# CONCEPTUAL BASE AND METHODOLOGY OF THE SPANISH INVENTORY OF SITES OF GEOLOGICAL INTEREST (IELIG)

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**ABSTRACT**

*This document briefly explains the background of the current Spanish Inventory of Sites of Geological Interest (IELIG, in its Spanish acronym), largely based on the pioneering national inventory of points of geological interest compiled by the Geological Survey of Spain (IGME) between 1978 and 1989. The methodology used is based on a detailed review of both national and international experiences in geological heritage inventories and their conceptual base.*

*We present the decision taken on the inventory model, and once the model is established, we describe in detail the methodology and workflow developed to identify the sites of geological interest in the target area, evaluate them quantitatively from the scientific or intrinsic point of view, and from the educational and tourist-recreational point of view. The starting point is the participation of a large panel of experts with proven experience in different fields of Earth sciences and in the specific geological domain being inventoried.*

*This document also deals with other aspects, some of which are rarely addressed, but that need to be considered when inventorying and managing the sites, such as their precise demarcation or their correct naming, and including their detailed description. An inventory would not be complete without assessing the risk of degradation of the sites of interest, based on their fragility, vulnerability and susceptibility to degradation. Therefore, in the interest of clarity, we define these terms and describe the procedure used to quantitatively estimate these attributes. Finally, using the experience gained after years applying this methodology, we put forward recommendations to prioritize protection measures based on the estimated degradation risk.*



**Key words:** Spain, Geoconservation, Inventory, Sites of Geological Interest, Geological Heritage.

## 1. BACKGROUND

The work of analysing and inventorying Spain's geological heritage was started relatively recently. Following a preliminary attempt made at the beginning of the last century, in which some particularly scenic geological enclaves were protected (the Mountains and Lakes of Covadonga, Ordesa Canyon, the Enchanted City of Cuenca or the Torcal de Antequera, among others), little further progress was made in the study of geological heritage and geoconservation over the following decades. It was only in the late 1970s when interest was rekindled by a group of professionals concerned with the conservation of palaeontological heritage (Aguirre et al., 1974), and the Geological Survey of Spain (IGME) launched a systematic project called the National Inventory of Points of Geological Interest (INPIG, in its Spanish acronym) in 1978 (Duque et al., 1979a and 1979b; Elízaga et al., 1980, 1994). The project involved compiling various different inventories in Galicia, Asturias, the Cantabrian Mountains, Valencia, Teruel, Murcia, Albacete and Menorca (Duque et al., 1983; Águeda et al., 1985; Elízaga, 1988). The INPIG project was interrupted for budgetary reasons in 1989, by which time only 16% of Spain had been inventoried. However, from then on, the identification of sites of interest was incorporated into the cartographic work of the National Geological Map (MAGNA), at a scale of 1: 50,000. During this stage, INPIG inventories were published by some regional governments, such as the Basque Country (Tamés et al., 1991) and Murcia (Arana et al., 1999).

After this, several institutions undertook studies and proposed methodologies, largely based on the work undertaken in the seventies by researchers associated with the IGME. Subsequently, some of the basic guidelines were laid down in different studies, such as those of Cendrero (1996a and b), Morales (1996), Elízaga and Palacio (1996), Palacio (2000), Morales et al. (2002), Romero Sánchez (2004), Villalobos et al. (2004), García-Cortés and Fernández-Gianotti (2005), Carcavilla et al. (2007) and Bruschi (2007). Durán et al. (2005) and Carcavilla et al. (2009) published a summary of the main research projects undertaken on the subject of geological heritage in Spain. This methodology has served as a basis for numerous inventories, such as that of Catalonia (Herrero et al., 2004; Druguet at al., 2004), Andalusia, with its Andalusian Strategy for Geodiversity Conservation (Junta de Andalucía, 2002, 2008, 2011), or more recently the Basque Country (Mendía et al., 2013) and Aragón (Departmento de Desarrollo Rural y Sostenibilidad, 2015). It is also important to mention the inventories compiled within the Global Geosites international project, the aim of which is to identify world geological heritage. In this project, a series of geological frameworks of international relevance are identified, and on this basis the sites of geological interest (known as *global geosites*) that define and characterize them are identified. In Spain, 20 geological frameworks of international relevance were identified (García-Cortés *et al.*, 2001; García-Cortés, 2008, 2009), to which a further framework was added in 2015, bringing the total to 21, and with 177 geosites exposed at exposed in a total of 276 outcrops.

Some 30 years later, the need arose to review the original approaches taken to compile the national inventory of 1978 for two reasons: to update the list in light of the advances made in the understanding of the geology of Spain, and to adapt it to emerging geoconservation policies, making it more useful for the authorities responsible for the conservation, management and use of geological heritage.

The catalyst for this methodological review was Act 42/2007, on Natural Heritage and Biodiversity. In article 9 of the text, the Ministry of Environment, in collaboration with Regional Governments and scientific institutions, undertakes to compile an inventory of sites of geological interest (SGI). A review of international experiences, summarised and duly updated in section 3, was conducted to establish the new methodology for the inventory. Once the methodology had been developed, the Spanish Inventory of Natural Heritage and Biodiversity, and specifically, the Spanish Inventory of Sites of Geological Interest (IELIG) was launched under Royal Decree (RD) 556/2011, and RD 1274/2011 entrusted its completion to the Geological Survey of Spain (IGME).

## 2. DEFINITIONS FOR ESTABLISHING A COMMON GEOCONSERVATION TERMINOLOGY

It is important to propose some definitions that clarify the meaning of certain criteria or indicators that have been given different meanings by different authors. Examples of this are, in our opinion, fragility, natural and anthropic vulnerability, susceptibility to degradation, and risk of degradation. The rest of the terms are interpreted in a similar way by different authors writing on this subject.

**Fragility**: quality of a SGI that makes it alterable due to its intrinsic characteristics, such as its lithology and its degree of fracturing and/or weathering. We prefer this definition, which is equivalent to the concept of fragility used by Fassoulas et al. (2012) or García-Ortiz et al. (2014), because it is more intuitive and consistent with the usual meaning of the term, as defined in the Oxford Dictionary (2014): *the quality of being easily broken or damaged*.

**Natural vulnerability**: a factor used to evaluate the possibility that real or potential natural processes (threats) might alter a SGI. The more fragile the site, the more intense the deterioration caused by geodynamic or biological processes. It is equivalent to the concept of fragility in Fuertes-Gutiérrez & Fernández-Martínez (2010), and encompasses the concepts of fragility and natural vulnerability in García-Ortiz et al. (2014).

