

Geosites Inventory in the Geopark Villuercas-Ibores-Jara (Extremadura, Spain): A Proposal for a New Classification

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Abstract Villuercas-Ibores-Jara is one of the most socioeconomically deprived areas of the Spanish region of Extremadura. However, its geological heritage and other natural resources have still not been sufficiently used. The recent integration of this region in the European Geoparks Network can be considered an important milestone for the promotion of a local socioeconomic development based on the sustainable management of natural areas. An inventory of 44 geosites was identified by the geopark's scientific committee in 14 categories by their main scientific interest. This article proposes a more straightforward classification of these geosites using only a total of six classes.

Keywords Geological heritage · Geosites · Inventory · Appalachian relief · Villuercas-Ibores-Jara · Spain

Introduction

The region of Villuercas-Ibores-Jara (Extremadura, SW Spain) has serious demographic problems such as depopulation,

sex-ratio imbalance and ageing, and low levels of economic development, which together with very bad accessibility make the region one of the most deprived areas of Spain. However, these socioeconomic weaknesses contrast with a strong potential consisting of important geological heritage. This natural richness has not gone unnoticed by civil administrations that have worked together to propose the area as a member of the European Geoparks Network (EGN). It was accepted on September 2011. To date, 2,700,000 Euros have been invested for the Stimulation Plan for the Villuercas-Ibores-Jara Touristic Product with the objective of generating local employment and increasing the incomes of farmers, artisans and local tourist agents, and 200,000 Euros in scientific, educational and information projects. This paper presents the geological heritage of the geopark through the description and classification of 44 geosites inventoried by the *Diputación Provincial de Cáceres* (Provincial Council of Cáceres), for the process of application to become a geopark.

The interest in geological heritage in Spain began in the decade of 1970, although, from an institutional point of view, it was only in 2007 that a legal framework that addresses the conservation of geological heritage at a national level was published. The law 42/2007 on natural heritage and biodiversity (*Ley 42/2007, 13 de diciembre de Patrimonio Natural y Biodiversidad*) was a step forward with respect to previous national regulations that did not mention geological heritage (Fuertes-Gutiérrez and Fernández-Martínez 2010).

A very important milestone in the conservation of geological heritage was the creation of the European Geopark Network in June 2000 in the island of Lesvos (Greece), with the participation of Spain through the Aliaga, Maestrazgo Cultural Park (Carcavilla et al. 2009). The EGN is a voluntary association of areas with the same working method to promote and care for their local heritage, particularly the geological (Zouros and Martini 2003). EGN is currently composed by 50 members, 7 of which belong to Spain. Furthermore,

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since 2005, UNESCO recognizes all the EGN geoparks as members of the Global Geoparks Network (Zouros and McKeever 2008).

The geological values of Villuercas-Ibores-Jara have been recognized by regional institutions that proposed it as candidate to join the EGN in 2009. This application process has been carried out in different stages as follows: (1) sign of a collaboration agreement between the national *Ministerio de Industria, Turismo y Comercio*, regional government *Consejería de Economía y Hacienda*, *Diputación Provincial de Cáceres*, *Asociación para la Promoción y el Desarrollo Rural de la Comarca de Villuercas-Ibores-Jara* (Association for Promotion and Rural Development of Villuercas-Ibores-Jara Region; APRODERVI) and *Asociación de Empresarios Turísticos del Geoparque Villuercas Ibores Jara* (GEOVILLUERCAS) in order to establish the Stimulation Plan for the Villuercas-Ibores-Jara Tourist Product; (2) the creation of a *Collaboration Protocol* for the establishment of the Geopark Villuercas-Ibores-Jara, signed on July 23, 2009, between the national *Ministerio de Industria, Turismo y Comercio*, the *Junta de Extremadura*, *Diputación Provincial de Cáceres*, *Universidad de Extremadura*, APRODERVI and GEOVILLUERCAS; and (3) the implementation of the action plan, consisting of a scientific project, an educational project, a geotourism strategy, a communication and dissemination plan and a legal framework.

In this context, an inventory of geosites in Villuercas-Ibores-Jara was carried out, under the scope of the abovementioned law 42/2007. The inventory of geosites is not a recent thing in Spain and neither is it in Extremadura. The National Inventory of Sites of Geological Interest (1978–1989) defined and inventoried a total of 889 geosites and described in detail 252 of them, covering up to 16 % of the national territory (Carcavilla et al. 2009).

The enacting of the law 4/1989 on the *Conservation of Wildlife and Natural Areas* involved the transfer of responsibility for environmental protection to the regional governments that have developed their own regional laws on natural heritage, including geological heritage conservation, and have elaborated lists of regional geosites (Fuertes-Gutiérrez and Fernández-Martínez 2010). In the case of Extremadura, a total of 26 geosites were considered by the regional government (described by Muñoz Barco and Martínez Flores 2010); 5 out of these 26 are located within the geopark.

In spite of the abundance of lists of geosites carried out at national and, above all, regional level, there is a lack of a geosites inventory made with scientific rigour and contrasting methodologies (Carcavilla et al. 2009). In the bidding process for geopark status, an inventory of geosites was carried out with respect to consultation with experts and a qualitative assessment was developed.

Taking into account the abovementioned considerations, the goals of this paper are (1) to emphasize the convenience of having an inventory of geological resources to support better natural and cultural heritage conservation and (2) to make a more straightforward classification of the geosites that may be more helpful to scientific users and managers.

