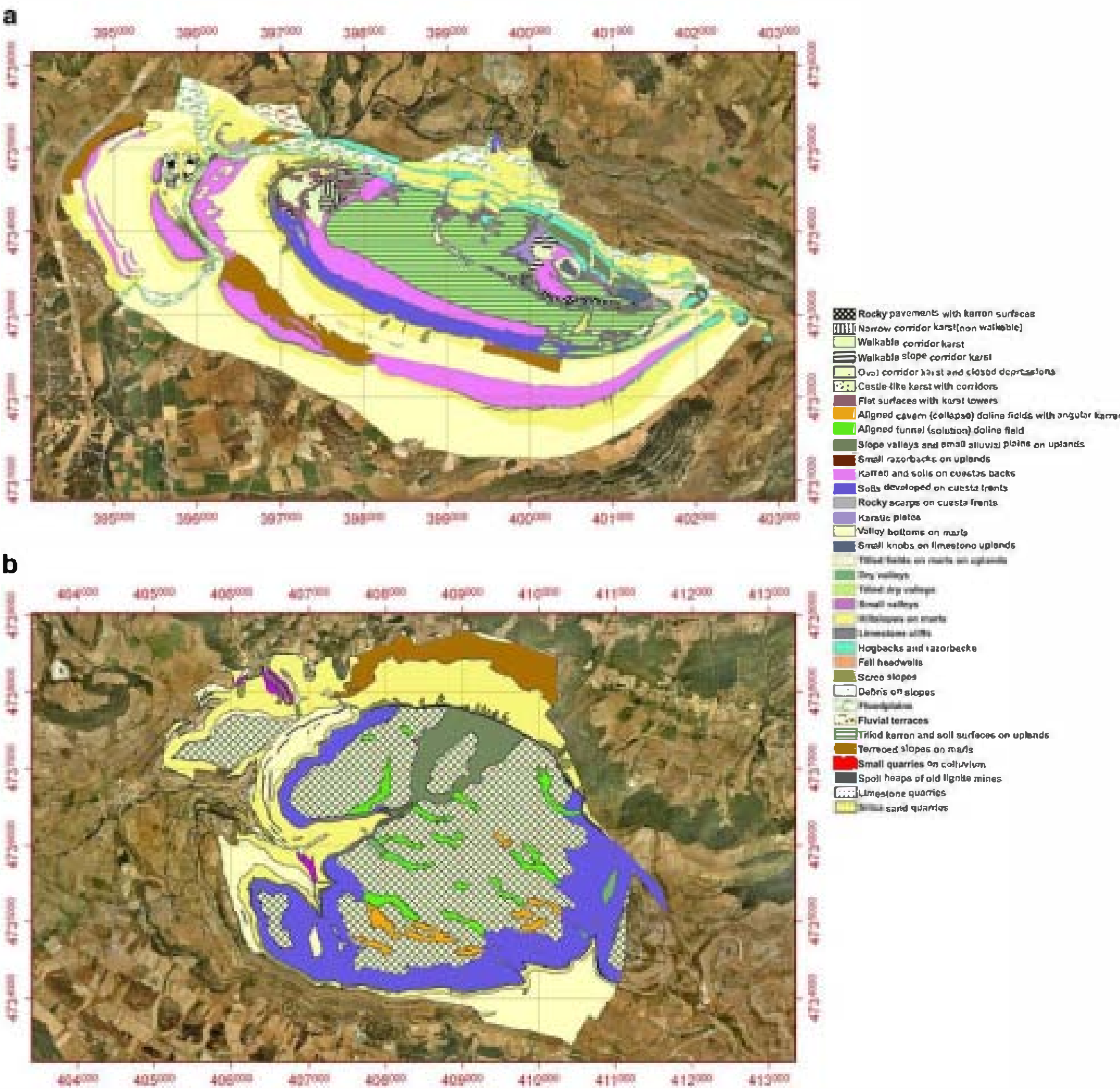


Fig. 7 Geomorphological mapping of the inventory. Geomorphological units. UTM coordinates, zone 30. *Upper*, 'Lora' of *Las Tuerces*; below, 'Lora' of *Valdivia* (*Covalagua*)

evaporites in the Iberian Peninsula and Balearic Islands' as one of the 20 Spanish geological settings of higest international relevance (Carcavilla et al. 2009) and *Covalagua* and *Las Tuerces* represent excellent examples of of such systems.

