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REVIEW ARTICLE

Geosites Inventory in the Leon Province (Northwestern Spain): A Tool to Introduce Geoheritage into Regional Environmental Management

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Abstract This paper deals with the main results and methodological processing of the first inventory of Geosites of the province of Leon (Autonomous Region of Castile and Leon, Spain). The inventory was designed to be used as a tool for introducing geoheritage in regional and local environmental management. This main aim determined the methodology of selection, study, description, and evaluation of every site. One of the main contributions in this work is the proposal of classifying Geosites in five typological categories: point, section, area, complex area, and viewpoint. This grouping allows one to summarize the basic features and the best way to popularize each geosite. We also detail both the problematic of dealing with diverse types of Geosites and the management advices proposed to solve it.

Keywords Geological Heritage · Geoheritage Management · Geosites · Inventory · Typology · Spain

Introduction

The interest of public administrations in geological heritage and its conservation is currently increasing in Spain. In this context, the law on natural heritage and biodiversity (Law 42/2007, *13 de diciembre de Patrimonio Natural y Biodiversidad*), passed in December 2007, is an outstanding step forward. Previous national regulations on natural heritage in Spain (Law 4/1989, *27 de marzo de Conservación de Espacios Naturales y de la Flora y Fauna Silvestre*) did not mention geological heritage and, therefore, this has practically been absent from national conservation policies. Nonetheless, some regional governments developed their own regional laws on natural heritage including geological heritage conservation. All these regions also made up various lists of regional Geosites and used them to some extent for environmental management. In addition, a great number of geological features are found inside nationally or regionally protected areas.

This disorganized situation changed after the passing of the Law 42/2007 that includes for the first time the concepts of geodiversity and geological heritage and prescribes geoconservation as one of the main bases for nature management and conservation in Spain (Introduction, Art. 2b and 2d). This new law also identifies public administrations of the Spain's autonomous regions as responsible entities for natural heritage preservation (Art. 5.2f) and hints that geoheritage must be inventoried by listing Geosites [*Lugares de Interés Geológico* (LIG)]. With this purpose, the Geological Survey of Spain [*Instituto Geológico y Minero de España*, (IGME)] has started a project to inventory National Geosites in Spain (methodological principles can be seen online at García Cortés and Carcavilla 2009). This project has to rely on the regional inventories and take into account the National and Global Geosites currently accepted in Spain.

This paper deals with the first Geosite inventory in the autonomous region of Castile and Leon. Despite the large amount of scientific publications on this region's geology and the occurrence of several sites of international importance (13 out of 142 Global Geosites in Spain are located in Castile and Leon), the regional government has not yet included geological heritage in its policies related to the conservation and management of nature. To make up

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for this, the region's environment council requested several specialists of Leon University to carry out an exhaustive Geosites inventory. As a first stage, this work paid attention to only two of the provinces of Castile and Leon (Leon and Palencia), and it had to lay the methodological foundations of the whole inventory. This paper is only concerned with the inventory of the province of Leon.

Because the present inventory work was mainly conceived as a tool to be used by regional or local authorities, it was designed taking into account four main issues:

1. Language. Geological concepts and processes must be translated from the geological language of scientific publications into more everyday language.
2. Furthermore, public administrations need specific information in addition to scientific, for example, that concerning the need for protection or the potential for public use.
3. Future use. Geological heritage must be integrated into various administrative processes, which can be divided into two types. (a) Processes concerning environmental impact assessments and civil engineering projects need an exhaustive inventory of the sites, their importance, and their present or potential threats and (b) geological heritage can also be used for spatial planning, especially in rural and protected areas where geology can be a tool for touristic, recreational, educational, and training activities. In this case, the management of the Geosite also needs to consider its potential for use.
4. Geoheritage conservation: geoheritage is being investigated on both an international (Global Geosites project) and a national scale (Spanish LIG inventory). Many Geosites will have some consideration in those studies, but many others will be included neither in an international and/or a national catalog nor in a protected natural area. Regional catalogs should pay attention to all these Geosites, to be preserved and used as local geotouristic resources.

These four issues, the lack of information, and particularly this inventory's potential for wide use conditioned the methodology, selection, study, and development of this work. In this context, the main purpose of this paper is to publish the results of this inventory and some methodological processes and concepts useful for drawing up a similar catalog elsewhere.

The Province of Leon: A Territorial Description

Leon is the most northwestern province of the Autonomous Regional Government of Castile and Leon (Fig. 1), and it is also the largest one in this region, with an extent of 15,581 km^2.

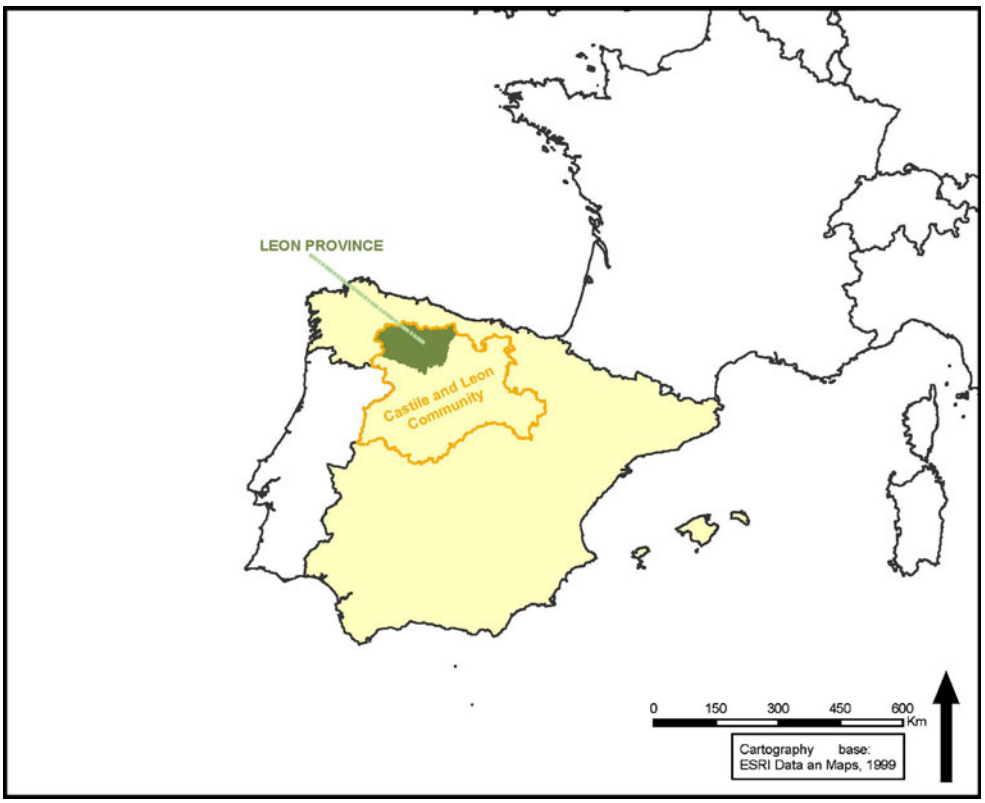

Fig. 1 Map of the Iberian Peninsula showing the geographical position of the Leon province

From a geological point of view, Leon belongs to four different geological zones: the Cantabrian Zone, West Asturian-Leonese Zone, Central Iberian Zone, and Duero Basin. The first three areas are part of the Iberian Massif formed in the Palaeozoic, whereas the last is Cenozoic, hence, its geodiversity. Moreover, the large number of Palaeozoic outcrops and their quality reinforce its geological importance. Five Global Geosites have been proposed in Leon so far: Esla Nappe region, Luna Valley Palaeozoic section, Salas de la Ribera graptolite site, Picos de Europa Mountains and Valporquero caves (Fig. 2).

In addition to its geological heritage, Leon has different types of present-day natural environment. It is located between the two macrobioclimes (Rivas-Martínez 2007) of the Iberian Peninsula: Temperate and Mediterranean. This means two different biogeographical regions (Eurosiberian and Mediterranean) with an interesting transitional band and the coexistence of plant and animal species from both biomes. Moreover, this province has a rich cultural, historical, and ethnographical legacy, protected by the Law on the Spanish historical heritage (Law 16/1985*, 25 de junio, del Patrimonio Histórico Español*).