Study Area

The Villuercas-Ibores-Jara Geopark covers 19 municipalities located in SE Cáceres (Extremadura, Spain), close to the provincial borders of Badajoz, Toledo and Ciudad Real (Fig. 1). This geographical unit with an area of 2,544 km² is characterized by well-defined physical, economical and cultural well-defined elements with an important homogeneity. Physical conditions have been traditionally unfavourable for development; slopes are steep and unsuitable for cultivation, and a peripheral location and poor accessibility by road have prevented greater trade with the major urban centres. Traditional agriculture is in crisis and the industrial and tertiary sectors are very weak. This area shows a low population density (5.5 people per km²), large proportion of the aged (38.8 %) and low percentage of children and the young (7.4 and 13.4 %, respectively). The demographic effects of these indicators are the continued decline in the population (3,002 fall between 2000 and 2010) and very negative socio-economic impacts: lack of entrepreneurship, leading to low production, unemployment and subsidy dependence (Pulido Fernández et al. 2011).

Despite its small area and its economic weaknesses, this geopark shows a wide range of natural resources. A complicated geological history has resulted in a large variety of attractive landscapes based on the singularity of typical landforms of Appalachian relief (Gómez Amelia 1985). The relief is the result, at the first order, of geological constrains such as tectonics, and then of the differential erosion on the following two dominant rock types: quartzite (Lower Ordovician, 485 Ma) and Precambrian rocks such as schist, shale or greywacke (Gómez Amelia 2010).

Geologically, Villuercas-Ibores-Jara constitutes an isolated Palaeozoic-age mountain system, formed by very old rocks (650–400 million years old vs. 3,200 million years in the Baltic Shield (Galer 1994)), surrounded by (1) two Cenozoic grabens, Tagus and Guadiana rivers, in the north and south, respectively, and by (2) extensive peneplains on Precambrian-age rocks in the east and west. Its landforms are characterized by some parallel mountains ridges (*sierras*) and valleys aligned in a NW–SE direction risen up during the Variscan orogenic movement and planed off by erosion during the Mesozoic era (Moreno Serrano 1974).

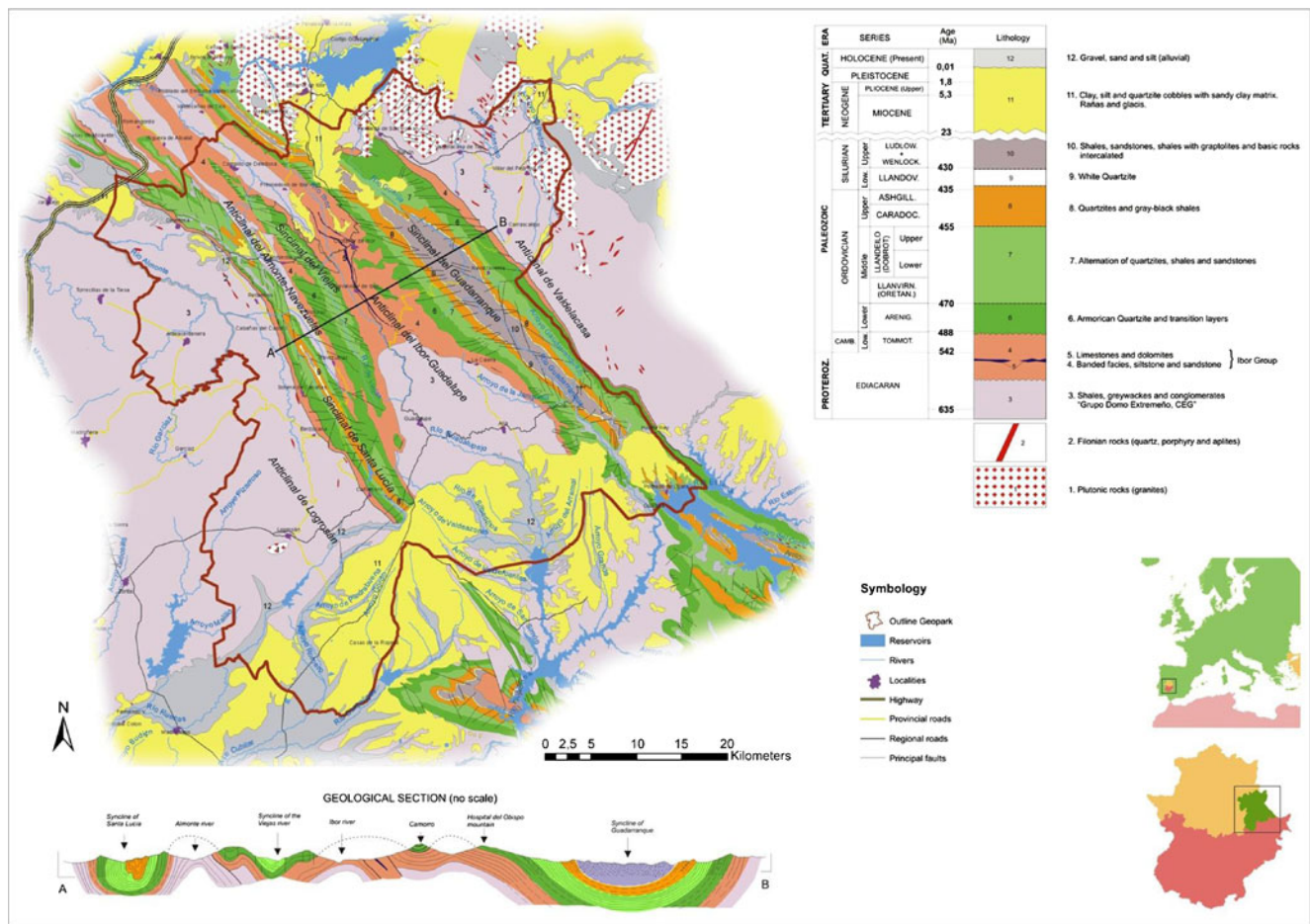


Fig. 1 Geological map of the geopark and surrounding area. Authors: David Lagar Timón and Juan Gil Montes (based on IGME digital continuous geological map (Geode Plan) sheets at scale 1:200,000)