In both cases, their valuable geomorphological heritage is the result of a spatial convergence of outstanding karstic features. At *Covalagua*: sinkhole field; the *Covalagua* spring and tufa deposits; the *Los Franceses* cave; a rich and varied karren typology; and the *Valcabado* viewpoint. At *Las Tuerces*: its labyrinth karst; the fluvio-karstic gorge of *La Horadada*, a relevant example of a limestone canyon with significant rock falls on its valley slopes and many karstic cavities on the scarp face; a castle-like relief within the gorge of *La Horadada*; the *Recuevas* valley; and also with a wide range of karren. It is, in fact, the overall grouping of these individual features and their inter-relationships which makes these two areas natural sites of especial importance.

The diagnosis also indicated that the combination of these two natural areas offered enormous possibilities for promotion and education, and hence for geotourism (Hose 2000 and 2012). Currently, it receives thousands of visitors (potentially as true geotourists in the future) per year interested in some of these facets. Although quality geological information and interpretative material intended for the

Table 2 Geomorphological classification of the inventory

Geomorphological groups

Code	Name	Geomorphological terminology		Local names
		International	Spanish	
I	Uplands (Las Loras)	Mesa and synclinal uplands	Sinclinal colgado, mesa and muela	Páramos and Loras
II	Slopes and valleys	Cuestas, hogbacks, razorbacks, ridges and valleys	Valles y depresiones ortoclinales (obsecuentes), cuestas y valles and crestas y valles	
III	Alluvial plains	Alluvial plain	Llanura fluvial	Vegas

general public already exists, it needs to be completed (increasing the contents on geomorphology) and improved (the texts should be more simple and appealing for the visitors). The current infrastructure including paths, walkways, viewpoints, a touristic cave and information panels provides an excellent foundation for setting up other interpretative facilities. Geomorphological features are not sufficiently developed and should be further exploited, supported by karstic landscapes. In addition, it should be combined with other biological and archaeological features, whenever it was possible. The areas of *Covalagua* and *Las Tuerces* could also be used to develop a whole suite of interpretative material for *Las Loras*, a structural geologic landscape system of undeniable heritage value from many points of view.

Tourism linked to the geological and geomorphological attractions, that is geotourism (Hose 2000, 2011, 2012), could be considered as the local economic activity with the highest potential for growth in this area and its immediate hinterland. There are no data records of geotourists for the area, due to the lack of geotourism visitor surveys, although anecdotal evidence suggests that there only seems to be significant visitor activity in the summer time as has been indicated in karstic regions in south-east Spain (Hose 2007). The major exception is for climbing and related activities in the karstic *Recuevas* valley that occur throughout the year. *Los Franceses* cave, on the other hand, receives 15,000 visits/year (known because the visitors have to buy tickets), which are channelled into other points of interest in the area (*Covalagua* spring, *Valcabado* viewpoint). The considerable local tourist potential of *Covalagua* and *Las Tuerces* will be reinforced as they are to be declared natural protected areas, but the structural weaknesses are evident, as this tourist activity is closely linked to specific resources, with considerable pulling power but which only generate short visits. The short visits are largely made by emigrants who come back to spend their summer holidays in the local villages.