When the same geodynamic processes that created or that characterise a particular site act to alter or damage it, we can call the vulnerability ***intrinsic vulnerability***, in the same sense as Master et al. (2012) use it to describe ecosystems. This concept, equivalent to fragility in Fuertes-Gutiérrez et al. (2013) or García-Ortiz et al. (2014), must be included in inventories due to its importance in the management of natural sites, since the use of geoconservation actions to address this type of natural vulnerability is arguable.

**Anthropic vulnerability**, or vulnerability due to anthropic causes: a factor used to evaluate the possibility that a SGI may be altered by human actions or threatened by human activity. This depends fundamentally on pressure from urban development, pressure from mining activities, susceptibility to pillaging or vandalism, and what we could call general anthropic pressure, not included in the other three. It is equivalent to sensitivity in Sharples (2002), vulnerability in Fuertes-Gutiérrez & Fernández-Martínez (2010), or anthropic vulnerability in García-Ortiz (2014).

**Susceptibility to degradation**: the ease with which a SGI may be degraded due to its fragility, its size, and its vulnerability (natural and/or anthropic).

**Risk of degradation**: an estimated factor that combines a site's susceptibility to degradation with its value, and which therefore estimates the potential damage or harm that geological heritage may suffer, based on the magnitude of the consequences of the degradation it undergoes. Given the same susceptibility to degradation, the risk of degradation will be greater the higher the value of the SGI. It is equivalent to the need for protection (De Wever et al., 2006), protection priority (García-Cortés and Carcavilla, 2009) or value due to need for protection (Fassoulas et al., 2012), and may be the best indicator to prioritize conservation actions. The risk of degradation ($R_D$) will be calculated using the equation $R_D = V \times S_D$, where V is the value (scientific, educational and recreational) of the site, and $S_D$ its susceptibility to degradation.

## 3. REVIEW OF THE MAIN INTERNATIONAL STUDIES AND THEIR APPLICABILITY TO THE NEW SPANISH INVENTORY OF SITES OF GEOLOGICAL INTEREST (IELIG)

Most of the methods used to compile the first inventories were focussed on providing data for identification, location, classification and valuation. This is the case of (a) the British inventory started in 1977, known as the Geological Conservation Review (Ellis et al., 1996), of (b) the aforementioned Spanish inventory of 1978, of (c) subsequent national projects in Norway (Erikstad, 1984), the Netherlands (Gonggrijp, 1988), Ireland (Daly, 1990), Switzerland (Grandgirard, 1996, cited in Bruschi, 2007) or the United Kingdom (UKRIGS, 2001), and of (d) international inventories, such as the Global Geosites project (Wimbledon, 1996; Cowie, 1993). These inventories identify the location of the selected sites, and their relevance within their geological framework. In some cases, the inventories also include an assessment of the state of conservation, as in the United States (Bostick et al., 1975), Australia (Australian Heritage Commission, 1978, in Duque et al., 1979b), Valle del Tevere, in Italy (Casto & Zarlenga, 1992), Switzerland (Strasser et al., 1995), or in the Italian regions of Modena (Bertacchini et al., 1999) and Emilia-Romagna (Bertacchini et al., 2003).

Nowadays, however, particular importance is given to a final diagnostic phase that identifies the current status of the site, not only its value and conservation status, but also its susceptibility to degradation and its potential for public use, as well as the recommendations and measures needed to improve or maintain the current situation, as appropriate. For this reason, the inventory must show not only the aspects already mentioned, but also the fragility and vulnerability of sites of interest (Figure 1). In addition, the site's location must be accurately demarcated. These demands are met by the most modern inventory methodologies, such as those proposed by Cendrero (1996a and 1996b), Bruschi & Cendrero (2005), Bruschi et al. (2011), or those used in the inventories conducted in Germany (Look, 1996), Switzerland (Grandgirard & Berger, 1997, cited in Bruschi, 2007), Italy (Servizio Geologico Nazionale, 2001, cited in Brancucci & Burlando, 2001), in the Spanish regions of Catalonia (Druguet et al., 2004; Herrero

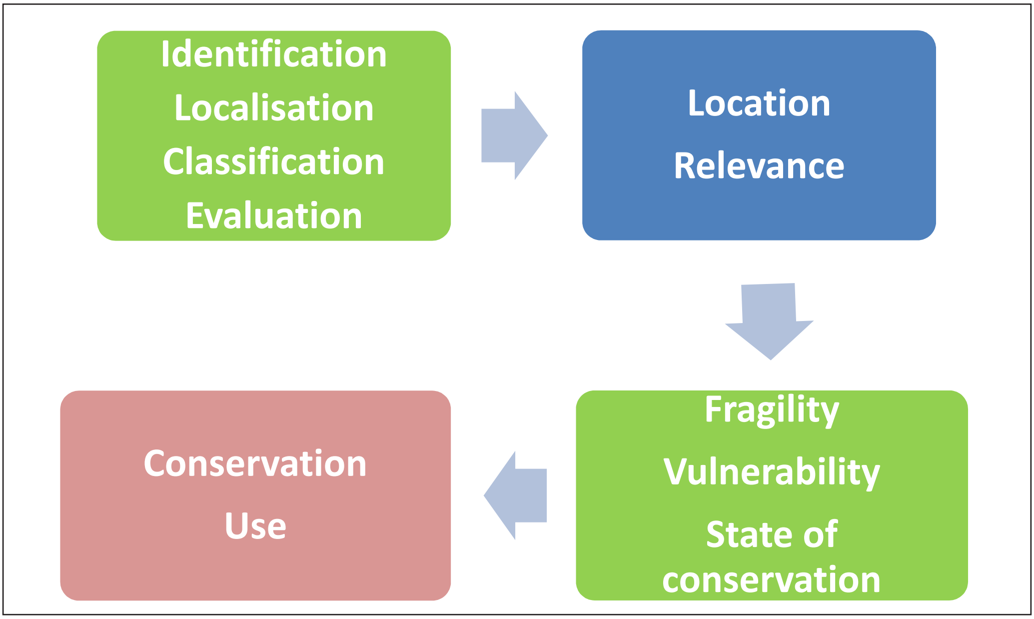


**Figure 1.** Data collected in geological heritage inventories to evaluate the location, relevance, conservation and use of target sites.

et al., 2004), Andalusia (Villalobos et al., 2004; Jódar et al., 2012), the Basque Country (Mendía et al., 2010; 2013), and France (De Wever et al., 2006). These factors were also taken into consideration in the new methodology designed for the Spanish Inventory of Sites of Geological Interest (IELIG in its Spanish acronym; García-Cortés & Carcavilla, 2009; García-Cortés et al., 2018) and in subsequent methodologies, such as the ones proposed for Brazil (De Lima et al., 2010) and for Greece (Fassoulas et al., 2012). This new approach allows inventories to not only identify the location and relevance of the GSI, but also to provide information that can be used to design measures for their conservation and sustainable public use, that is, for the management of the selected sites, both individually and altogether.