Alpine orogenic movements (Cenozoic) rejuvenated the landforms by fracturing the rocks and the raising and depressing of fault blocks. Finally, during the Quaternary period, the river network was superimposed in the terrain, configuring the current geomorphology of the region. This kind of landform is commonly known as Appalachian relief due to similarities it has to the Appalachians of North America—caused by the same origin of both mountain systems during the Precambrian and Palaeozoic.

Three forms of modelling characterize the relief of Las Villuercas as follows: (a) the *surrounding peneplain*, formed by shales and greywackes of Precambrian-aged rocks, extended around the Palaeozoic synclinorium of Las Villuercas. In the east, it may be highlighting the Valdelacasa Anticline and its eroded granite batholiths. (b) The *quartzite sierras*, the main relief element, formed of quartzite and characterized by steep slopes topped by crests, peaks or crags. These landforms have survived due to the hardness of their rocks (quartzite and sandstones). (c) The *inner valleys*, product of the downcutting of the river network, such as valleys of the Gualija, Ibor,

Viejas, Almonte, Cuernacabras and Garganta de Santa Lucía (tributaries of the River Tagus), Guadarranque, Guadalupejo and Ruecas (tributaries of the Guadiana) rivers.

Geosites Inventory: Location, Classification and Description

A geosite is understood as a remarkable geological locality where one or more elements of geodiversity are present and unique values of scientific, pedagogical, cultural or touristic interest are shown (Brilha 2005). The geosites of Villuercas-Ibores-Jara Geopark were selected by experts with a great knowledge of the geology, under the view of a scientific and educational committee specially constituted to prepare the EGN application.

Two specialists of the *Asociación Geológica de Extremadura* (AGEX) and two experts from the University of Extremadura were responsible for selecting the final 44 geosites. A fieldwork campaign based on expert's visits was carried out in order to

identify potential geosites. A total of 22 geosites were initially proposed. The rest were added in subsequent expert's visits to the geopark. The choice of the geosites was based on scientific and touristic criteria. From a scientific point of view, some key aspects such as geological history, stratigraphy, petrology, palaeontology, tectonics, geomorphology or mining, among others, have been considered. Tourism issues such as accessibility for visitors or the possible objectives of a tourist's visit have been also addressed.

An exhaustive bibliographical search was made of geological maps and their memoirs, journal articles, handbooks, etc. Geological map sheets (*Serie Magna* at scale 1:50,000) of *Instituto Geológico y Minero de España* (IGME) were initially utilized. However, these sheets had no spatial continuity between them, and it was necessary to use the digital continuous geological map (scale 1:200,000, the most accurate at the time of the inventory) from IGME. This cartographical data formed the basis for the final edition of the geological map (Fig. 1). All the information collected was tested in situ by fieldwork and by use of aerial images. This phase of the work was carried out by technicians of the *Organismo Autónomo para el Desarrollo Local* of the *Diputación Provincial de Cáceres* and by researchers at the *Universidad de Extremadura*.

Finally, the geosites were located in the field, georeferenced by a handheld GPS and mapped (Fig. 2). A much more detailed description of these 44 geosites is available online at <http://geoparquevilluercas.es/oadl/es/listado-geositos.html>.

These geosites were reclassified in 6 classes, reducing the 14 classes of main scientific interest initially proposed by the geopark's scientific committee as follows: (1) *high relief*, geosites located at elevated points where the surrounding landscape can be observed under high-quality conditions; (2) *Inner valley*, located between narrow quartzite ridges and produced by the river downcutting; (3) *geology*, more attractive places (a priori) for a geologist than for usual visitors; (4) *palaeontology*, main deposits of fossils; (5) *natural*, sites of interest not addressed in the previous classes where water, soil or vegetation play a more important role than the geological features; and (6) *mining*, generally old mines.

This reclassification is intended to be a simplification of the previous one. On one hand, the number of classes is reduced and, on the other, the names of the classes are more familiar for non-specialists. The *high relief* class groups geosites such as viewpoints, giving better landscape observation. The *inner valleys* class group geosites with the same landforms, regardless of their geological characteristics. Classes such as *geology*, *palaeontology*, *natural* and *mining* are used to highlight the most important scientific interest of each geosite, avoiding the confusion of the earlier classification.

A total of 9 geosites were classified as having *high relief* (Table 1): the peak of *La Villuerca* (1), *Cancho del Reloj* (Clock's Crag) (9), *Canchos de Las Sábanas* (Sheets Ridges) (10), *El Brazo Hill* (13), Viewpoint of the *Risco Gordo* (18),

Cancho de las Narices (Nose's Crag) (25), *Sierra de la Breña* (29), *Cancho del Ataque* (Attack's Crag) (30) and *San Cristóbal Hill* (2). The first five geosites have a predominantly geomorphological scientific interest, the next three are characterized by their structural geology, and the last by its mineralogical and petrological characteristics.