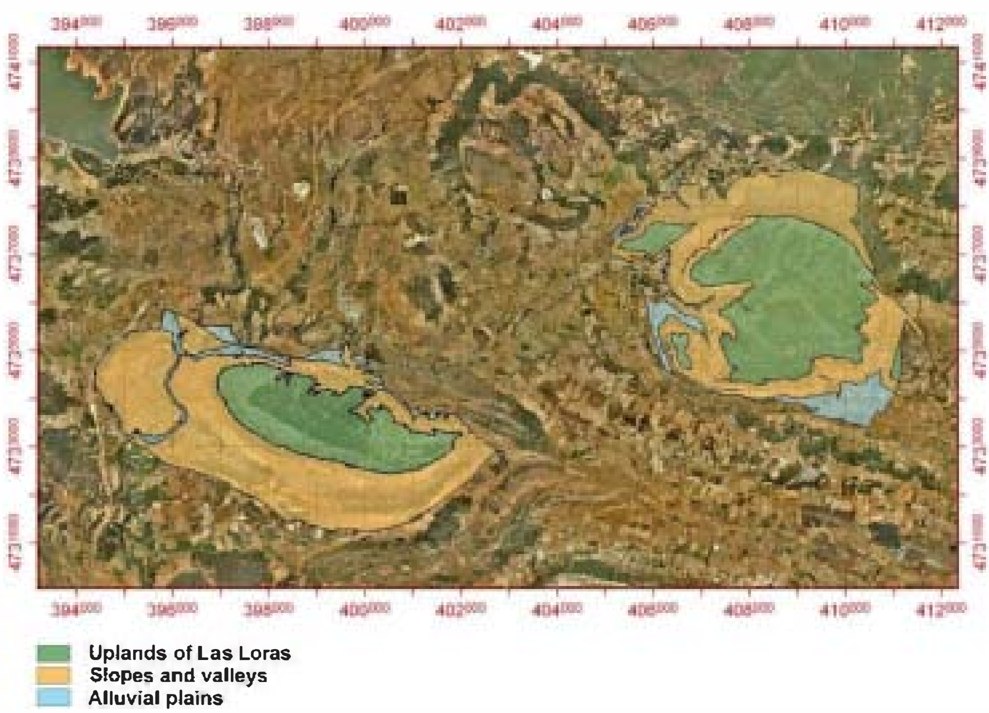


Fig. 8 Geomorphological mapping of the inventory. Geomorphological groups. UTM coordinates, zone 30

Table 3 Geomorphological classification of the inventory

Code	Name (geomorphological terminology)	Local name
A	Sinkholes (funnel type and solution)	*Hoyas, Hoyos, Hogas* and *Hoyal*
B	Sinkholes (cavern type and collapse)	*Torcas*
C	Uvalas	
D	Small karst powers	*Torres*
E	Sinks	
F	Caves	
G	Natural bridges and arches	
H	Alcoves	
I	Corridor karst	
J	Tufa	*Toba*
K	Springs	*Manantiales*
L	Rockfalls	
M	Gullied slopes	
N	Active channels	
O	Ephemeral channels	
P	Abandoned channels	

Geomorphological elements of interest

Regulation Phase

Once the phases above were completed, the planning and management measures were defined, to guarantee the appropriate conservation of the natural values of the area, and also to ensure compatibility with the measures to maximise its potential for public use and local development, including geotourism.

This phase was carried out at two levels: (1) the geological team established measures referring to the geological and geomorphological elements, and the specialists responsible for other theme-based studies (such as biological or cultural) did the same. In other words, the specialist teams defined their own measures, which were then compared and discussed by the team as a whole in various joint meetings; (2) in these meetings, other management measures were adopted in relation to the natural and cultural resources as a whole, based on the conclusions of the socio-economic study. These joint decisions referred specifically to: (a) land zoning, (b) regulating uses and activities and (c) defining conservation measures. In this phase, the local authority responsible for the future management of these natural areas played an important role, thus ensuring that the proposal was also appropriate to its aims and action capacity.

Some of the conclusions reached which are most relevant to geoconservation and geotourism are shown below. It should be noted that one of the main advances of this project is that these conclusions are reflected in the officially approved regulation and are therefore mandatory. Hence, they should be actioned in the future.