Even in the first inventories conducted, the need to conserve GSI was based on the interest and importance of these sites for science and education (Bostick, 1975; Duque et al., 1979b; Ellis et al., 1996). However, some authors also considered other types of interest, such as cultural, recreational or scenic, among others. For example, the heading of the inventory form of the Australian Heritage Commission (1978) includes values such as (in this order) *aesthetic, historic, scientific or social significance, or other special values for future generations or for the present community*. This could be more a theoretical than a real discussion, since according to the aforementioned Geological Conservation Review (Ellis et al., 1996), values of Earth science sites are important for *scientific research, education, training, economic use,* *leisure and aesthetic purposes*. Likewise, for Duque et al. (1979b), SGI are important for their scientific, educational, touristic or economic potential.

These two views on the value of geological heritage, on the one hand as exclusively scientific, and the other as educational, recreational and cultural (in addition to scientific), largely define the two main approaches that, according to Sharples (2002), produce two types of inventories: systematic inventories and reconnaissance inventories. In the first type, the geological elements are classified into thematic blocks that correspond to chronostratigraphic units, large fossil groups, structural events, metallogenetic and mineralogical provinces, morphogenetic systems, etc., and then a panel of specialists selects the sites that best represent each of these thematic blocks, based on their expert knowledge and field experience. Systematic inventories are time consuming and require considerable human resources, and were therefore rarely conducted at the national or regional level, with the exception of the British Geological Conservation Review's inventory of sites of special scientific interest (SSSI) (Nature Conservancy Council, 1991). Sites are selected exclusively on the basis of their scientific value, such as their type locality or historical character, their historic value, their representativeness in the geological record, the importance of the processes taking place in them, or their rarity (Ellis et al., 1996). In reconnaissance inventories, on the other hand, or advanced reconnaissance inventories as described in Carcavilla et al. (2007), sites are selected by experts in the geology of the target area using Delphi-type questionnaires or similar methods. In these inventories, it is impossible to prevent experts from proposing sites that are relevant to them, not only for their scientific value, but also for their educational, recreational, ethnological or other merits. Therefore, in addition to the scientific value of the site, the criteria for reconnaissance inventories must include the opinion of different authors about the educational, cultural, heritage and economic value (UKRIGS, 2001), the potential for use (Cendrero, 1996b; Bruschi and Cendrero, 2005), the educational and recreational value (Villalobos, 2004; García-Cortés and Carcavilla, 2009; De Lima et al., 2010; Mendía et al., 2010), or the global value, simply called heritage value (De Wever et al., 2006), as shown in Table 1. This table is not intended to be a comprehensive compilation, but merely an example of quantitative valuation methodologies (methodologies used for the assessment of value) used in the United Kingdom, Spain, France, Brazil and Greece.

To overcome the drawback of having so many different approaches, and to facilitate management of inventoried SGI, experts consider that the evaluation of the intrinsic values and the potential use of the site should produce three different types of mutually exclusive SGI: a) sites with a primarily scientific interest and use, b) educational sites, and c) touristic-recreational sites (Villalobos et al., 2004). Some sites may offer several possibilities of use, but they must maintain their own primary potential use. This will avoid basing the evaluation of such sites on all three potential types of use (scientific, educational and touristic-recreational), in order to prevent that sites of great scientific interest are excluded from the inventory because they lack beauty or visibility, or because they have little educational or recreational interest (García-Cortés and Carcavilla, 2009; García-Cortés et al, 2018).

**Table 1:** Parameters for the assessment of the value of SGI, according to different authors.

| | **Scientific value** | | |
|---|---|---|---|
| **JNCC (1993)** | Representativeness | | |
| | Rarity | | |
| | Type locality or historical locality | | |
| | **Scientific/educational value and geodiversity** | **Cultural and economic value** | **Accessibility and safety** |
| **UKRIGS (2001)** | Representativeness | Historical site for science | Roads and parking |
| | Rarity | Scenic/aesthetic value | Safe access to the site |
| | | Association with cultural values | Safe to use |
| | | Economic geology of interest | Need for authorization |
| | | | Visibility |
| | **Intrinsic value** | **Potential use** | |
| **Bruschi & Cendrero (2005)** | Type locality | Potential for activities | |
| | Rarity | Visibility | |
| | Representative as a model | Accessibility | |
| | Association with other natural heritage | Logistic infrastructures | |
| | Extent | Extent | |
| | Scientific knowledge | Social and economic context | |
| | Geological diversity | | |
| | Age | | |
| | Association with cultural value | | |
| | State of conservation | | |
| **Fuertes (2013)** | Representative of regional geology | Potential use (scientific, educational or recreational) | |
| | Rarity | Visibility | |
| | Relevance | Accessibility | |
| | Representative as a model | Extent | |
| | Geological diversity | Land ownership | |
| | State of conservation | State of conservation | |
| | Aesthetic or scenic value | Association with ecological and cultural values | |
| | Scientific or geohistorical value | Educational potential | |
| | | Accessible for disabled people | |
| | **Heritage value** | | |
| **De Wever et al. (2006)** | Primary geological interest | | |
| | Secondary geological interest | | |
| | Educational interest | | |
| | Interest for the history of geology | | |
| | Rarity | | |
| | State of conservation | | |
| | Additional cultural or ecological interest | | |

| | Scientific value | Educational value | Recreational value |
|---|---|---|---|
| **Villalobos (2004)** | Representativeness | Population density | Scenic/aesthetic value |
| | Type locality | Accessibility | Accessibility |
| | Scientific knowledge | Logistic infrastructure | Logistic infrastructure |
| | Visibility | Visibility | |
| | | Position in the network of natural protected areas | Position in the network of natural protected areas |
| | | Extent | Extent |
| | | Association with ecological or cultural values | Association with ecological or cultural values |
| | | Educational potential | Educational potential |
| **García-Cortés & Carcavilla (2009)** | Representativeness | Representativeness | Extent |
| | Type locality | Type locality | Potential for public outreach |
| | Scientific knowledge | Educational potential | Recreational potential |
| | State of conservation | State of conservation | Proximity to recreational areas |
| | Visibility | Visibility | Visibility |
| | Rarity | Rarity | Social and economic context |
| | Geological diversity | Geological diversity | |
| | | Logistic infrastructure | Logistic infrastructure |
| | | Population density | Population density |
| | | Accessibility | Accessibility |
| | | Association with ecological or cultural values | Association with ecological or cultural value |
| | | Scenic/aesthetic value | Scenic/aesthetic value |
| **De Lima et al. (2010)** | Representativeness | Representativeness | Recreational potential |
| | State of conservation | Visibility | Visibility |
| | Scientific knowledge | Geological diversity | Proximity to recreational areas |
| | | Educational potential | Social and economic context |
| | | Logistic infrastructures | Logistic infrastructure |
| | | Population density | Population density |
| | | Accessibility | Accessibility |
| | | Vulnerability to human activities | Vulnerability to human activities |
| | | Association with ecological or cultural values | Association with ecological or cultural values |
| | | Scenic/aesthetic value | Scenic/aesthetic value |
| **Mendía et al. (2010)** | Representativeness | Educational potential | Logistic infrastructure |
| | Rarity | Visibility | Association with cultural values |
| | Scenic/aesthetic value | Accessibility | Accessibility |
| | State of conservation | | Scenic/aesthetic value |
| | Scientific knowledge | Association with other natural heritage | Association with other natural heritage |
| | | | Recreational potential |