The peak of *La Villuerca* gives its name to the region and is the highest point inside the geopark (1,601 m). The Appalachian relief and its complex system of anticlines, synclines and faults, the surrounding peneplain, the inner valleys and the *rañas* (sedimentary formations composed by tertiary alluvial and colluvial sediments) can be perfectly observed (Sos Baynat 1956). The *Cancho del Reloj* is a large vertical rocky outcrop composed of quartzites. The origin of its name comes from the fact that the first rays of the sun in the morning fall on it, resembling a sundial.

The *Canchos de Las Sábanas* consist of Ordovician quartzite crests with the presence of caves and a waterfall known as *El Lloroero* (crying place). *El Brazo Hill* is a viewpoint where the watershed of the Gadiana and Tagus rivers basins and different sedimentary units of Ordovician and Silurian may be seen. *Risco Gordo* is a high vertical crag where the Appalachian relief of Las Villuercas, the Rucas river gorge, the syncline of Santa Lucía, the surrounding peneplain and the *raña* may be observed.

The *Cancho de las Narices* is a fault surface on the confluence of the Viejas and Ibor rivers that runs parallel with the Syncline of Viejas and Anticline of Ibor. In the *Sierra de la Breña*, the system of transverse fractures on the quartzites, the *raña* of the Deleitosa–Almonte River and the peneplain of Extremadura can be perfectly viewed. Some geological macrostructures may be observed from the *Cancho del Ataque*: syncline of Guadarranque and Anticline of Ibor. *San Cristóbal Hill* is a granite dome, sitting 200 m above the surrounding peneplain and with a great diversity of minerals (Fig. 3).

A total number of 6 geosites have been classified as *inner valleys*: Rucas River Gorge (12), Guadalupejo River Valley and Valdegracia Ravine (14), syncline of Santa Lucía (21), Almonte River Anticline (22), Guadalupe and Ibor Rivers Anticline (23) and Valdelacasa Anticline (24). The second has a high geomorphological value, typical inner valleys of the Appalachian relief, and the others may be distinguished by their structural geology: large fold structures such as anticlines and synclines.

The gorge of the Rucas River is a product of the fluvial erosion over a long tectonic fault between hard quartzites. The valley of the Guadalupejo River and the ravine of Valdegracia are also a product of the fluvial erosion, but developed over materials of varying nature, mainly Precambrian shales. The parallel valleys of the Santa Lucía, Almonte, Viejas and Ibor rivers are the main Appalachian mega-structures of the Appalachian relief of the region where the low ground is formed by the anticlines and the most elevated areas by