Land Planning and Geoconservation Measures

The information collected and generated led to the preparation of land planning and geoconservation guidelines. The official guidelines for the environmental protection of both natural areas describe: (1) the characteristics considered of value of each area and (2) the specific objectives to preserve the integrity of the formations and their active geological and geomorphological processes, and to boost their heritage, interpretative, educational and scientific values—all essential undeprinnings of geotourism provision.

As an integrated conservation measure, the declaration of a single Protected Landscape Area (PLA) was proposed, comprising both the *Covalagua* and *Las Tuerces* natural areas, which actually took effect in 2011. The protected area totals 4,340 ha, divided into two sub-areas, with a protected peripheral buffer zone. The main aim of this PLA is to 'preserve and protect its natural values, habitats, flora, fauna, landforms and landscapes, to preserve its geodiversity and biodiversity and maintain and/or optimise the dynamic and structure of its ecosystems' (Junta de Castilla y León and GAMA 2010).

The presence of singular geological features and their inherent fragility was essential also when defining a land zoning, linked with different regulations for the protection and public use for each zone.

Other regulations were developed to address the protection of the dynamics of the karstic processes that have shaped this landscape and are still currently active. To guarantee the maintenance of the active processes involved, ensuring that water infiltration into the karstic sinkholes is not interrupted, to maintain the natural resurgence rhythms of the springs (which in turn affects the development of the tufa deposits) and avoiding any alteration of the hydrological cycle.

To warrant the appropriate conservation of the natural values of these areas, the regulatory measures stipulate also that projects proposed for this area that are subject to Environmental Impact Assessment must obtain a favourable report from the relevant Natural Area Authority.

To sum up, the outcome of the phases described above was to establish guidelines for the conservation of the geological and geomorphological processes and assets, including proposals to: (1) prevent any mining, construction and earth moving activities which might alter the volume, profile or other natural or landscape characteristics; (2) protect the active geological processes within the natural areas, especially the karstic processes, where these occur on karren surfaces or on other features, avoiding any activity which might interrupt or disturb these processes; (3) boost the educational potential and