According to data from the National Statistics Institute, the last population census published (1 January 2009) indicates that the province of Leon has 500,200 inhabitants, a rather low population density. During recent years, the population has declined (in 2009, 2,455 inhabitants less). The population age distribution is also worth mentioning: 10.52% are under 14 years; 65% are between 14 and 64 years and 24.4% are 65 years and older. This means an aging index of 231.93, i.e., 231.92 retired people as against 100 young people.

In Leon, the ownership of the land is not private, but, in a high degree, rests with the local administration. Because most of the Geosites are located in rural areas, it is important to have some data concerning these areas. Low density, negative growth, and aging of the population are specially marked in rural areas where nowadays the economy depends on state and EU subsidies. For several

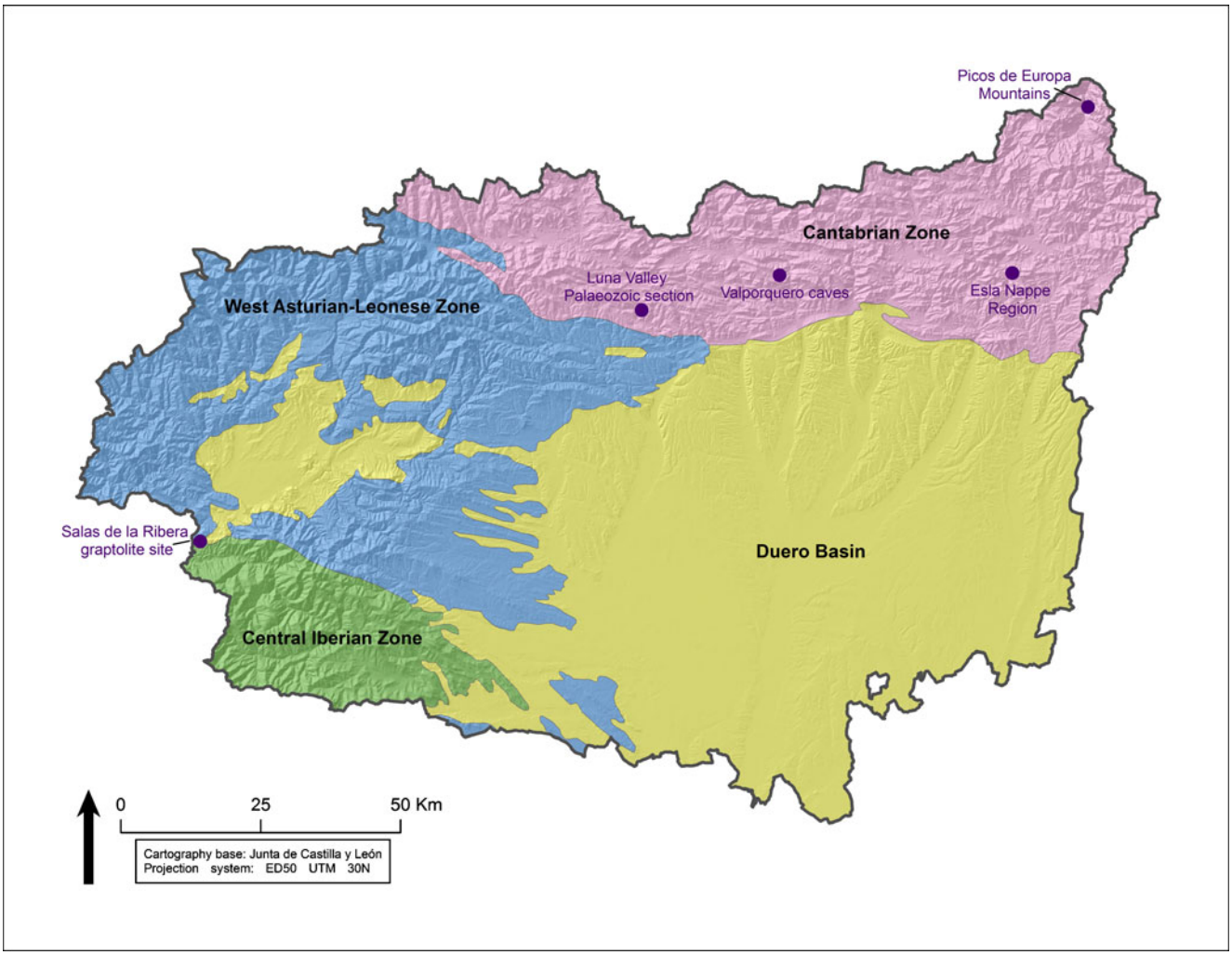

Fig. 2 Source: Rodríguez Fernández and Heredia (1994), modified. Geological sketch map of the Leon province showing the regional geological zones and the Global Geosites proposed in this territory

years, both administrations have tried to direct their efforts to develop a type of tourism based on environment and cultural heritage. It has given birth to a wide number of local museums, rural hotels, and small tourist companies. Most of these new companies and activities are mainly related to natural heritage, but, up to now, they practically ignore the geological sites.

Previous Works

This work is the first exhaustive inventory of the Geosites in Leon. Nevertheless, some previous inventories and papers have mentioned several Geosites located in the province. The most important of these is an IGME report (Elízaga et al. 1983), in the context of the "National Geosites Inventory" project. In Leon, this study only approaches the areas corresponding to the Cantabrian and West Asturian-Leonese Zones, where 88 sites were listed with 26 studied in detail. Even though this report has not been published, the results are available online (www.igme.es).

Alonso Herrero and Gallego Valcarce (1995) named 69 sites in Leon. This inventory includes the main interest and importance of each site, but they are not described in detail.

In 2001, Nuche del Rivero edited a book about the *Geological Heritage of the Autonomous Region of Castile and Leon*, and this contains a chapter devoted to the Leon province. Although the book does not provide a list of the Geosites, the geological description of the territory highlights several important localities.

Lastly, García Cortés (Ed.) (2008) gathered information about geological frameworks in Spain, listing the five Global Geosites in Leon indicated above.

In addition, there is another group of papers that refer either to a part or to the whole territory and can be useful for the purpose of this project: Fernández-Martínez (Coord.) (1998), Sáez Ridruejo et al. (Ed.) (1998), Fernández-Martínez (2000), Nuche del Rivero (Ed.) (2001), and Alonso Herrero (Coord.) (2004).

Methodology

This section is divided into three chapters, corresponding to the phases of the project. First concerns the methodology used to select regional Geosites; the second analyses the selected points, and the third deals with the methodology for the development of Geosites.

Selection Methodology

The main purpose of this part was to find a selection methodology to achieve a final inventory that reflected the geodiversity of this large province. Geodiversity is the range (or diversity) of geological (bedrock), geomorphological (landform), and soil features, assemblages, systems, and processes (Sharples 2002; Gray 2004).

The starting point was a bibliographical revision to allow recognition of every possible Geosite. At the end of this process, we realized the lack of papers about soil in the territory. Unfortunately, in the context of this project, it was impossible to deal with an exhaustive study about soils, and this subject is not well-represented in this catalog.

The compilation of sites mentioned in previous literature was completed by consulting experts on geology. This initial list was made up of 285 Geosites and encompasses the location, main interest, and relationship with a protected area of each site. This document is intended to be a database to make the administration's staff aware of the places of geological interest in the province. Nonetheless, the target of the inventory is a larger one, as mentioned above. We expected to throw some light onto sites where the conservation of geoheritage should be prioritized over other possible land uses. Thus, a second selection process became necessary to select the sites to be studied further. It was organized using a Delphi methodology. Nine experts were consulted and selected a number of 125 Geosites. In the future, the resulting list should be periodically revised and will be open to new additions and subtractions. The criteria given for the selection were:

1. Every site should posses a relevant intrinsic value. This concept was widely discussed by Sharples (2002), Gray (2004), and Brilha (2005). Intrinsic value refers to ethical belief that some things are of value simply for what they are rather than that they can be used by humans. At this stage, we would try to minimize the subjectivity implicit in this idea, and we would emphasize it, leaving for later stages such parameters as, for instance, human activities, as well as circumstances connected with the site degradation and potential for use.
2. The inventory had to be representative of the geodiversity of Leon. From our point of view, that involves two different aspects:
   (a) Every geological terrain in Leon must be represented. As Wimbledon et al. (2000) indicate, sites must be judged in an objectively identified context, not in isolation. On this regional scale, we assume that the most suitable context for reference is not global frameworks, but regional geological zones.
   (b) Every geological subject must be represented. This factor is particularly interesting for the management of geodiversity and geotourism. Some Geosites are easier understood by the general public

than others (e.g., geomorphological sites versus tectonic sites), and some are more vulnerable than others (e.g., paleontological versus tectonic). Thus, according to the main interest, sites were divided into seven categories: mineralogical, petrological, paleontological, stratigraphical (which includes sedimentological), geomorphological, hydrogeological and tectonic.