| | | | |
|---|---|---|---|
| **Fassoulas et al. (2012)** | Representativeness | Representativeness | Potential for activities |
| | Representative of regional geology | Representative of regional geology | Vulnerability |
| | Geological diversity | Geological diversity | Fragility |
| | Rarity | Rarity | Accessibility |
| | State of conservation | State of conservation | Resilience |
| | | Presence of viewpoints | Presence of viewpoints |
| | | Scenic/aesthetic value | Scenic/aesthetic value |
| | | Association with cultural values | Association with cultural values |
| | | Association with other natural heritage | Association with other natural heritage |
| | | Contribution to ecotopes | Level of protection |
| | | Protection measures | Number of visitors |
| | | | Importance or scope of attraction |

The most relevant parameters frequently used to establish the intrinsic or scientific value of a particular site, as shown in Table 1 (which should be considered merely indicative), are: 1) the representativeness of the site, 2) its rarity, 3) the state of conservation or integrity of the site, 4) the level of scientific knowledge, 5) if it is a type or reference locality, and 6) the geological diversity of the site. These criteria are enhanced by the presence of remarkable surface landforms or scenic landscapes.

It is interesting to focus on the most relevant parameter, **representativeness**, as understood by most authors, since it is open to different interpretations. In this study, following the general consensus, representativeness is defined as the capacity of a SGI to adequately represent the features, events and processes that are essential to the geological history of a given region.

This definition is in line with JNCC (1993), Ellis et al. (1996), Joyce (2010) and De Lima et al. (2010), and considers the usefulness of the site as a model for processes, facies, etc., as well as its ability to illustrate and facilitate an understanding of the geology of a given region.

Some authors (Fassoulas, 2012; Fuertes, 2013) interpret representativeness to be the abundance of a certain feature in the geology of a region. It should be noted in this regard, as Sharples (2002) observes, that a representative feature may be rare or abundant, since its interest lies not in these characteristics but in its being a good example of a certain class, its development or good exposure. We believe, therefore, that there is no point in overestimating the value of a representative feature of the geology of a given region and prioritizing it over others simply because it is abundant or characteristic of that region. This would be equivalent to prioritizing localism over the global value of geology. Besides, it is unnecessary and redundant, because if a feature is abundant in a given region, there will most likely be examples that, due to their development and exposure, will be considered SGI.

If the inventory is intended to be a truly useful territorial management tool, it must not only provide information about the value of the SGI, but also about its potential use and the risk of degradation. Evaluating these aspects separately allows to guide management strategies towards an approach based on the site's value, potential use, and risk of degradation (Carcavilla et al., 2007).

According to Table 1, with the aforementioned exceptions, the most prominent criteria or indicators for assessing the potential use are, in this order: 1) accessibility, 2) visibility, 3) association with cultural values, 4) association with other natural heritage, 5) spectacularity or beauty, and 6) the logistic infrastructure of the surroundings. These are followed by, in decreasing order of relevance, educational and recreational potential, surrounding population density, the state of conservation, the size of the site, the social and economic development of the surroundings, and the geological diversity.

In this list, the site's cultural value or its association with other cultural elements carries far more weight than its scientific interest. However, as will be seen later, this should not lead us to consider that geological heritage is cultural heritage. It is a type of natural heritage and in no way a result of intentional human activity, regardless of whether it may have, in certain cases, a cultural value because of its relationship with human issues.

Quantitative evaluation systems are very useful for comparing SGI selected using the same methodology, and allows us to create ordered lists of sites that greatly facilitate management (De Lima et al., 2010). There are numerous methodologies for quantitative evaluation that were initially designed to assess the interest of the site, its accessibility and safety for visitors (UKRIGS, 2001), but which are now also used to assess potential use, susceptibility to degradation, and protection priorities (Cendrero, 1996a and 1996b; Villalobos et al., 2004; Bruschi & Cendrero, 2005; De Wever et al., 2006; García-Cortés & Carcavilla, 2009; García-Cortés et al., 2018; Mendía et al., 2010 and 2013; De Lima et al., 2010; Bruschi et al., 2011; Fassoulas et al., 2012; Jódar et al., 2012). Methodological approaches for geomorphological sites, a specific type of SGI, started earlier, such as Grandgirard (1995), Rivas et al. (1995; 1997) and Barba et al. (1997), also with other more recent proposals (Bonachea et al., 2005; Pralong, 2005; Reynard et al., 2007; Zouros, 2007).

We must, of course, accept the notion that there is no single universal system for evaluating SGI, but rather an array of methodologies, each adapted to the circumstances of the studied area. This is why it is so useful to review the existing bibliography and select the assessment criteria best adapted to the scale and outcomes sought in each case. We must acknowledge that a quantitative system for evaluating the interest of a site, its potential use and its risk of degradation, cannot give totally accurate and objective results. It is essential to understand that the objective of these quantitative evaluation systems is, on the one hand, to limit the degree of subjectivity in the assessment, and on the other hand, to maximise the convergence between different experts from across the country. This guarantees, or at least significantly increases, the repeatability and reproducibility of the evaluations, and therefore their reliability, and gives homogeneous results across the territory where the system is applied, but without attempting to achieve perfect accuracy.

If we take the algorithms put forward by the authors listed in Table 1 to calculate scientific value, and unify the notations, we obtain Table 2.