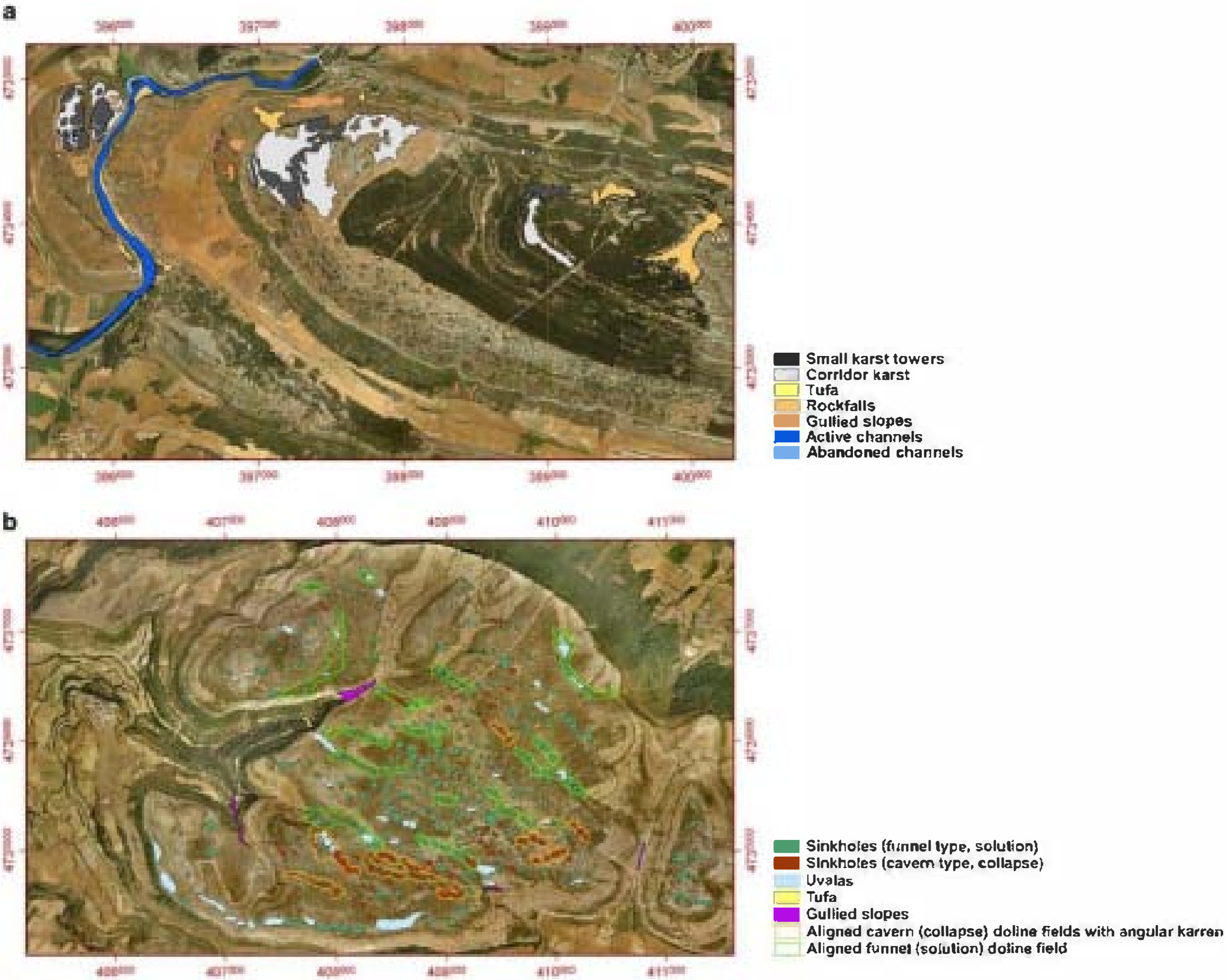


Fig. 9 Geomorphological mapping of the inventory. Selection of geomorphological units and of geomorphological elements of interest. UTM coordinates, zone 30. *Upper*, 'Lora' of *Las Tuerces*; below. 'Lora' of *Valdivia* (*Covalagua*)

public use of the geological and geomorphological resources of the natural areas, installing signposting; (4) stablish specific guidelines for restoring areas affected by public works or private facilities; (5) promote systematic study and inventory of existing caves within the natural areas and ensuring an use compatible with their conservation; (6) encourage a wider understanding and scientific promotion of the geomorphological features and processes, and the development of the potential interpretational, educational and public use compatible with conservation as already outlined; and (7) devise an appropriate model to develop the educational and interpretative potential, guaranteeing the conservation of landforms and processes.

Table 4 Geomorphological classification of the inventory

Karren terminology in Spanish	International karren terminology	Geomorphological unit which characterise
Microdolinas and tinajitas	Kamenitzas, solution basins, solution pits and pans	2, 3, 4 and 5
Lapiaz en estrias	Rillenkarren	
Lapiaz redondeado	Rundkarren	
Lapiaz en surcos	Rinnenkarren	8
Lapiaz tubular, cavernoso and perforado	Holhkarren Kavernosekarren	1 and 10
Lapiaz structural	Kluftkarren	1; also 2 a 5, but at a landscape scale