3. The promoter of the project (regional government) demanded of us that we meet three requirements:
   (a) The inventory will only include sites and will not take into account portable heritage (e.g., collections).
   (b) As far as possible, every geographical area in Leon should be represented in the inventory.
   (c) Sites included within of protected areas would be favored, as far as possible. These sites have the advantage of being already protected in some way, and regulations may be applied, where they are in danger. It is also easier for the regional government to attempt the popularization of geoheritage or geotourism programs in these areas, already known and appreciated by society. In fact, they enjoy some infrastructure (nature interpretation centers, paths, observatories and viewpoints, well-established accesses, and parking lots, etc.).

Analysis of Selected Sites: Typology and Value Assessment

After 125 sites had been identified, we proceeded to analyze and classify them according to their typology and value assessment.

Typology is a common concept in the field of geological heritage, and it has been used with quite different meanings by several authors (see, for a summary, Carcavilla et al. 2007). In this paper, we will use typology differently from the mentioned authors and will try to define five categories. Our aim was to use typology to provide the non-skilled staff with an approximate idea of the nature of the selected sites, according to easily interpretable factors: size, object shape and disposition, fragility, and vulnerability. The last two factors need to be precisely defined. Fragility is a factor adapted from other sciences (Botany or Ecology). It has been mentioned before in this context (Morales Romero 1996; Sharples 2002; Carcavilla et al 2007), but its application here is substantially different. The fragility of a site measures its degradation risk under present natural conditions, i.e., without the intervention of Man. A site is fragile when a process of either a rapid (human scale) damage or destruction occurs. Fragile Geosites in Leon are, for example, the remains of glacial ice and peats, as well as highly erodible elements, such as Tertiary sequences. The management of these sites should attempt not to increase its rate of degradation due to natural factors. On the other hand, vulnerability measures the risk of destruction due to human activity. The sites are vulnerable when intensive human activity affects them or when their dimensions are so small that any human activity (even some which are not so aggressive) can cause damage.

According to these criteria, we distinguished five different categories:

1. Points: Small-sized (usually about 1 ha, but, in our territory, some of them are larger) isolated features. Whether fragile or not, they are always vulnerable because of their dimensions. (Fig. 3).
2. Sections: Chronological (stratigraphical) sequences and/or features having linear spatial development (e.g., a gorge or some braided channels along a river). They are usually composed of smaller outcrops. In the event of one element being damaged, the whole sequence would lose value. That increases the fragility and vulnerability of sections (Fig. 4).
3. Areas: Larger-sized sites including just one type of interest. Their fragility and vulnerability is low because of their dimensions (Fig. 5).
4. Viewpoints: In our typological classification, a viewpoint includes two different elements: a large area of geological interest and an observatory from where this area may be viewed. None of these two elements are fragile themselves: the area because of its large dimensions and the observatory because of its site's far external location. Nonetheless, the panoramic quality of the viewed landscape may be extremely vulnerable to any activity that causes a visual impact (Fig. 6).

Fig. 3 Typology of geosites in Leon. Points: Ripples at Piornedo Geosite

Fig. 4 Typology of geosites in Leon. Sections: Stratotype of La Vid Group Geosite

Fig. 6 Typology of geosites in Leon. Viewpoint: Piedrashitas Viewpoint, located in the Picos de Europa National Park

5. Complex areas: Large Geosites with a physiographic homogeneity. They are composed of several points, sections, areas, and/or viewpoints. This concept coincides with what Wimbledon et al. (2000) called complex-interest Geosites or sites with high geodiversity. The fragility and vulnerability of whole is quite low, but it must be understood that they are composed by elements whose status might be different (Fig. 7).

Additionally, the typological classification turns out to be an adequate guide for potential geotouristic use of each site (Table 1), since it gives some hints on how to popularize the sites, as well as their resistance to impacts, i.e., how much tourist pressure they can stand without damage:

1. Points: They can be easily popularized by means of simple panels for their interpretation. Sometimes, they need to be protected physically because of their small size and rarity (in other words, their vulnerability). For the same reason, their resistance to user pressures is quite low.
2. Sections: Visitors should follow a marked route where they would find material for the understanding or interpretation of the sites. It is of the highest importance to preserve the whole section.
3. Areas: They should be interpreted similarly to points, even though they can stand a higher pressure.
4. Viewpoints: Quite peculiar as far as their management is concerned: they can withstand high pressures as the geological sites of interest are at a distance.
5. Complex areas: They are sites that can be incorporated into the net of regionally protect nature areas (many of them are already included). They can sustain much use and visitor numbers and can be popularized using guides and/or designing itineraries along the various localities included in the complex area.

Fig. 5 Typology of geosites in Leon. Areas: Liordes depression Geosite, located in the Picos de Europa National Park

The value of assessment is evaluated through the degree of interest. This parameter is divided in four categories: international, national, regional, or local. The degree of interest was previously used by García-Cortés et al. (1992) and by Alonso Herrero and Gallego Valcarce (1995). Global Geosites will have international interest. Sites which are included in any national or regional protected area will be in most cases ratified with the same category. In the rest, experts must grade the interest of each element. The importance of this parameter lies on the inclusion of sites, which will be exclusive to the provincial inventory.

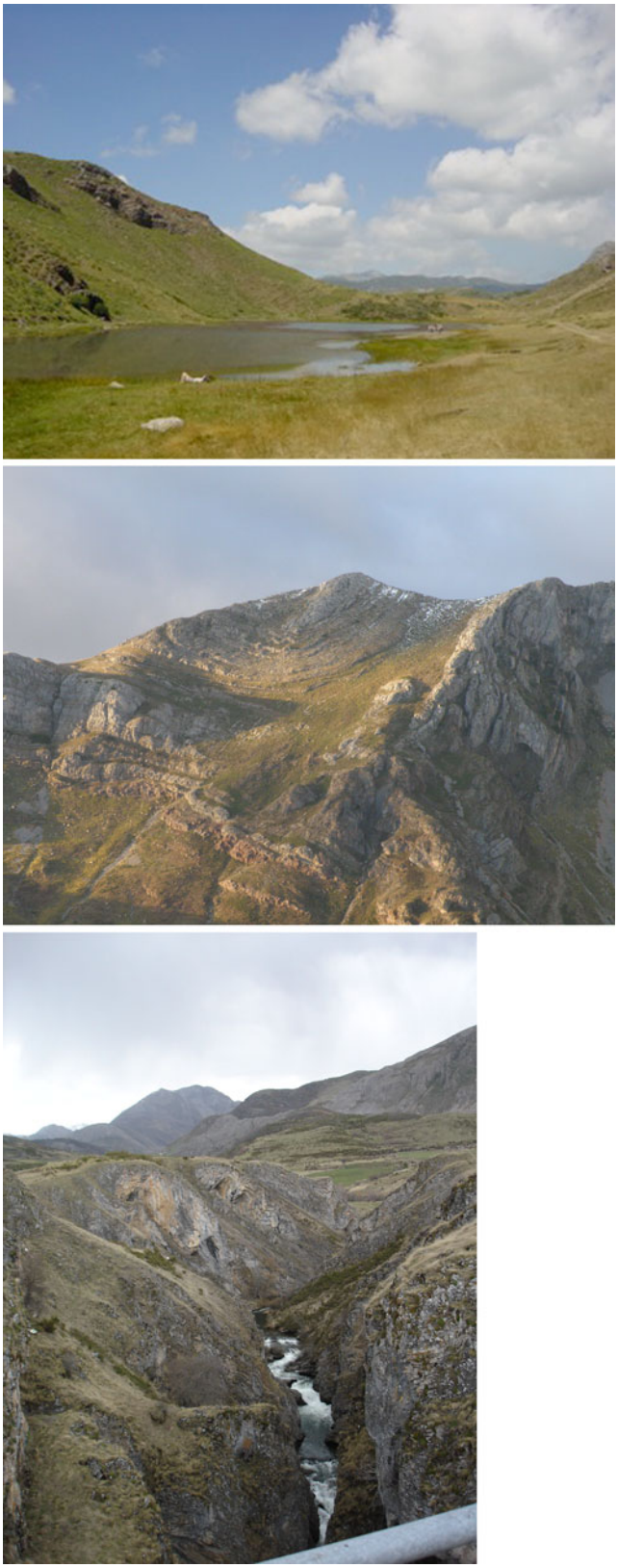

Fig. 7 Typology of geosites in Leon. Complex areas: some sites belonging to the Luna and Sil Rivers high basin. From *top* to *bottom*: Glaciar lake called *Lago de Babia;* folds and faults of Cacabillo-Quejo and stream capture of the Luna river by the Sil river

Methodology for Development of Sites

Our work methodology will follow the traditional framework. The content of the surveys was designed based on the proposals by Cendrero (1996a, b) and Carcavilla et al. (2007). The work of previous authors was a significant compilation of different methods to describe and assess Geosites.