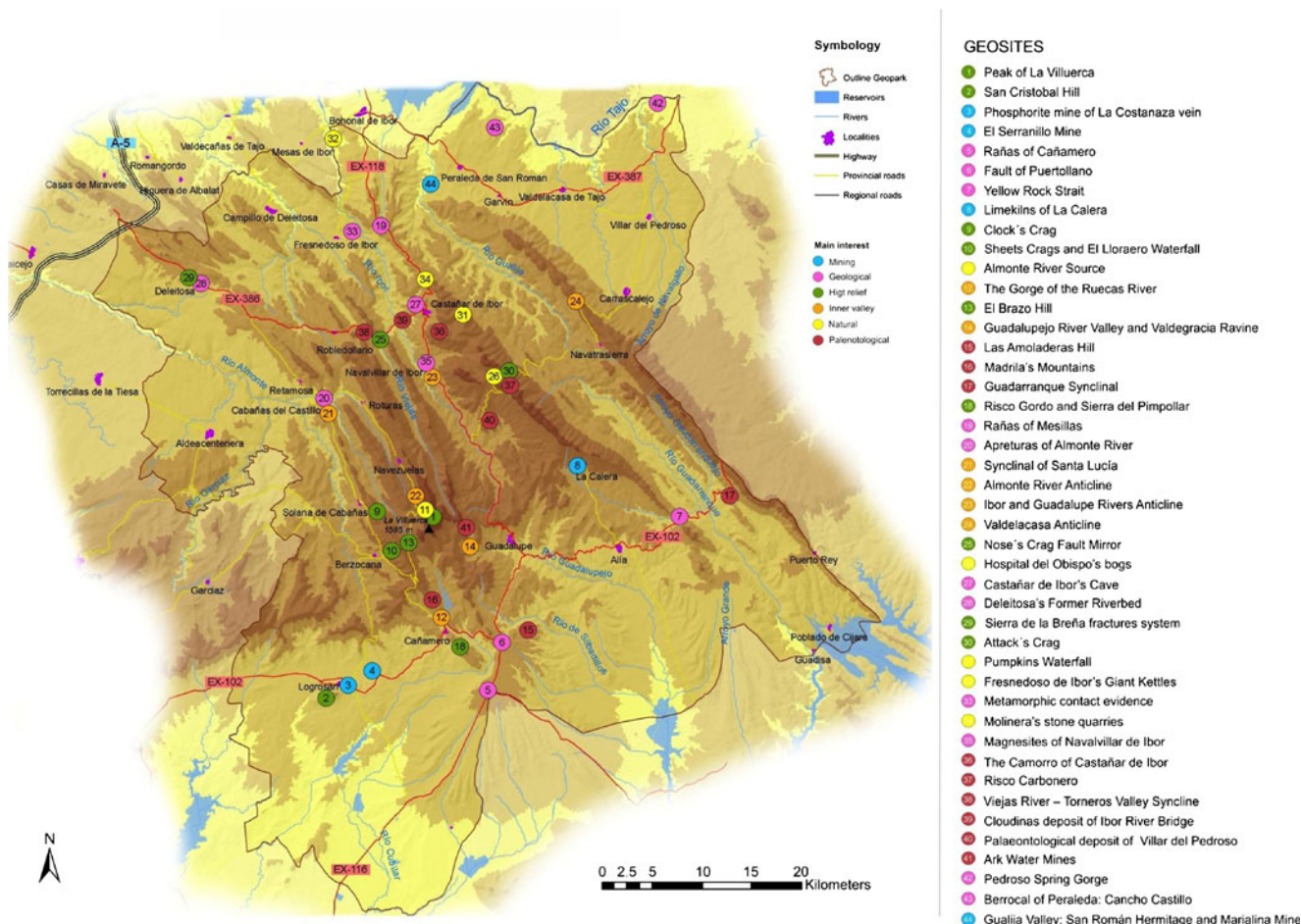


Fig. 2 Geographical location and main interest (the classes are explained in the text) of the 44 geosites. Authors: David Lagar Timón and Juan Gil Montes

synclines, what is known as “inverted relief”. The Valdelacasa Anticline is located in a flat area developed over granite, but still having the same structures.

Five geosites have been classified as *geology* by their geological value as follows: the *raña* of Cañamero (5) and of Las Mesillas (19), a fault at Puertollano (6), the *Estrecho de la Peña Amarilla* (Yellow Rock Strait) (7) and the *Berrocal* (granite formations) at Peraleda (43). The *raña* of Cañamero and of Las Mesillas are typical plateaux of large extent (Martínez Flores 2010) composed of boulder and smaller stones, of different sizes and shapes, mixed in a clayey–sandy matrix of Pliocene age (IGME 1985).

The fault located in the Puerto de Puertollano (Puertollano's Port), an Alpine orogenic structure, has a transverse movement, relative to the folding, and it controlled sedimentation in the Tertiary syncline that lies in the south of the Las Villuercas region. One of its main tourism attractiveness is related to the abandonment of the construction of a railway line in 1962. Railway constructions close to the geosite such as a large bridge built in 1929 can be visited in the municipality of Guadalupe.

The *Estrecho de la Peña Amarilla* is notable for showing unique biology, yellow lichens, on its quartzites. The Berrocal

of Peraleda is characterized by unusual erosive forms on granite, caused by mechanical and chemical weathering, such as rounded blocks, *piedras caballeras* (“stone cavaliers”) or mushroom-shaped rocks (Fig. 4).

The following geological values are reflected in more geosites reclassified as *geology*: *Apreturas* (defile) of the Almonte River (20), the cave of Castañar de Ibor (27), former river bed of Deleitosa (28), and metamorphic contact at Castañar de Ibor (33), magnesites of El Madroñal (35) and the *Desfiladero del Pedroso* (gorge of Pedroso) (42). In the defile of the Almonte River, large outcrops of folded and fractured Ordovician quartzites can be observed.

The cave of Castañar de Ibor contains a great diversity of speleothems (stalactites, stalagmites, anthodites, etc.) formed by the infrequent mineral aragonite, distributed through a sophisticated network of halls and galleries of 2,135 m long (Muñoz Barco et al. 2006). In 1997, it was declared a natural monument by the *Junta de Extremadura* (Decree 114/1997, 23th September). A very low number of visitors are allowed in the cave in order to preserve the aragonite forms (1,000 a year since 2007), and waiting times to visit can be as much as 2 years. However, an

Table 1 List of geosites and their main scientific and tourism interest. A superscript letter has been added to the geosites protected or located inside a protected area (figure of protection can be read in the table footnote)