Karstic surficial microlandforms. Karrentypes

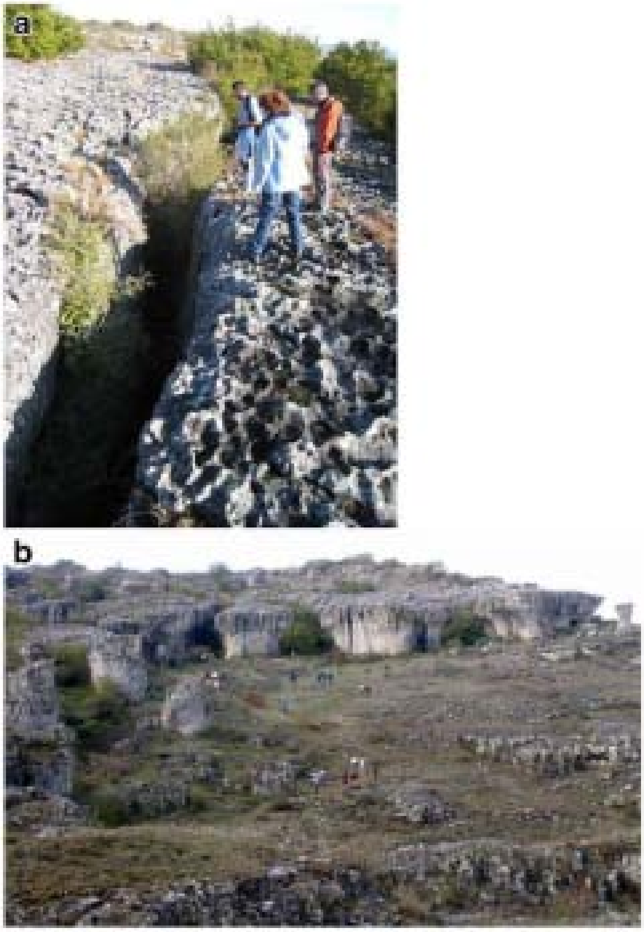


Fig. 10 Differences between the units 'non-walkable corridor karst with narrow box valleys' (geomorphological unit 2, *upper image*) and 'walkable corridor karst (geomorphological unit 3, *lower image*). The latter shows the access to the box valleys from the geomorphological unit 7 ('flat surfaces with scattered towers')

These guidelines, especially (3), (6) and (7), are clearly also appropriate for sustainable geotourism provision as widely promoted in Europe (Hose 2000, 2011, 2012).

Measures in Relation to Public Use

The official declaration of this PLA establishes as main objectives to: 'facilitate and promote the knowledge and enjoyment of the natural and cultural values of these Natural Areas, from an educational, scientific, recreational and touristic point of view and encourage their public use, controlled to ensure a scrupulous respect for these values which this declaration attempts to protect' (Junta de Castilla y León and GAMA 2010). It also identifies contributing to the socioeconomic development of the local villages based on the sustainable use of natural resources as a management objective for these areas. Given the importance of the local geo (morpho)logy, geotourism emerges as one of the outstanding features which could encourage public use.

To this end, the regulatory document identifies 15 guidelines intended to encourage public use, many of them linked to geology (it has to be noted that this study aims at integral management of the natural environment, not only of the geological heritage). Among these, a public use within an educational and interpretational framework is encouraged, which will boost new and sustainable economic initiatives, such as geotourism, linked to leisure and spare time activities. This will involve creating the necessary infrastructures to facilitate and optimise public visits, including information and visitor centres, paths and guided trails. Action will also be undertaken to reduce visitor impact on the most commonly used areas. This will involve attempting to control visitor access and traffic with appropriately marked trails, boosting the circuits with lowest impact and passively dissuading the use of areas of highest fragility or least security. The educational, recreational and sporting facilities were planned depending on the relative capacity of different areas, channelling visitors into less fragile areas and encouraging activities with low environmental impact.

The design of this infrastructure will note the capacity and limitations of the geological and geomorphological settings (based on the conclusions from the diagnostic phase). This means that the plans for public use will necessarily include specific conservation measures (given the high value and fragility of some of the landforms), and leisure and public use promotional measures. As a result, this study includes a detailed proposal for visitor and interpretative material for both sectors. The proposal for *Las Tuerces* karst corridor is shown in Fig. 12.