In spite of this, some minor changes have been introduced to adapt some parameters to our purpose and project requirements.

For the study of each site in depth, we followed this methodological framework:

1. Compilation of scientific publications.
2. Fieldwork: collection of data and photographs and cartography, site description and assessment.
3. Division of all the inputs into two different sections:
   (a) The site general information for each locality is organized as a descriptive survey, which consists of two main chapters:
      - Generalities and location of the site (maps and graphics included)
      - The site's geological setting
   (b) The site conservation status and management information. Each site is linked to a second assessment survey. It includes three types of information:
      - Assessment parameters
      - Suggestions on management
      - Site management information

We believe that one of the most successful methodological principles is to maintain a clear division between descriptive and evaluative information. This aspect turns out to be very useful when using the report in differing circumstances. For instance, the description of the sites will be essential to make geoheritage more popular and better known. Likewise, the assessment of the sites will be a key question for the preservation of the geoheritage.

Results

The results can be read in Fernández-Martínez and Fuertes-Gutiérrez (Coord.) (2009).

The fieldwork revealed that some of the 125 Geosites had disappeared, mainly by material extraction and public engineering works. Some others were seriously damaged or had lost their value. Moreover, some features that were located close to each other were combined in the list or brought together in larger areas. Finally, the inventory

Table 1 Basic features of the different typological categories proposed in this paper

Typology	Definition	Fragility	Vulnerability	Resistance to pressure	Proposals
Point		Low to high	High	Low	Need protection
Section		Medium	Medium	Medium	A marked route has to be followed
Area		Low	Low	High	Easy to popularize
Viewpoint		Low	High (the panoramic)	High	Good sites to popularize
Complex area		Low, but locally high	Low, but locally high	High	Incorporation to natural protected areas

consists of 97 Geosites (Appendix). Due to the length of the results, they are divided in three sections: (1) results related to the descriptive survey, (2) results related to the assessment, and (3) results related to the conservation status and proposals on management.

Results related to the descriptive survey

1. Typology of sites: 22 sites are points (23%); 29 sections (30%), 32 areas (33%), four viewpoints (4%), and ten are complex areas (10%) (Fig. 8a).
2. Main interest: 15 Geosites have mainly stratigraphical interest (16%); ten are paleontological (10%), seven are mineralogical (7%), three are petrological (3%), 48 are geomorphological (50%), four are hydrogeological (4%), and ten are tectonic Geosites (10%). In this grouping, only the main interest is considered, but it is important to note that 19 Geosites have two or more types of geological interests (Fig. 8b).
3. As for sites' degree of interest, our proposal is as follows: 21 international sites (22%), 11 national sites (11%), 36 regional sites (37%), and 29 provincial sites (30%; Fig. 8c).
4. Within a protected area: five sites are located both in the National Park of Picos de Europa and in the Regional Park of Picos de Europa; 11 sites are located only in the Regional Park Picos de Europa; 22 sites are sited in different areas which are under process of being declared protected (five sites are in Sierra de Ancares

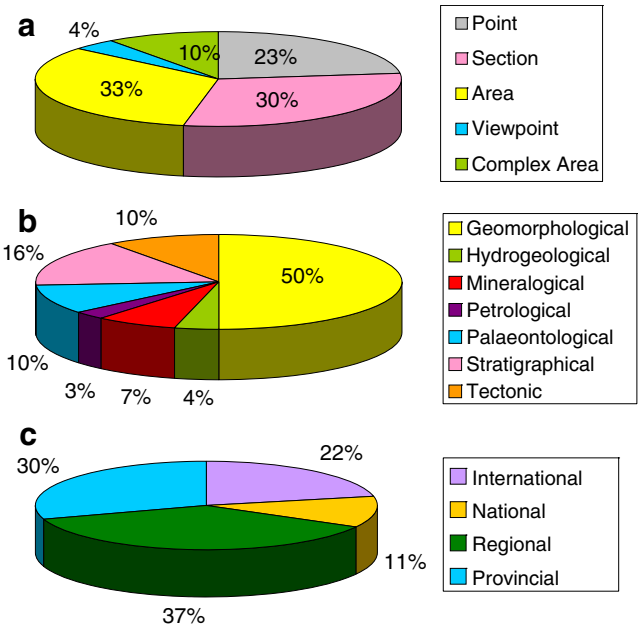

Fig. 8 Results related to the descriptive survey. **a** Pie chart illustrating the relative magnitudes of the sites according their typology. **b** Pie chart showing the relative magnitudes of the sites according their main interest. **c** Pie chart illustrating the relative magnitudes of the sites according their grade of interest

Natural Area; five sites are in Alto Sil Natural Area, five sites are in Valle de San Emiliano Natural Area; three sites are in Hoces de Vegacervera Natural Area; two are in Las Médulas Natural Monument; one is in La Baña Natural Monument, and one is in Lago de Truchillas Natural Monument; Fig. 9).

Results Related to the Assessment

Our assessment followed the three main groups of criteria proposed by Cendrero (1996b): intrinsic value, risk of degradation, and potential for use. It should be noted that this project is meant to be used for the geoheritage conservation and popularization purposes (scientific, didactic, and touristic). The complete results would have been very extensive and would not have made any practical contribution to such purposes. Nonetheless, according to the theme of this paper, it is important to emphasize several general conclusions for environmental management, especially those concerning the risk of damage and potential for use. The estimates of risk give the administration an exact idea of which sites are already damaged or about to disappear. Sites in such condition need, at least, urgent attention and perhaps a rapid intervention to avoid their disappearance. On the other hand, the assessment of its potential for use reveals sites which are ready for an immediate popularization. They are robust (non-fragile) sites and have a high resistance to user pressures. But, those sites possessing an important potential for use either have some previous infrastructure and interpretative material or are easy for the general public to comprehend.

Results Related to Proposals for Management

When suggesting some proposals for a better management of the geoheritage, we introduced two apparently opposite elements at an early stage. On the one hand, there already exists a favorable fact that must be kept and used to the