Geosite name	Description	Scientific	Touristic
1 Peak of La Villuerca ^{a, c}	Highest point of the mountain system (Montes de Toledo, 1,601 m). It gives the region its name.	Geomorphology	High relief
2 San Cristóbal Hill ^c	Isolated granitic mountain (680 m) surrounded by an extensive peneplain (Precambrian rocks).	Mineralogy and Petrology	High relief
3 Phosphorite mine in the La Costanaza vein	Former phosphorite mine which in the 1920s became the most important deposit of phosphates in Europe.	Mining and Petrology	Mining
4 El Serranillo Mine	The last tin mining in the region was active until the 1950s.	Mining and Petrology	Mining
5 Rañas of Cañamero	Typical Pliocene or Plio-Quaternary-age sediments composed of rounded quartzite pebbles within a sandy-clay matrix.	Geomorphology	Geological
6 Fault of Puertollano ^c	Tectonic fault originated in the Alpine Orogeny that divides the Tertiary Graben and the mountain system.	Tectonics and Geomorphology	Geological
7 Estrecho de la Peña Amarilla ^a	River gorge produced by the Jarigüela spring downcutting into Lower Ordovician quartzites.	Tectonics, Geomorphology and Palaeontology	Geological
8 Limekilns of La Calera ^{a, c}	Group of kilns, very important in the construction of the Royal Monastery of Guadalupe (XIV century).	Mining, Petrology and Palaeontology	Mining
9 Cancho del Reloj ^{a, c}	Large quartzite ridge located in the <i>Sierra del Castillejo</i> . It is a very good place for bird watching, and it is located close to an archaeological site.	Tectonics, Petrology and Geomorphology	High relief
10 Cancho de Las Sábanas and El Lloraoero Waterfall ^{a, c}	Quartzite ridge where it is possible to see a frozen waterfall of great beauty in winter.	Tectonics, Petrology and Geomorphology	High relief
11 Almonte River Source ^{a, c}	Large quartzite screen formed on the western slope of the peak of La Villuerca during the Quaternary Period at the river's source.	Petrology, Geomorphology and Hydrogeology	Natural
12 The gorge of the Ruecas River ^c	Ruecas River develops between hard quartzites, rocks crossing a long tectonic fault and surrounded by high quartzite ridges.	Geomorphology	Inner valley
13 El Brazo hill ^{a, c}	Slightly elevated area of the Ruecas river valley located in the border between the Tagus and the Guadiana basin.	Geomorphology	High relief
14 Guadalupejo River Valley and Valdegracia ravine ^{c, e}	Geosite with a great geological interest and excellent panoramic views of the landscape.	Geomorphology	Inner valley
15 Las Amoladeras hill	Important presence of ichnofossils such as <i>Daedalus</i> .	Petrology, Geomorphology and Palaeontology	Palaeontological
16 Sierra de la Madrila ^a	Elevated system where it is possible to observe important geomorphologic features. It is also possible to find examples of Cruziana and other ichnofossils.	Petrology, Geomorphology and Palaeontology	Palaeontological
17 Guadarranque Synclinal ^a	Geomorphological macrostructure above 100 km in length and 5 km in width composed by Ordovician and Silurian rocks.	Palaeontology, Geomorphology and Petrology	Palaeontological
18 Risco Gordo and Sierra del Pimpollar	Risco Gordo is a vertical quartzite ridge (836 m) located in the most elevated point of the Sierra del Pimpollar.	Geomorphology, Palaeontology and Petrology	High relief
19 Rañas of Mesillas ^c	Typical geomorphological feature formed by alluvial deposits developed during the formation of the current drainage network.	Stratigraphy and Sedimentology	Geological
20 Aperturas (defile) of Almonte River ^{b, c}	Fluvial gorge produced by the crossing of Almonte River. A very large monoclinical “knee-shaped” fold can be perfectly observed.	Structural Geology	Geological
21 Synclinal of Santa Lucía	Tectonic megastructure belonging to the Villuercas' synclinorium. A Moorish castle is located on one of its quartzite ridges.	Structural Geology	Inner valley
22 Almonte River anticline ^{a, c}	Fold megastructure which was formed during the first phase of the Armorican orogeny. One of the best examples of Appalachian relief.	Structural Geology	Inner valley
23 Ibor and Guadalupe rivers anticline ^a	Geological macrostructure formed by two river valleys belonging to different large basins (Guadiana and Tagus rivers).	Structural Geology	Inner valley
24 Valdelacasa Anticline ^{a, c}	Megastructure with an Upper Precambrian core and granite intrusions and sedimentary rocks.	Structural Geology and Geomorphology	Inner valley

Table 1 (continued)

Geosite name	Description	Scientific	Touristic
25 Cancho de las Narices Fault ^a	Tectonic fracture below a quartzite ridge, located in the confluence of two subsequent rivers: Viejas and Ibor.	Geology, Palaeontology and Mineralogy	High relief
26 Hospital del Obispo bogs ^{a, c}	Hanging valley situated at 1,000 m with 6000 m ² peat surface in the valley bottom.	Pedology	Natural
27 Castañar de Ibor's Cave a, d	Cave (2,135 m in length) formed with a great variety of aragonite speleothems.	Sedimentology, Stratigraphy, Structural Geology and Mineralogy	Geological
28 Former river bed of the Deleitosa	“Fossilized” water channel corresponding to a former torrential spring.	Sedimentology	Geological
29 Sierra de la Breña fracture system	Tangled transversal fractures system that interrupts the continuity of the quartzite ridge.	Structural Geology	High relief
30 Cancho del Ataque ^{a, c}	Quartzite ridge above a defile formed by the gorge of Hospital del Obispo.	Structural Geology	High relief
31 Chorrera de Calabazas ^{a, c}	Water fall produced by differential erosion that has followed a SW-NE fault.	Structural Geology	Natural
32 Fresnedoso de Ibor's giant kettles holes	Pot-shaped erosional features cut by the Ibor river in the granitic bedrock.	External Geodynamics	Natural
33 Metamorphic contact (Castañar de Ibor)	Contact between plutonic (granite) and metamorphic (quartzite) rocks, well seen from the road.	Endogenous Petrology and Structural Geology	Geological
34 Pedreras de La Molinera ^a	Pleistocene-age periglacial features.	External Geodynamics	Natural
35 Magnesites of Navalvillar de Ibor ^a	A mass of large brown crystals of magnesite can be seen penetrating fractures and replacing grey dolomite.	Sedimentology	Geological
36 The Camorro (plateau) of Castañar de Ibor a, e	Fossil-bearing beds with <i>Daedalus</i> are located in this elevated area (1,100 m).	Palaeontology	Palaeontological
37 Risco Carbonero (Coaler Ridge) ^{a, c}	Quartzite with ichnofossils may be found in this site.	Palaeontology	Palaeontological
38 Viejas River—Torneros Valley Syncline ^a	In this geological megastructure, a large accumulation of trilobites, graptolites and spiriferids brachiopods in shales can be found.	Palaeontology	Palaeontological
39 <i>Cloudina</i> deposit of Ibor River Bridge ^a	Carbonate rocks with fossils of <i>Cloudina hartmannae</i> .	Palaeontology	Palaeontological
40 Palaeontological deposit of Villar del Pedroso ^{a, c}	Shales with Ediacaran <i>Sabellidites</i> and Vendotaenid fossils.	Palaeontology	Palaeontological
41 Mines of the Arca del Agua ^{a, c}	Drinking water collection, transmission and distribution system to the Royal Monastery of Guadalupe, built in 1350.	Mining and Palaeontology	Palaeontological
42 Pedroso Spring Gorge	The Pedroso Spring cuts through granitic rocks forming rapids, waterfalls and giant kettles.	Geomorphology	Geological
43 Berrocal of Peraleda: Cancho Castillo (Castle's Crag)	Erosive forms produced by mechanical and chemical erosion of granites.	Geomorphology	Geological
44 Gualija Valley: San Román Hermitage and Marialina Mine	Former zinc and copper mines of the nineteenth century exploited by English companies.	Mining and Geomorphology	Mining