Discussion and Conclusions

Making geoconservation and geotourism compatible requires legal mechanisms which allow planning and management measures to be established for the activity areas. If these are not put into place, all the work done might well be in vain; this is because there is no legal basis to prevent activities which may lead to deterioration of the geoheritage in question. The regulatory framework offered by protected areas ensures that this cannot occur. The working methodology used in the Natural Resources Management Plan for *Covalagua* and *Las Tuerces* in Northern Spain attempted to solve the usual problems with conservation of geological and geomorphological heritage (Carcavilla et al. 2007) and to ensure the compatibility of this conservation with geotourism. The central feature of this compatibility between conservation and tourism, including geotourism, in the protected areas is the regulatory framework and public use programmes.

To meet the conservation and geotourism objectives, the role of geological and geomorphological information in the

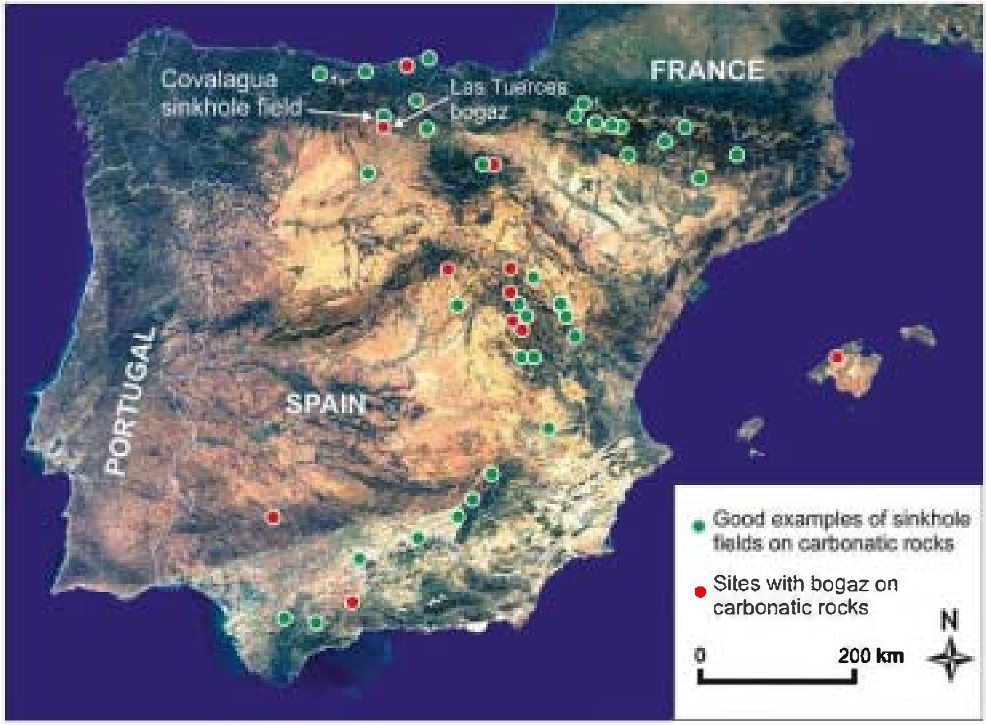


Fig. 11 Compilation of Spanish sites of bogaz on carbonatic rocks (*in red*, including *Las Tuerces*) and compilation of good examples of sinkhole fields on carbonatic rocks in Spain (*in green*, including the sinkhole field of *Covalagua*)

declaration, land use planning and management of the *Covalagua* and *Las Tuerces* protected area was essential both to structure the rest of the ecological and landscape based information for these areas, and also to establish a significant proportion of the directives and regulations for their public use. Geology and geomorphology turned out in fact to be essential features when creating a land planning and management tool. This methodological model could well be applicable to other land areas with similar geomorphological characteristics to explain the dynamic and configuration of their ecosystems