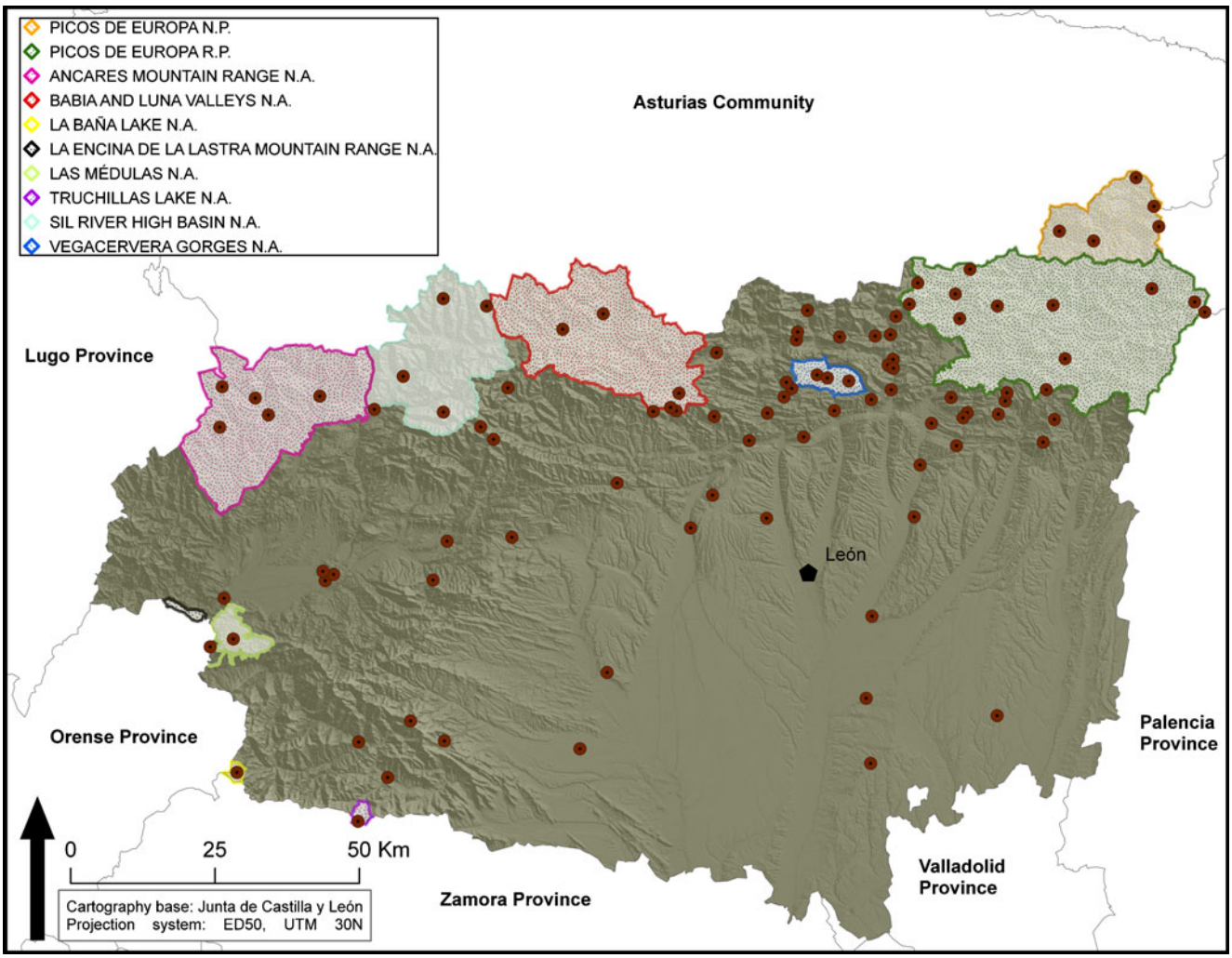

Fig. 9 Map of the Leon province showing the sites located inside natural protected areas

maximum by the regional government: 95 out of 97 Geosites (Marqués Valley and San Adrián Thermal spring excepted) have, at least, a high percentage of their areas inside public lands. In some sites, maintaining this situation is especially important, as they are sites capable of exploitation for monetary gain (for example, hydrogeological points). On the other hand, the situation with legislation on natural heritage is not satisfactory at all. Even in the protected areas, there is a huge deficiency. There are nine protected areas of different categories in Leon. One of them is the Picos de Europa National Park, and the rest were proposed in a law passed in 1991 (Law 8/1991, *de 10 de mayo de Espacios Naturales de la Comunidad de Castilla y Leon*). Some popularization programs have been implemented in these areas, but only one of them (the Picos de Europa Regional Park) has so far drawn up a scheme for a natural resource planning, a necessary legal text for any site declared a protected area. Although the Picos de Europa Regional Park has already been declared, there is a lack of legal measures in this zone; for instance, a specific plan for the running of the park has not yet been written.

Besides, despite the fact that every protected area in Leon has a very important geological content, it suffers from the same problems as in other countries: that the managers of protected areas are primarily interested in biology (Dias and Brilha 2004; Pereira et al. 2004). As Brilha (2002) argues, real nature conservation can only be achieved if geology is integrated into management of the protected areas at the same level of importance as biology, and all the natural processes need to be considered together. One general proposal to be implemented in every site should be to make geology present as a fundamental issue during the development of the legislation and popularization of natural areas. The inventory described in this paper took this proposal into account, and it was consequently and particularly designed for management staffs which are lacking any geologist.

Furthermore, geoheritage, in general, is often threatened by certain human activities. Some Geosites need studies and control of the impacts provoked by the use—geological materials extractions, reforestations, windfarms, urban development, etc. Some of them might not seem to act directly against geological features, but, as far as Geosites are concerned, they should be under regulation and each case separately considered, since these activities may hide some kind of economic or commercial interests (e.g., a reforestation) or decrease of the visual interest of the site, which is one of the basic aspects to be preserved.

A final consideration on this matter takes a look onto the geotouristic planning at the sites. Permanent interpretative material must be incorporated only at sites with low fragility and vulnerability (for example, with no risk of illicit collecting). An adequate selection for the location of these materials (panels, boards) is also important. They must always be placed next to pre-existing infrastructure, such as habitations, roads, or car parks. Geosites far from these infrastructures will have materials which involve no construction, such as brochures and pamphlets.

To conclude, the sites can be classified in four groups, according to the management proposals recommended in this work: (1) sites which need urgent intervention; (2) sites with scientific interest; (3) sites with didactic and/or touristic interest, and (4) viewpoints.

These categories are not mutually exclusive, as some sites may share various characteristics, e.g., a viewpoint may have a didactic interest and at the same time, it might need urgent intervention.

1. Sites in need of urgent intervention:
   (a) Paleontological sites. Due to the fact that there is no regional legislation on paleontological heritage, every paleontological section with risk of illicit collection is presumed to be highly vulnerable. Morales Romero (1996) states that the utilization of paleontological inventories should be restricted, in order to avoid the disappearance of these sites. That is why, we judge, the location of these sections should not be disclosed if the site protection is not guaranteed. Moreover, mechanisms of control should be strictly applied, either by means of installing physical barriers or by keeping the outcrop permanently watched on. In case the outcrop is used as a geotouristic attraction, it must be kept under a special management regime. Some specimens could be exhibited in a visitor center or museum, but visits to the outcrop must always be guided, and the access should be restricted. During these visits, fossil collections should not be shown. Sites such as Santa Lucía Formation reefal rocks at El Millar (Fig. 10), the paleontological site at Colle, and the reefal rocks at Matallana de Torio are, among others, seriously threatened sections. In these sites, a special status for scientific studies should be arranged, allowing the sampling of specimens under control.
   (b) Rare fragile points, for example, the Fonfría peat and the glacial ice remain in Trasllambrión Jou (Fig. 11). As it was said before (see typology definition), management of these sites should guarantee that its natural rate of destruction is not being accelerated by human activities.
   (c) Vulnerable sites that are threatened and at risk of disappearance because they are being seriously damaged by some human activity. They are either "single" points or points included in a complex area. If the damaging activity were not slowed down or regulated, the sites could disappear. Let

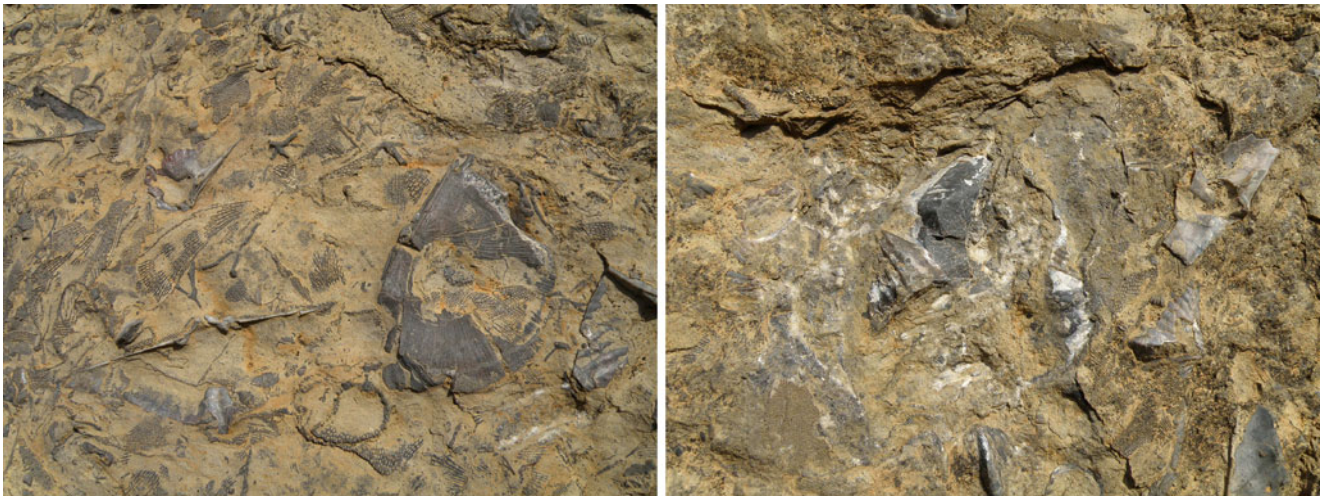

Fig. 10 Sites that need urgent intervention, paleontological sites. Fossiliferous rocks of the Devonian Santa Lucía Formation at El Millar locality (*left*) show damages by hammering and sampling (*right*)

us see some examples: the point grèzes litées at Truchas (construction material extraction; Fig. 12), each point of the complex area endorreism in Tierra de Campos (intensive agriculture is drying up these wetlands), the glacial landforms at Páramo and Susañe del Sil, and the complex area of La Baña with its moraines and lakes (the last two both threatened by slate quarries).