**Table 2:** Different formulas for evaluating the scientific or intrinsic interest of SGI.

| | |
|---|---|
| **JNCC (1993)** | $V_C = f\,(R, A, T)$ |
| **De Lima et al. (2010)** | $V_C = f\,(R.\ C, K)$ |
| **Villalobos (2004)** | $V_C = w_R \text{ x } R + w_K \text{ x } K + w_T \text{ x } T + w_O \text{ x } O$ |
| **Bruschi & Cendrero (2005)** | $V_C = w_R \text{ x } R + w_C \text{ x } C + w_A \text{ x } A + w_K \text{ x } K + w_D \text{ x } D + w_T \text{ x } T + w_E \text{ x } E + w_{Ag} \text{ x } Ag + {} + w_{Ch} \text{ x } Ch + w_N \text{ x } N$ |
| **García-Cortés & Carcavilla (2009)** | $V_C = w_R \text{ x } R + w_C \text{ x } C + w_A \text{ x } A + w_K \text{ x } K + w_D \text{ x } D + w_T \text{ x } T + w_O \text{ x } O$ |
| **Mendía et al. (2010)** | $V_C = R + C + A + K + N$ |
| **Fassoulas et al. (2012)** | $V_C = R + C + A + D + Rr$ |
| **Fuertes (2013)** | $V_C = w_C \text{ x } C + w_R \text{ x } R + w_A \text{ x } A + w_D \text{ x } D + w_N \text{ x } N + w_{Rr} \text{ x } Rr + w_I \text{ x } I + w_{Sc} \text{ x } Sc$ |
| **De Wever et al. (2006)** | $V_C = w_{IP} \text{ x } IP + w_{IS} \text{ x } IS + w_{ID} \text{ x } ID + w_{Sc} \text{ x } Sc + w_A \text{ x } A + + w_C \text{ x } C + w_{NCh} \text{ x } NH$ |
| R: representativeness; C: conservation status; A: rarity; K: scientific knowledge; D: diversity; T: type locality; O: visibility; E: size; Ag: age; Ch: association with cultural elements; N: association with natural values; Rr: representativeness of regional geology; I: importance; Sc: scientific or geohistorical value; IP: primary geological interest; IS: secondary geological interest; ID: educational interest; NH: association with natural or cultural values. $W_Y$ : Factor Y weighting coefficient | |

In fact, in the case of the British Geological Conservation Review, special scientific interest is evaluated according to the site's representativeness, rarity and type locality, without resorting to a quantitative assessment. The same is true of the methodology proposed by De Lima et al. (2010) for Brazil, where scientific value is a function of representativeness, conservation status and the degree of scientific knowledge of the site. In the second section of the table, the parameter expressions proposed by different authors have been grouped to obtain the scientific value, which some also call the intrinsic value or intrinsic quality. These algorithms are the sum of the evaluation parameters, weighted by the corresponding coefficients shown in Table 3. One case is unique, and has been included in the third section of Table 2: this is the system put forward by De Wever et al. (2006) for France, where the value obtained is the so-called heritage value, which is obtained by the weighted sum of the primary and secondary geological interest, educational interest, historical interest, rarity, conservation status, and association with natural and cultural elements.

**Table 3:** Weighting coefficients of the parameters used in the algorithms shown in Table 2, according to different authors, normalized to a maximum value of 1.

| Author | $w_C$ | $w_R$ | $w_A$ | $w_K$ | $w_D$ | $w_T$ | $w_O$ | $w_N$ | $w_{Rr}$ | $w_I$ | $w_{Sc}$ | $w_{IP}$ | $w_{IS}$ | $w_{ID}$ | $w_{NH}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Villalobos (2004)** | | **1** | | **0.5** | | **0.75** | **0.25** | | | | | | | | |
| **García-Cortés & Carcavilla (2009)** | **0.33** | **1** | **0.5** | **0.5** | **0.33** | **0.33** | **0.33** | | | | | | | | |
| **Fuertes (2013)** | **1** | **0.6** | **0.6** | | **0.6** | | | **0.6** | **0.6** | **1** | **0.6** | | | | |
| **De Wever et al. (2006)** | **0.5** | | **0.5** | | | | | | | | **0.5** | **1** | **0.75** | **0.75** | **0.25** |

Table 4 shows some of the formulas for evaluating the potential use of the SGI with regard to their educational and recreational value, as put forward by the authors listed in Table 1. Bruschi & Cendrero (2005) and Fuertes (2013) evaluate the potential use of the SGI using a single value, while the other authors propose differentiating the educational value from the touristic or recreational value.

**Table 4:** Different formulas for evaluating SGI on the basis of potential use. $V_U$: value based on potential use, $V_D$: educational value, and $V_T$: touristic value.

| | |
|---|---|
| **Bruschi & Cendrero (2005)** | $V_U = w_{PTR} x P_{TR} + w_O x O + w_{Ac} x Ac + w_E x E + w_{IL} x I_L + w_{Es} x E_S$ |
| **Fuertes (2013)** | $V_U = w_{IU} x IU + w_O x O + w_{Ac} x Ac + w_E x E + w_P x P + w_C x C + w_{NH} x NH + w_{CDD} x C_{DD} + w_H x H$ |
| **Villalobos (2004)** | $V_D = w_{CDD} x C_{DD} + w_O x O + w_{Ac} + Ac + w_E x E + w_{IL} x I_L + w_{Dp} x D_P + w_{NPA} x NPA + w_{NH} x NH$<br>$V_T = w_{CDD} x C_{DD} + w_B x B + w_{Ac} x Ac + w_E x E + w_{IL} x I_L + w_{NPA} x NPA + w_{NH} x NH$ |
| **García-Cortés & Carcavilla (2009)** | $V_D = w_R x R + w_T x T + w_C x C + w_{CDD} x C_{DD} + w_A x A + w_D x D + w_O x O + w_{Ac} x Ac +$<br>$+ w_{IL} x I_L + w_{Dp} x D_P + w_{NH} x NH + w_B x B$<br>$V_T = w_{CDV} x C_{DV} + w_{PTR} x P_{TR} + w_{ZR} x Z_R + w_O x O + w_B x B + w_{Ac} x Ac + w_E x E +$<br>$+ w_{Es} x E_S + w_{IL} x I_L + w_{Dp} x D_P + w_{NH} x NH$ |
| **De Lima et al. (2010)** | $V_D = w_R x R + w_{CDD} x C_{DD} + w_D x D + w_O x O + w_{Ac} + Ac + w_{IL} x I_L + w_{Dp} x D_P +$<br>$+ w_{NH} x NH + wVu x Vu + w_B x B$<br>$V_T = w_{PTR} x P_{TR} + w_{ZR} x Z_R + w_O x O + w_B x B + w_{Ac} x Ac + w_{Es} x E_S + w_{IL} x I_L +$<br>$+ w_{Dp} x D_P + w_{NH} x NH + w_{Vu} x Vu$ |
| **Mendía et al. (2010)** | $V_D = C_{DD} + O + Ac + N$<br>$V_T = B + Ac + I_L + Ch + N + P_{TR}$ |
| **Fassoulas et al. (2012)** | $V_D = 0.4 V_C + 0.2 Ch + 0.2 B + 0.2 Ecol$; where $V_C = 1/5 (C+R+A+D+Rr)$ and $Ecol = ½ (CE+P)$<br>$V_T = 0.4 B + 0.2 Ch + 0.2 P_U + 0.2 Econ$<br>Where $P_U = 1/5 (P_{TR} + Vu + F + Ac + Rs)$ and $Econ = 1/3 (Vi + I + OP)$ |