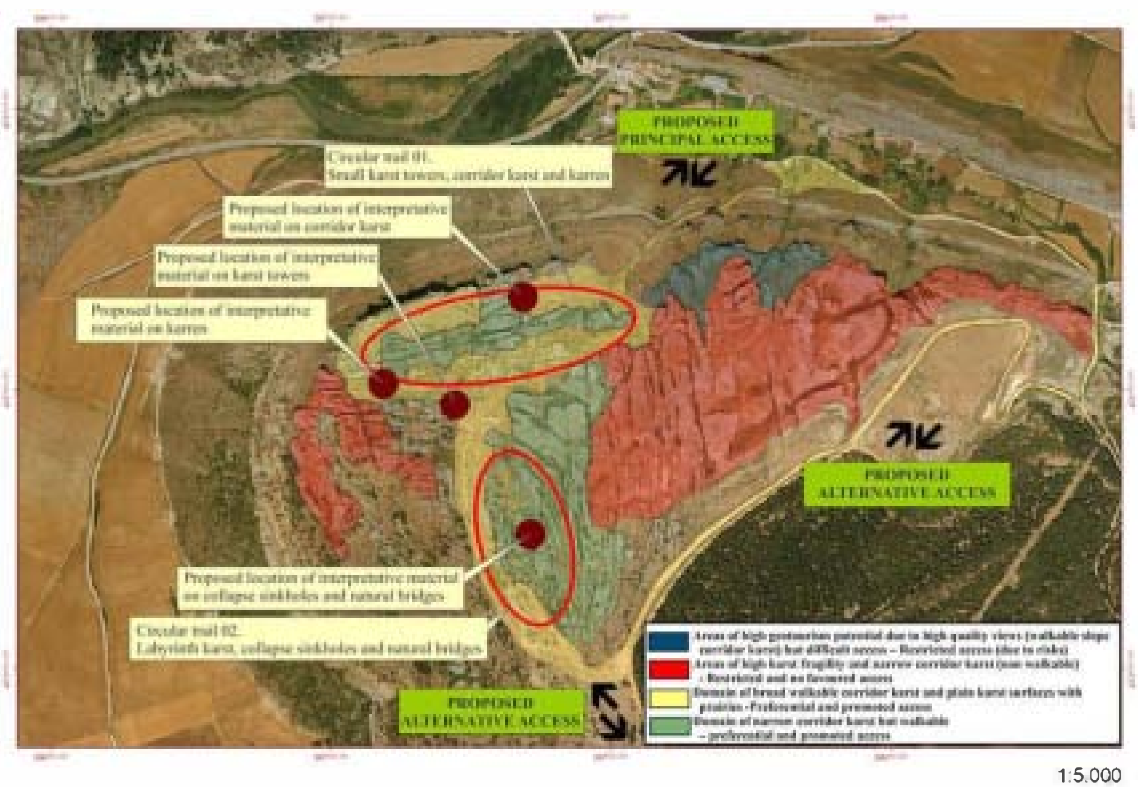


Fig. 12 Proposal of location of paths and location of interpretative material for visitors and geotourists at the protected area of *Las Tuerces*

and landscapes, as is frequent in many protected areas on a global level, including karstic, granitic, volcanic, glaciated or desert landscapes, among others.

In this context, the methodology developed in the *Covalagua* and *Las Tuerces* Plan includes new concepts and methodologies designed to solve the most usual problems found in documents of this type, including: (a) the accumulation of a large quantity of information which is of no use for land planning purposes and (b) the minimal relationship between the information included in inventories and the evaluation, diagnostic and regulatory phases. For the former, it is common that large amounts of information that do not have any link with land use planning purposes 'fill' the reports. For the latter, even when an appropriate inventory is made, it is common that the information of the inventory does not 'flow' into the subsequent phases of planning. This is common because, usually, the people involved in the inventory phases neither are the same than those in charge of writing the evaluation, diagnostic and regulatory phases, nor they have an appropriate communication. Overall, the study herein presented provides a methodology useful to other landscape planners and geoconservationists faced with the requirement to research and publish evidence based documentation for statutory conservation purposes.

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