(d) Mineralogical points. Although this group is composed of a great variety of sites and, therefore, each one must be considered separately, they all share some common features. Tourist visits to these sites may result an irreparable damage nowadays. Many of them are, in fact, mine galleries dating back to the early or mid-twentieth century, which have not so far gone through any sort of restoration (Fig. 13). The gallery entrances are open and, in some cases, without protection at all. Being in such a state, it does not make any sense to divulge the mineralogical points. At the same time, as these excavations are all subsurface mines of limited dimensions with small-sized dumps, its visual impact is low. We feel they should be restored with a view to the development of geotourism, not in a conventional way. The dumps would be stabilized, but not reforested, as some specimens of mineral could still be found in them. The galleries would be filled in, or, in some cases, they could be fitted out with the necessary structures to allow touristic visits, as could be the case of San Andrés mine, a talc and pyrite mine at Puebla de Lillo. In any case, the visits will have to be guided with a strict control over collecting.

Fig. 11 Sites that need urgent intervention. Glaciar remains in the Trasllambrión Jou needs urgent intervention due its high fragility

2. Sites with scientific interest: these are points and sections, which possess a scientific interest, and so, they should be dedicated to research and education. Some of them have not yet been well-studied; so, our first proposal for their management is to ask the administration to back up and finance research programs in those areas. Many paleontological sections (1a) and every fragile point (1b) mentioned above would be included in this chapter, as well as some others, e.g., the area called lake and moraine at Respina. It is also important to note that some sections with scientific interest are used as teaching localities (at university level) or visited by geological enthusiasts. In some of them (e.g., the Palaeozoic stratigraphical sequence at Los Barrios de Luna), hammering is particularly intensive, strongly affecting the feature (Fig. 14).
3. Sites with didactic and/or tourist potential: In this group, we have included sites that are not fragile or

Fig. 12 The point Grèzes litées near Truchas locality is threatened by quarrying and there is a high risk of destruction

vulnerable to use through popularization. They are divided into two groups:

(a) Sites (sections along riverbanks, areas, and complex areas) that are already being used and receive a large number of visitors. Most of them are located in protected areas. Geology in these sites is not explained, even though it is their main attraction, e.g., the Cares Gorge section, the Liordes depression area (Fig. 5), and the complex area of the Luna and Sil rivers high basin (Fig. 7). Their previous infrastructure and high resistance to user pressures should be used for the popularization of geology.

In this group, show caves prepared for visitors constitute a special case (Fig. 15) because, in the three caves included in present catalog, geology is not properly emphasized; furthermore, in one of them, the geological interpretation is completely wrong. But, there is still something rather worrying: the humidity and temperature conditions in the caves are not properly controlled, and they lack a study on the resistance to visits.

(b) Sites (areas and points) not being already used. All the sites in this group should go through a serious analysis to determine their resistance to pressure, what other attractions are nearby, and estimate their popularization. Some examples are the point called erratic boulder between Puebla de Lillo and Redipollos, the Boeza river terraces area, and the Peña Galicia syncline and Devonian stratigraphical section at Aviados complex area (Fig. 16).

4. Viewpoint

The inclusion of viewpoints in this sort of catalogs has always been a controversial issue. They are particular sites, as they enjoy no spatial continuity and consist of two clearly different parts: the observation point and the place to be looked at, a large area with geological interest and high esthetic value (Fig. 6). According to their definition (see typology definitions above), viewpoints are only Geosites when some geological interest emerges from them, and they require an external point to observe and appreciate such interest. In our opinion, there are two main reasons to include viewpoints in the present inventory and develop proposals for their management. On the one hand, the effective conservation of viewpoints involves both the preservation of the observatory and, above all, the conservation of the landscape that is viewed, i.e., the conservation of large interesting geological areas. As the elements in these areas are large, a variety of activities can happily be accommodated in them, except those involving

Fig. 13 Blue aragonite (*left*) deposit in the Antonina mine near Requejo is an important mineralogical point. As shown in the picture (*right*), the old mine has not been restored and the site remains in a quite dangerous condition

Fig. 14 A view of the Paleozoic stratigraphical section at Los Barrios de Luna, a Geosite of international interest where intensive hammering is strongly affecting the feature (note fallen rocks just at the *bottom of the section*)

visual impact. On the other hand, we agree with Palacio (1999) in considering viewpoint sites suitable for introducing and popularizing geological heritage particularly with secondary-level students and the general public. Besides, the localities already enjoy some advantages, such as accessibility, infrastructures, and probably, being known to the people.

In our case, we have remarked the relevance of already known viewpoints (e.g., Piedrashitas viewpoint, Fig. 6) and propose some other places as suitable for installation of a geological observatory. The main objective is to preserve the element of interest itself, but it is the aim of popularizing these sites that requires one to establish and maintain the observatory (e.g., faults in limestone at Mallo de Luna).

Fig. 15 Caves prepared for public visits are a special case. Valdelajo Geosite is a very small cave showing a stunning diversity of speleothems

Fig. 16 Peña Galicia syncline and Devonian stratigraphical section at Aviados is an interesting area mostly visited by students and mountaineers but it is not being used as Geosite

Discussion and Conclusions

In the present situation of greater concern for geoheritage, exhaustive inventories of smaller territories with generic purposes are needed in order to join up with efforts for geoconservation at an international and national level. One of the aims of this paper is to insist on the relevance of inventorying and preserving local sites that will not be labeled as Global or National Geosites, or included in a Protected Area. The present inventory encompasses 36 regional sites and 29 provincial sites. Some sites from the first group are located inside the perimeter of a protected area, but the second group of sites, which lie under no protection, constitute 30% of the total. It is important not only to highlight their existence, but also to point them out as possible geotouristic resources. We strongly feel that listing and evaluating geoheritage in detail is one of the keys to tackle the challenge of an integral real geoconservation. A deep knowledge of the geoheritage will allow its integration in administrative and legal processes and, what is more important, link them to local economies.

It is also our objective to contribute to future inventories by means of suggesting useful instruments for the management of geoheritage. With this goal in mind, two special tools are proposed in this paper. The first is the use of the typology as a key factor to summarize the specifications of geoheritage in a region. We propose and define five different categories (points, sections, areas, viewpoints, and complex areas) related to site dimensions and shape, but also, more importantly, to their vulnerability and fragility.

The second tool emerges from combining typology with the main interest and/or the potential of the site itself. It involves distinguishing four groups of sites, and this will help the local authorities to outline the best strategies for

site management: sites in need of urgent intervention, sites with scientific interest, sites with didactic and/or tourist potential, and viewpoints.

Taking this catalog as a base, the next phase should be to determine site limits and to establish the measures for their protection, which is a task to be performed by the regional government. With a starting point like this, the administration would be able to decide the way to preserve geoheritage. This way may vary from the inclusion of sites in a Nature Protected Area to the development and application of specific legislative measures on these features. At that stage, we think it of the greatest importance to follow the proposals that are suggested herein for their management, even in some cases (fragile and vulnerable sites) in a very strict manner.

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Appendix

Map of the Leon province showing the position and main interest of the Geosites considered in this inventory.