$P_{TR}$: recreational potential; O: visibility; Ac: accessibility; E: size; $E_S$: social and economic settings; IU: interest for use; P: protection measures; C: conservation status; NH: association with natural or cultural values; $C_{DD}$: educational potential; H: facilities for people with disabilities; $I_L$: logistic infrastructures; $D_P$: population density; NPA: relationship with natural protected areas; R: representativeness; T: type locality; A: rarity; D: diversity; B: beauty; $C_{DV}$: informative potential; $Z_R$ : proximity to recreational areas; Vu: vulnerability; N: association with natural values; Ch: association with cultural elements; $V_C$: scientific value; Ecol: ecological factors; Rr: representativeness of regional geology; CE: contribution to ecotopes; $P_U$: potential use; Econ: economic factors; Rs: resilience; Vi: number of visitors per year; I: importance; OP: level of protection. $w_Y$: factor Y weighting coefficient.

Table 5 shows the weighting coefficients proposed by the different authors in their formulas for calculating the value on the basis of the potential use, educational value and touristic value of the site.

**Table 5:** Weighting coefficients used by the different authors in their algorithms for calculating the value for potential use (upper block), educational value (intermediate block) and touristic value (lower block). The coefficients have been normalized to a maximum value of 1.

| Author | $W_{IU}$ | $W_O$ | $W_{Ac}$ | $W_E$ | $W_P$ | $W_C$ | $W_{NH}$ | $W_{CDDu}$ | $W_H$ | $W_{IL}$ | $W_{DP}$ | $W_{NPA}$ | $W_B$ | $W_{ES}$ | $W_R$ | $W_T$ | $W_A$ | $W_D$ | $W_{CDV}$ | $W_{PTR}$ | $W_{ZR}$ | $W_{Vu}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.6 | 0.6 | 1 | 1 | 1 | 1 | 0.6 | 0.6 | 0.6 | | | | | | | | | | | | | |
| 2 | | 0.5 | 0.5 | 0.75 | | | 1 | 1 | | 0.25 | 0.5 | 0.5 | | | | | | | | | | |
| 3 | | 0.25 | 0.75 | | | 0.25 | 0.25 | 1 | | 0.75 | 0.25 | | 0.25 | | 0.25 | 0.25 | 0.25 | 0.5 | | | | |
| 4 | | 0.33 | 0.33 | | | | 0.17 | 1 | | 0.5 | 0.33 | | 0.17 | | 0.17 | | | 0.17 | | | | 0.17 |
| 2 | | | 0.6 | 0.6 | | | 0.8 | 0.4 | | 0.2 | | 0.4 | 1 | | | | | | | | | |
| 3 | | 0.25 | 0.5 | 0.75 | | | 0.25 | | | 0.25 | 0.25 | | 1 | 0.5 | | | | | 0.75 | 0.25 | 0.25 | |
| 4 | | 0.25 | 0.5 | | | | 0.5 | | | 0.5 | 0.25 | | 0.75 | 0.25 | | | | | | 1 | 0.25 | 0.75 |
| 1: Fuertes (2013); 2: Villalobos (2004); 3: García-Cortés & Carcavilla (2009); 4: De Lima et al. (2010). | | | | | | | | | | | | | | | | | | | | | | |

The foregoing authors go one step further, and suggest including the site's need for protection, its potential threats, or its risk of degradation, this latter one referring to susceptibility to degradation. Only some of them (De Wever et al., 2006; García-Cortés & Carcavilla, 2009 and 2014; Fassoulas et al., 2012) include the interest or value of the site in their analysis, which is really equivalent to the risk of degradation, and on this basis they estimate the need for protection.

Table 6 shows the evaluation parameters used in the quantitative methodologies followed in the different inventories analysed. The most important parameters in this case are 1) anthropic threats in general, 2) protection measures, 3) population density, 4) accessibility, 5) size, 6) land ownership, and 7) natural threats or natural vulnerability. Immediately following this, the fragility of the site, the mining potential, and the risk of plunder are considered.

**Table 6.** Parameters for evaluating threats, risk of degradation, or need for protection of SGI, according to different authors.

| | |
|---|---|
| **Cendrero (1996b)**<br><br>**Need for protection** | Current or potential threats |
| | Accessibility |
| | Proximity to populated areas |
| | Population density |
| | Size |
| | Economic value of land |
| | Protection measures |
| | Risk of plunder |
| | Mining potential |
| | Fragility |

| | | |
|---|---|---|
| **Bruschi & Cendrero (2005)** **Need for protection** | Population density | |
| | Current or potential threats | |
| | Risk of plunder | |
| | Protection measures | |
| | Mining potential | |
| | Land ownership | |
| **Bruschi et al. (2011)** **Potential threats and need for protection** | Proximity to infrastructures | |
| | Fragility | |
| | Relationship with human activity | |
| | Protection measures | |
| | Size | |
| | Land ownership | |
| | State of conservation | |
| **De Wever et al. (2006)** **Need for protection** | Heritage interest | |
| | Natural vulnerability | |
| | Anthropic threats | |
| | Protection measures | |
| **De Lima et al. (2010)** **Risk of degradation** | Vulnerability due to natural or human factors | |
| | Proximity to mining, industrial, urban, recreational areas | |
| | Protection measures | |
| | Accessibility | |
| | Population density | |
| **Mendía et al. (2010)** **Fragility/Vulnerability/Risk of degradation** | Intrinsic vulnerability | |
| | Accessibility | |
| | Size | |
| | Current or potential anthropic threats | |
| **Jódar et al. (2012)** **Threats** | Intrinsic factors | Fragility |
| | | Natural vulnerability |
| | External factors | Exploitation, urbanisation, public works, etc. |
| | | Direct actions on SGIs |
| | | Protection measures |
| | | Territorial and urban context |
| | | Land ownership |
| | | Population density |
| **Fassoulas et al. (2012)** **Value due to the need of protection** | Scientific interest | |
| | State of conservation | |
| | Ecological Risk Factor | Contribution to ecotopes |
| | | Protection measures |

| | | |
|---|---|---|
| **Fuertes (2013)**<br><br>**Risk of degradation** | Accessibility | |
| | Size | |
| | Proximity to populated areas and/or influx of people | |
| | Current or potential threats | |
| | Anthropic vulnerability | |
| **García-Cortés et al. (2018)**<br><br>**Susceptibility to degradation**<br><br>**Risk of degradation** | Fragility | Lithology |
| | | Size |
| | Natural vulnerability | |
| | Anthropic vulnerability | Proximity to infrastructures |
| | | Accessibility |
| | | Protection measures |
| | | Physical or indirect protection |
| | | Land ownership |
| | | Population density |
| | | Proximity to recreational areas |
| | | Potential for mining or water supply |
| | | Risk of plunder |
| | Scientific, educational and recreational value | |

The formulas put forward to calculate the need for protection, threats, and susceptibility or risk of degradation are shown in Table 7, and the weighting coefficients used in the formulas are indicated in Table 8.