^a Located inside of the sites of community importance and special protection areas for bird—ES4320039—Sierra de Las Villuercas y Valle del Guadarranque

^b Located inside of the special protection areas for bird—ES4320018—Riberos del Almonte

^c Ecological and biodiversity Corridor Río Guadalupejo—Decree 62/2003, 8th May—Junta de Extremadura

^d Natural monument cave of Castañar—Decree 114/1997, 23th September—Junta de Extremadura

^e Vegetation formations protected by Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora)

interpretative centre was built to show and explain the geological features of the cave (Fig. 5).

At Deleitosa, a former river bed of the Almonte River may be viewed. Evidence of contact metamorphism can also observed in Castañar de Ibor where mica schists are located close to the granitic batholith. Some kilometres to the east, in the

Navalvillar de Ibor municipality, deposits of magnesite and dolomite are present. Curious erosive forms of the granite rocks are found in the *Desfiladero del Pedroso*, in the Villar del Pedroso municipality.

Palaeontological heritage is found in a total number of 9 geosites or deposits reclassified as *palaeontology*, some

Fig. 3 Panoramic view from the Peak of *La Villuerca* (geosite no. 1) where Almonte River Anticline (geosite no. 23, reclassified as *Inner Valley*) can be perfectly viewed. Author: Organismo Autónomo para el Desarrollo Local, Diputación Provincial de Cáceres



of them are restricted area for visitors as follows: *Las Amoladeras* (restricted area) (15), *Sierra de la Madrila* (a restricted area) (16), Guadarranque syncline (restricted area) (17), Camorro (plateau) of Castañar de Ibor (restricted area) (36), Risco Carbonero (37), Viejas River and Torneros valley syncline (restricted area) (38), Ibor River bridge (restricted area) (39), Villar del Pedroso (restricted area) (40) and the Mines of the *Arca del Agua* (41). *Las Amoladeras*, Risco Carbonero and the Camorro of Castañar de Ibor are deposits of ichnofossils. In the *Sierra de la Madrila*, fine examples of *Cruziana* may be observed, and in the syncline of the Guadarranque River trilobites, brachiopods, gastropods and graptolites are found.

In the Viejas River and Torneros Valley, fossils of the seas from the beginning of Palaeozoic, such as arthropods, crinoids or brachiopods are found. Limestone rocks with *Cloudina* (Ediacaran fossil) occur around the bridge of Ibor River (Fig. 6).

Other natural interests are also present in the following 5 geosites reclassified as *natural*: the source of the Almonte

River (11), mountain bogs in *El Hospital del Obispo* (26), *Chorrera de Calabazas* (Pumpkins Waterfall) (31), giant kettles holes of Fresnedoso de Ibor (32) and, finally, *Pedreras de la Molinera* (Molinera's scree slope) (34). The Almonte River is one of the most important tributaries of the Tagus River. Its source is located at 1,485 m, surrounded by deposits of rocks known as scree slope, produced by gelifraction during the Quaternary period (Fig. 7).

Peat and mountain bogs can be observed in the Hospital del Obispo. These are considered as habitats of priority interest according to the Habitats Directive of the European Union. The *Chorrera de Calabazas* was produced by differential erosion generated by the spring called *Arroyo de Calabazas*. Great botanical diversity exists at this site, with little frequent species such as laurels. Other beautiful natural forms as potholes and stone quarries (*pedreras*, above explained) may be observed in Fresnedoso and Castañar de Ibor, respectively.

Cultural values associated to former mining activities also occur in the following 4 geosites reclassified as *mining*: the phosphorite mine of La Costanaza vein (3), the El Serranillo



Fig. 4 Bright yellow lichens on quartzite rocks from the Yellow Rock Strait (left side, geosite no. 7) and rounded block from *The Berrocal of Peraleda* (right side, geosite no. 43). Author: Juan Gil Montes



Fig. 5 Karst forms of aragonite in the Cave of Castañar de Ibor (geosite no. 27). Author: Organismo Autónomo para el Desarrollo Local, Diputación Provincial de Cáceres

cassiterite mine (4), limekilns at La Calera (8) and evidence of mining in the Guadalija Valley (44). The La Costanaza vein was exploited from the late nineteenth century to 1944, and in the 1920s was the largest deposit of phosphate in Europe (Fig. 8).