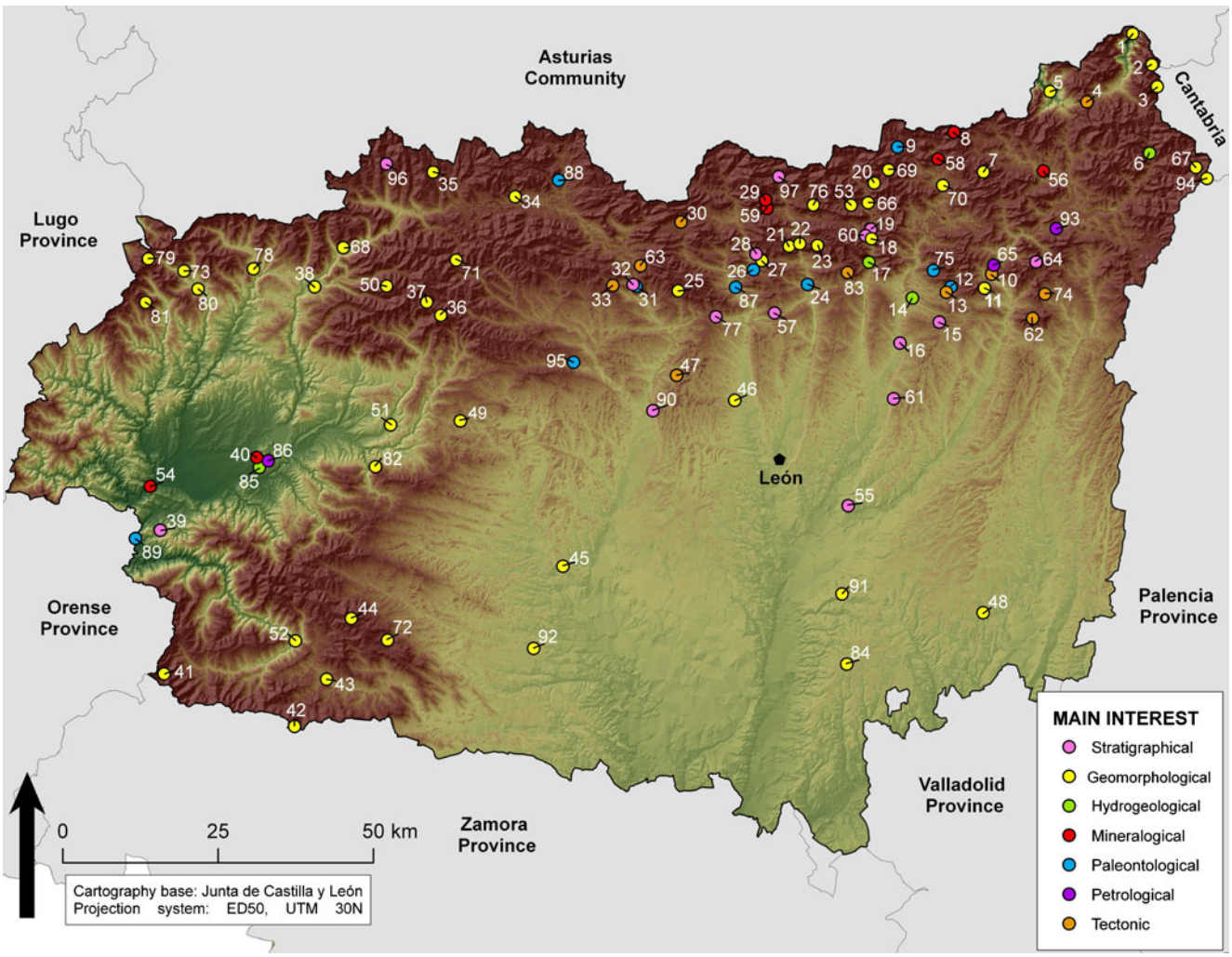

Table listing the Geosites considered in the inventory. For each Geosite, the name, typology, main interest, and membership to a protected area are indicated.

Table 2 Analysis of selected sites

Number	Spanish site name	English site name	Typology	Main interest	Protected area
1	Desfiladero del Cares	The Cares Gorge	Section	Geomorphological	Picos de Europa National Park and Regional Park
2	Jou del Trasllambrión	Trasllambrión Jou	Area	Geomorphological	Picos de Europa National Park and Regional Park
3	La Vega de Liordes	Liordes depression	Area	Geomorphological	Picos de Europa National Park and Regional Park
4	Mirador de Piedrashitas	Piedrashitas Viewpoint	Viewpoint	Tectonic	Picos de Europa National Park and Regional Park
5	Desfiladero del Beyo	El Beyo Gorge	Section	Geomorphological	Picos de Europa National Park and Regional Park
6	Fuente sulfurosa en Llánaves de la Reina	Sulfide spring at Llánaves de la Reina	Point	Hydrogeological	Picos de Europa Regional Park
7	Complejo glaciar de Mampodre	Mampodre glacial complex	Complex area	Geomorphological	Picos de Europa Regional Park
8	Yacimientos de cinabrio en Riosol y el Puerto de las Señales	Riosol and Las Señales Pass cinnabar deposits	Area	Mineralogical	Picos de Europa Regional Park
9	Turbera de Fonfría	Fonfría Peat	Point	Geomorphological	Picos de Europa Regional Park
10	Cabalgamiento del Manto del Esla en Valdoré	Esla Nappe at Valdoré	Section	Tectonic	
11	Cueva de Valdelajo	Valdelajo Cave	Point	Geomorphological	
12	Yacimiento Paleontológico de Colle	Paleontological site at Colle	Section	Paleontological	
13	Cretácico discordante en Colle	Unconformable Cretaceous rocks at Colle	Section	Stratigraphical	
14	Manantial termal de San Adrián	San Adrián thermal spring	Point	Hydrogeological	
15	Estratotipo de la Formación Vegaquemada en La Acisa de las Arrimadas	Vegaquemada Formation stratotype at La Acisa de las Arrimadas	Section	Stratigraphical	
16	Afloramiento de la Formación Candanedo en Lugán y estratotipo en Candanedo de Boñar	Candanedo Formation at Lugán and stratotype at Candanedo de Boñar	Section	Stratigraphical	
17	Cascada de Nocedo	Nocedo Waterfall	Point	Hydrogeological	
18	Hoces de Valdeteja	Valdeteja Gorges	Section	Geomorphological	
19	Laguna estratigráfica y estratotipo en el Arroyo de Barcaliente	Stratigraphical gap and stratotype at Barcaliente creek	Section	Stratigraphical	
20	Till subglaciar de Villaverde de la Cuerna	Subglacial till at Villaverde de la Cuerna	Area	Geomorphological	
21	Cueva de Valporquero	Valporquero Cave	Area	Geomorphological	Vegacervera gorges natural area
22	Hoces de Vegacervera	Vegacervera Gorge	Section	Geomorphological	Vegacervera gorges natural area
23	Valle del Marqués	Marqués Valley	Area	Geomorphological	Vegacervera gorges natural area
24	Yacimiento arrecifal de Matallana de Torío	Reefal rocks at Matallana de Torío	Section	Paleontological	

Table 2 (continued)

Number	Spanish site name	English site name	Typology	Main interest	Protected area
25	Hoces de los Calderones de Piedrasecha	Los Calderones Gorge at Piedrasecha	Section	Geomorphological	
26	Yacimiento arrecifal de la Fm. Santa Lucía en el Arroyo del Puerto	Santa Lucía Formation at El Puerto creek	Section	Paleontological	
27	Hoces de Villar-Ciñera	Villar-Ciñera Gorge	Section	Geomorphological	
28	Estratotipo del Grupo La Vid	La Vid Group stratotype	Section	Stratigraphical	
29	Mina La Providencia	La Providencia Mine	Point	Mineralogical	
30	Valle de Arbas	Arbas Valley	Complex area	Tectonic	
31	Yacimiento de trilobites en Los Barrios de Luna	Trilobites site at Los Barrios de Luna	Point	Paleontological	Babia and Luna valleys natural area
32	Serie del Paleozoico en Los Barrios de Luna	Paleozoic stratigraphical section at Los Barrios de Luna	Section	Stratigraphical	Babia and Luna valleys natural area
33	Discordancia angular entre el Precámbrico y el Cambrico en Irede de Luna	Angular unconformity between Precambrian and Cambrian rocks at Irede de Luna	Point	Tectonic	Babia and Luna valleys natural area
34	Cuenca alta de los ríos Luna y Sil	Luna and Sil rivers high basins	Complex area	Tectonic	Babia and Luna valleys natural area
35	Valle de Lumajo	Lumajo Valley	Area	Geomorphological	Sil River high basin, natural area
36	Conjunto glaciar-periglaciar de Arcos de Agua-Peña Cefera	Glacial and periglacial complex in Arcos de Agua-Peña Cefera	Area	Geomorphological	
37	Valle glaciar del Boeza (Campo de Santiago)	Boeza glacial valley (Campo de Santiago)	Area	Geomorphological	
38	Restos glaciares de Páramo y Susañe del Sil	Glacial forms at Páramo and Susañe del Sil	Area	Geomorphological	Sil River high basin natural area
39	Las Médulas	Las Médulas Site	Area	Stratigraphical	Las Médulas natural area
40	Yacimiento de scheelita en Ponferrada	Scheelite deposits at Ponferrada	Point	Mineralogical	
41	Morrenas y lagos de la Baña	La Baña moraines and lakes	Area	Geomorphological	La Baña Lake natural area
42	Modelado glaciar del Macizo de Vizcodillo	Vizcodillo Massiff glacial morphology	Area	Geomorphological	Truchillas Lake natural area
43	Grèzes litées de Truchas	Grèzes litées at Truchas	Point	Geomorphological	
44	Morfología periglaciar y campos de piedras del Teleno	Periglacial features and block fields in Teleno peak	Area	Geomorphological	
45	Las Torcas de Barrientos	Las Torcas badlands at Barrientos	Area	Geomorphological	
46	Lecho móvil (canales braided) en el Arroyo de Riosequín	Braided channels in Riosequín creek	Section	Geomorphological	
47	Puntos de observación geológica en Rioseco de Tapia	Geological viewpoints at Rioseco de Tapia	Viewpoint	Tectonic	
48	Endorreísmo en Tierra de Campos	Endorreism in Tierra de Campos	Complex area	Geomorphological	
49	Superficie finipontiense de Brañuelas	Finipontian surface at Brañuelas	Area	Geomorphological	
50	Glaciares rocosos de Valdeiglesia-Braña Librán	Valdeiglesia-Braña Librán rock glaciers	Area	Geomorphological	Sil River high basin natural area
51	Terrazas del Boeza	Boeza river terraces	Area	Geomorphological	