**Table 7:** Formulas put forward to calculate the need for protection ($N_P$), susceptibility to degradation ($S_D$), risk of degradation ($R_D$) or threats (Th), according to different authors.

| | |
|---|---|
| **Bruschi & Cendrero (2005)**<br>**Need for protection** | $N_P = w_{Dp} \times D_P + w_{VuA} \times Vu_A + w_{VuEX} \times Vu_{EX} + w_P \times P + w_{VuM} \times Vu_M + w_{Ts} \times T_S$ |
| **De Wever et al. (2006)**<br>**Need for protection** | $N_P = Vp + Vu_N + Vu_A + P$ |
| **De Lima et al. (2010)**<br>**Risk of degradation** | $R_D = w_{Vu} \times Vu + w_{VuI} \times Vu_I + w_{Ac} \times Ac + w_P \times P + w_{Dp} \times D_P$ |
| **Mendía et al. (2010)**<br>**Risk of degradation** | $R_D = Vu_N + Ac + E + Vu_A$ |
| **Bruschi et al. (2011)**<br>**Potential threats and need for protection** | $N_P = w_{VuI} \times Vu_I + w_F \times F + w_{Hu} \times Hu + w_P \times P + w_E \times E + w_{Ts} \times T_S + w_C \times C$ |
| **Jódar et al. (2012)**<br>**Threats** | $Th = w_F \times F + w_{VuN} \times Vu_N + w_{VuA} \times Vu_A + w_{VuEX} \times Vu_{EX} + w_P \times P + w_{PL} \times PL +$<br>$+ w_{Ts} \times T_S + w_{Dp} \times D_P$ |
| **Fassoulas et al. (2012)**<br>**Value due to the need of protection** | $V_{NP} = 1/3 [V_C + CE/P + (1.1 – C)]$ |

| | |
|---|---|
| **Fuertes (2013)**<br>**Risk of degradation** | $R_D = w_{Ac} \text{ x } Ac + w_E \text{ x } E + w_{VuI} \text{ x } Vu_I + w_{VuA} \text{ x } Vu_A + w_{VuAG} \text{ x } Vu_{AG}$ |
| **García-Cortés et al. (2018)**<br>**Susceptibility to degradation (natural and anthropic)**<br>**and Risk of degradation** | $S_{DN} = S_{DN} = E \text{ x } Vu_N = E \text{ x } F \text{ x } A_N$<br>$S_{DA} = E \times ( w_{VuM} \times Vu_M + w_{VuEX} \text{ x } Vu_{EX} + w_{VuI} \times Vu_I + w_{Ac} \times Ac + w_P \text{ x } P + w_{PF} \text{ x } P_F + w_{TS} \text{ x } T_S + w_{Dp} \text{ x } D_P + w_{ZR} \text{ x } Z_R)$<br>$R_D = S_D \text{ x } V$ |
| $D_P$: population density; $V_{UA}$: vulnerability due to anthropic threats; $Vu_{EX}$: vulnerability to plunder; P: protection measures; $Vu_M$ : mining potential; $T_S$: land ownership; $Vu_I$: proximity to infrastructures; F: fragility; Hu: relationship with human activity; E: size; C: conservation status; Vp: heritage value; $Vu_N$: natural vulnerability; Lt: lithology; Ac: accessibility; $P_F$: physical protection; $Z_R$: proximity to recreational areas: V: value of the site; Vu: vulnerability due to anthropic and natural causes; PL: relationship with urban planning; $V_c$: scientific value; CE: contribution to ecotopes; $Vu_{AG}$: general anthropic vulnerability.<br>$W_Y$ : Y factor weighting coefficient | |

**Table 8:** Weighting coefficients used by different authors in their algorithms for calculating the need for protection and susceptibility to degradation or risk of degradation. The coefficients have been normalized to a maximum value of 1.

| Author | $W_{Dp}$ | $w_{VuA}$ | $w_{VuEX}$ | $w_P$ | $w_{VuM}$ | $w_{Ts}$ | $w_{VuI}$ | $w_F$ | $w_{Hu}$ | $w_E$ | $w_C$ | $w_{Ac}$ | $w_{PF}$ | $w_{ZR}$ | $w_{PL}$ | $w_{Vu}$ | $w_{VuN}$ | $w_{VuAG}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **De Lima et al. (2010)** | **0.29** | | | **0.57** | | | **0.57** | | | | | **0.43** | | | | **1** | | |
| **Bruschi et al. (2011)** | | | | **0.57** | | **0.57** | **0.86** | **0.86** | **0.57** | **0.43** | **1** | | | | | | | |
| **Jódar et al. (2012)** | **0.1** | **1** | **0.3** | **0.3** | | **0.1** | | **1** | | | | | | | **0.2** | | **1** | |
| **Fuertes (2013)** | | **1** | | | | | **1** | | | **1** | | **1** | | | | | | **0.8** |
| **García-Cortés et al. (2018)** | **0.2** | | **1** | **0.2** | **1** | **0.2** | **0.6** | | | | | **0.4** | **0.2** | **0.2** | | | | |

## 4. INVENTORY MODELS

Countries are increasingly beginning to understand the need to compile inventories using either quantitative or qualitative methods as a first step towards good management of their geological heritage. Without these instruments, the actions planned may be meaningless. Following the example set by the United States, United Kingdom, Australia, Spain, Germany, Brazil, France, Greece, Ireland, Italy, the Netherlands and Switzerland, other countries, such as Albania, Belgium, Belarus, Bulgaria, Denmark, Slovakia, Estonia, Finland, Hungary, Kazakhstan, Latvia, Lithuania, Norway, Poland, Portugal, Czech Republic, Romania, Russia, Serbia, Turkey and Ukraine (Wimbledon & Smith-Meyer, 2012), South Africa (Viljoen & Reimold, 1999), Kenya, Tanzania and Uganda (Schlüter et al., 2001), Ethiopia (Metaseria et al., 2004), Namibia (Schlüter, 2008), New Zealand (Hayward, 1989) and Colombia (SGC, 2019) have now accordingly undertaken similar projects.