Cassiterite crystals (SnO_2) may be observed with quartz forming a stockwork deposit in the El Serranillo mine. The



Fig. 6 Trilobites' fossil evidence found in the Geopark. Author: Organismo Autónomo para el Desarrollo Local, Diputación Provincial de Cáceres

mines of the *Arca del Agua* consists of a drainage network galleries or water mines excavated in the soil as a cistern. In the valley of the Guadalija, the Marialina mine is located where veins of quartz and metals ores cut quartzites, granites, etc.

Most geosites of Las Villuercas-Ibores-Jara are not directly protected (only geosites nos. 14 and 27), but many of them (30 out of 44) are protected by any figure of protection, not always related to their geological heritage (see above Table 1). At this moment, two figures of protection by UNESCO exist in this territory as follows: Royal Monastery of Guadalupe, recognized as a World Heritage Site in 1993, and the Biosphere Reserve of Monfragüe, in 2003, in the municipality of Deleitosa.

Discussion

An inventory of geosites is crucial to understand the concept of geoconservation. Many authors have remarked the role of the inventories in this sense. Wimbledon (1996) stressed the need for a global inventory for overcoming the view of the contemporary geologists who considered that geoconservation was only necessary to damaged or lost sites. Other works reflect the importance of the geosites inventory at different scales, mainly national (e.g. Wimbledon et al. 1995; Grandgirard 1999; El Wartiti et al. 2008; Joyce 2010).

The first step for conducting a geosites inventory is very often given for the particular interest of the government (from local to national). Firstly, it has been traditionally recommended the consultation of experts on geology of the study area with the goal of saving time and money costs. For example, the Regional Government of Castile and Leon (Spain) consulted nine experts from the University of León (Fuertes-Gutiérrez and Fernández-Martínez 2010). In this case, the Provincial Council of Cáceres (the most involved in the EGN candidacy) consulted four important researchers (leaders of the scientific committee); two from AGEX and two from the University of Extremadura.

After consultation of experts and information-gathering processes, it was necessary to select the geosites, at least the candidates for the final list. In this phase, two different trends have been found as follows: (1) a tendency for a decrease in numbers of geosites in the inventory (e.g. Fuertes-Gutiérrez and Fernández-Martínez 2010 reduce 285 to 125 geosites) and (2) a tendency for increase, as with geosites not previously recognized or identified—an initial amount of 22 geosites was increased to 44.

The Delphi methodology has been applied as the best way to achieve a consensus over decisions on which geosites may or may not be placed in a final inventory (Lima et al. 2010). This methodology is also used to classify the geosites under different interests, etc. In our case, the geopark scientific

Fig. 7 The Source of the Almonte River (geosite *no. 11*). Author: Organismo Autónomo para el Desarrollo Local, Diputación Provincial de Cáceres



committee classified the geosites in 14 classes, according to main scientific interest, but in some geosites, this classification is too technical and not clear for visitors or non-specialist managers. Furthermore, too many classes have been used for arranging geological features that could be grouped in the same class, i.e. external geodynamics and geomorphology, tectonics and structural geology, petrology, mineralogy or endogenous petrology.

We have proposed in this article a further reclassification of the geosites from 14 classes of main scientific interest to 6 classes, combining scientific and touristic interests. One of our classes “high relief” encompasses geosites with geological value per se but located at strategic points where the surrounding landscape can be perfectly observed. This class is in part based on the category “viewpoint”, proposed by Fuertes-Gutiérrez and Fernández-Martínez (2010). The “inner valley” category is intended to include geosites with the typical landform of inverted or reversed valley, characteristic of the

Appalachian relief. The rest are aimed at highlighting the most important scientific or touristic interests of each geosite.

The proposed reclassification is satisfactory in many ways as follows: (a) the geosites that can be used as a viewpoint and typical large landforms such as the inner valleys have been well distinguished, and (b) the main interest for a scientific or touristic visit to a geosite has been stressed: predominance of geological features, presence of fossils, evidence of human activities, etc. This reclassification will probably influence managers' decisions about future actions such as signposting of geosites or elaboration of information panels.

Notwithstanding this, some key issues in the new classification, related to the subjectivity of the process, are still not at all satisfactory: (a) the number of classes and their names is still an open issue that could change in the future; (b) many geosites can be grouped in different classes because of their heterogeneity and, finally, (c) there is not enough information



Fig. 8 Outside and inside views of the phosphorite mine of La Costanaza vein (geosite *no. 3*). Author: Juan Gil Montes

for us to know who the main beneficiaries are of such proposals: tourists, scientist, managers, etc.

Conclusion

The inclusion of an area as an EGN geopark is a very important milestone in the valuation of its geological heritage and, hence, a great possibility for promoting its local economy. In the Villuercas-Ibores-Jara region, a total of 44 localities were firstly inventoried as geosites by the geopark scientific committee and, secondly, grouped in 6 classes that identify the main interest (scientific and/or touristic) of each one. This classification can be very helpful in the elaboration of tourism material such as information panels, signposting or hiking trail design and as a criterion for the selection of potential new geosites. There are still outstanding matters such as the reaction of tourists, managers and scientists to the new classification as they carry out its implementation.

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