Table 2 (continued)

Number	Spanish site name	English site name	Typology	Main interest	Protected area
52	Captura fluvial del río Eria	Eria river capture	Area	Geomorphological	
53	Cueva de Coribos	Coribos Cave	Point	Geomorphological	
54	Aragonito azul de mina Antonina en Requejo	Blue aragonite deposit in Antonina mine at Requejo	Point	Mineralogical	
55	Estratotipo de la Formación Mansilla de las Mulas en Villasabariego	Mansilla de las Mulas Formation stratotype at Villasabariego	Section	Stratigraphical	
56	Fluorita en Burón	Fluorite at Burón	Point	Mineralogical	Picos de Europa Regional Park
57	Afloramiento mesozoico y terciario de Brugos de Fenar	Mesozoic and Tertiary outcrop at Brugos de Fenar	Section	Stratigraphical	
58	Talco y piritas de Puebla de Lillo	Talc and pyrite at Puebla de Lillo	Point	Mineralogical	Picos de Europa Regional Park
59	Mina La Profunda	La Profunda Mine	Point	Mineralogical	
60	Estratotipo de la Formación Valdeteja	Valdeteja Formation stratotype	Section	Stratigraphical	
61	Estratotipo de la Formación Barrillos en Vegas del Condado	Barrillos Formation stratoype at Vegas del Condado	Section	Stratigraphical	
62	Macizo de Peña Corada	Peña Corada Massiff	Area	Tectonic	
63	Fallas en las calizas de Mallo de Luna	Faults in limestone at Mallo de Luna	Viewpoint	Tectonic	
64	Sinclinal de Aguasalio	Aguasalio syncline	Area	Tectonic	
65	Meandro del río Esla y rocas volcánicas en el entorno del Pajar del Diablo (Crémenes)	Esla river meander and igneous rocks around El Pajar del Diablo (Crémenes)	Complex area	Petrological	
66	Complejo morrénico de Valdelugueros	Moraine complex at Valdelugueros	Area	Geomorphological	
67	Difluencia glaciar del Boquerón de Bobias y morrenas del Naranco	Boquerón de Bobias glacial diffluence and Naranco moraines	Area	Geomorphological	Picos de Europa Regional Park
68	Estrías glaciares de Palacios del Sil	Glacial striae at Palacios del Sil	Point	Geomorphological	Sil River high basin natural area
69	Laguna y morrena de Respina	Respina lake and moraine	Area	Geomorphological	Picos de Europa Regional Park
70	Bloque errático entre Puebla de Lillo y Redipollos	Erratic boulder between Puebla de Lillo and Redipollos	Point	Geomorphological	Picos de Europa Regional Park
71	Captura fluvial y depósito glacio-lacustre del Puerto de la Magdalena	River capture and glacio-lacustrine sediments in La Magdalena Pass	Complex area	Geomorphological	
72	Captura fluvial del río Llamas en Tabuyo del Monte	Llamas stream capture at Tabuyo del Monte	Area	Geomorphological	
73	Deslizamiento en Tejedo de Ancares	Landslide in Tejedo de Ancares	Area	Geomorphological	Ancares mountain range natural area
74	Discordancias progresivas y paleorrelieves del Carbonífero en Ocejo de la Peña	Carboniferous progressive disconformities and paleo-reliefs at Ocejo de la Peña locality	Section	Stratigraphical	
75	Sección del Devónico en Adrados	Devonian stratigraphical section at Adrados	Section	Paleontological	
76	Valle de Sáncenas	Sáncenas Valley	Area	Geomorphological	
77	Sección del Carbonífero marino en Olleros de Alba	Carboniferous marine stratigraphical section at Olleros de Alba locality	Section	Paleontological	

Table 2 (continued)

Number	Spanish site name	English site name	Typology	Main interest	Protected area
78	Encajamiento del río Cúa en Cariseda	Cua river incision at Cariseda	Viewpoint	Geomorphological	Ancares mountain range natural area
79	Circo y valle Glaciar del Cuiña	Cuiña glacial cirque and valley	Area	Geomorphological	Ancares mountain range natural area
80	Depósito fluvioglaciar de Sorbeira	Fluvioglacial deposit at Sorbeira	Point	Geomorphological	Ancares mountain range natural area
81	Conjunto morrénico de Campo del Agua-Porcarizas	Campo del Agua-Porcarizas moraine complex	Area	Geomorphological	Ancares mountain range natural area
82	Río de piedras de San Andrés de las Puentes	Block-stream at San Andrés de las Puentes	Point	Geomorphological	
83	Sinclinal de Peña Galicia y sección del Devónico en Aviados	Peña Galicia syncline and Devonian stratigraphical section at Aviados	Complex area	Tectonic	
84	Cárcavas en Quintanilla de los Oteros	Badlands at Quintanilla de los Oteros	Area	Geomorphological	
85	Fuente del azufre en Ponferrada	Sulfide spring at Ponferrada	Point	Hydrogeological	
86	Alteración del granito en Montearenas	Weathered granite (saprolite) at Montearenas	Point	Petrological	
87	Yacimiento arrecifal de la Fm. Santa Lucía en El Millar	Santa Lucía reefal rocks at El Millar	Section	Paleontological	
88	Yacimientos del Carbonífero marino en San Emiliano	Marine carboniferous outcrops at San Emiliano	Complex area	Paleontological	Babia and Luna valleys natural area
89	Sección del Paleozoico inferior y Yacimiento de graptolitos en el embalse de Peñarrubia	Lower Paleozoic stratigraphical section and graptolite outcrop in Peñarrubia Reservoir	Complex area	Paleontological	Las Médulas natural area
90	Estratotipo de la Formación Villarroquel en Villarroquel	Villarroquel Formation stratotype at Villarroquel	Section	Stratigraphical	
91	Jano en Rebollar de los Oteros	Jano at Rebollar de los Oteros	Area	Geomorphological	
92	Canales braided en el río Duerna (entre Destriana y Villalís de la Valduerna)	Braided channels in the river Duerna (between Destriana and Villalís de la Valduerna)	Section	Geomorphological	
93	Rocas ígneas en Horcadas	Igneous rocks in Horcadas	Area	Petrological	Picos de Europa Regional Park
94	Modelado glaciar y periglaciar de Tres Provincias-Hoyo Empedrado	Tres Provincias Peak and Hoyo Empedrado glacial and periglacial landforms	Complex area	Geomorphological	Picos de Europa Regional Park
95	Yacimiento del Carbonífero continental en Valdesamario	Continental carboniferous outcrop at Valdesamario	Section	Paleontological	
96	Pórfidos en la mina El Feixolín	Porphyries in El Feixolín Mine	Section	Stratigraphical	Sil River high basin natural area
97	Ripples de Piornedo	Ripples at Piornedo	Point	Stratigraphical	

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