As mentioned above, the United Kingdom is probably the only country to have completed a truly systematic inventory, although a similar method was used in the Irish inventory (Parkes & Morris, 2002). Other countries have complied their inventory using methodologies that require fewer human and economic resources, and have produced reconnaissance or advanced reconnaissance inventories (Carcavilla et al., 2007). In this latter type of inventory, the territory is classified into geological regions, and sites are selected in each region with the help of experts with experience in that region and in the different geological disciplines relevant to the area.

Inventories can also be compiled thematically (Sharples, 2002) by making a comprehensive comparison of all the features and systems of a given topic, for example, palaeontological sites, stratigraphic sections, karst or other morphogenetic systems, soils, etc. This has been the approach taken in countries such as Finland (Kananoja et al., 2012), where inventories of moraines, wind formations and caves have been created, or Hungary (Bolner-Takàcs et al., 2012), where a complete inventory of caves was compiled in 1977. This particular methodology may also be chosen for a variety of reasons in addition to the advantage of classifying the geological environment (in this case, thematically). For example, in the case of sites of palaeontological and mineralogical interest, thematic inventories may be justified due to the particular importance of the moveable geological heritage (removed from its source and exhibited in collections and museums) of such sites, which is usually managed differently from other natural heritage sites (Díaz-Martínez et al., 2016; Vegas et al., 2017 and 2019; Delvene et al., 2018). Methods for inventorying and protecting palaeontological heritage have been developed in various different studies (Wild, 1986; Crowther & Wimbledon, 1988; Alcalá & Morales, 1991), although the same cannot be said of mineralogical heritage sites. Geomorphological heritage, meanwhile, has been studied and inventoried independently of the other geological heritage due to the studies on geomorphosites or sites of geomorphological interest promoted by the International Association of Geomorphologists (IAG) for the past twenty years (Haff, 1995; Grandgirard, 1995; Rivas et al., 1995 and 1997; Barba et al., 1997; Panizza, 2001). We can also distinguish between (a) sites of geomorphological interest that are important because they provide a record of ongoing surface geological processes and their relationship with landforms and landscapes, and (b) other geological sites that mainly serve as a record and manifestation of the evolution of the Earth from its origins (Dingwall et al., 2005). For the same reason, in addition to their renewable nature, thematic inventory techniques can also be applied to sites of hydrogeological interest. This, however, should not mask the fact that all the themes combined contribute, individually and decisively, to our understanding and interpretation of the geological history of the Earth and to the processes that have formed it, and are therefore part of a single type of natural heritage: the geological heritage.

In some countries with a federal or decentralized territorial organization, nation-wide inventories are not undertaken. Instead, the responsibility of inventorying SGI falls on the different states or regions, and the compilation of all these individual inventories is what makes up the national inventory. In these cases, it is vital that regional inventories use the same methodology for selecting, evaluating and delineating SGI, so they can be integrated into a national compilation. This is the case in Germany and France, where national guidelines have been generated (Look, 1996, and De Wever et al., 2006, respectively), and of Spain, where the Geodiversity working group of the committee charged with coordinating natural heritage inventories recently approved a metadata profile and a minimum data model, in accordance with the European INSPIRE Directive, that must be followed in all regional inventories (MAGRAMA, 2013).

Some countries, such as Albania (Serjani, 2012), Bulgaria (Todorov & Nakov, 2012), Portugal (Brilha, 2005) and the Ukraine (Gritsenko et al., 2012), have recently adopted the methodology used in the Global Geosites project (Wimbledon, 1996; Wimbledon et al., 1999; Gonggrijp, 2000), which has been encouraged by ProGEO since 1990 and was supported by the IUGS. This involves a two-phase approach to identify sites of international relevance in each country. These sites should then be compared with those of nearby countries, and the most representative geosites on a global scale are selected. In the first phase, a series of geological frameworks are defined that can be applied to any regional geological element, tectonic, metallogenic or any other type of event, stratigraphic series, paleobiological association, etc., which is relevant on a global scale. Subsequently, in a second phase, the specific sites (geosites) that represent these geological frameworks are identified and illustrated. Once the national list has been compiled, frameworks and geosites from nearby countries are compared in order to establish a common list. The Portuguese inventory is a good example of this approach, where the original methodology has been adapted to the country's particular situation, obtaining very good results: based on a similar initiative adopted in Spain (García-Cortés et al., 2001; García-Cortés, 2008 and 2009), 14 geological frameworks of international relevance were identified in Portugal (Brilha et al., 2005). Unlike Spain (where only frameworks of international relevance were identified), 13 other geological frameworks of national relevance were also identified in Portugal (Brilha, 2010). Thus, the Global Geosites project methodology itself was used to identify sites of both international and national relevance, greatly facilitating the work of compiling a national geological heritage inventory. This approach can be particularly useful in large countries, such as Brazil, in which the definition of geological frameworks would be useful during the phase of identifying specific sites (De Lima et al., 2010). In these large countries, a systematic inventory would be too time consuming and take up too many resources, and even an advanced reconnaissance inventory could pose problems due to possible knowledge deficits in certain geological regions of the country.

To facilitate good management of geological sites, inventories must not only evaluate the interest, potential use, and susceptibility to degradation of the SGI, but must also include an appropriate delineation and mapping system, based on the characteristics of the sites to be inventoried and the objectives of the inventory. We should bear in mind that an inventory is a resource management and territorial planning tool that requires sites of geological interest to be both correctly located and accurately delineated. In a detailed inventory, the SGI, a surrounding protection zone, and one or more viewpoints must be accurately mapped.

## 5. METHODOLOGY USED IN THE SPANISH INVENTORY OF SGI (IELIG)

The following is a description of the IELIG methodology adopted following the review described in section 3. IELIG is the acronym for *Inventario Español de Lugares de Interés Geológico*, i.e., the Spanish Inventory of Sites of Geological Interest. Specifically, in the first version of the methodology (García-Cortés and Carcavilla, 2009), the method for estimating the value and priority of protection of SGI was established following a review of the studies published by the JNCC (1993), Cendrero (1996b), UKRIGS (2001), Villalobos (2004), Bruschi & Cendrero (2005) and De Wever et al. (2006), among others. In 2014, after completion of a pilot inventory project in the Iberian System to validate the methodology, some minor modifications were introduced and recently-published studies were reviewed, such as those of Mendía et al. (2010), De Lima et al. (2010), Bruschi et al. (2011), Jódar et al. (2012), Fassoulas et al. (2012) and Fuertes (2013), some of which contained SGI from IELIG. This allowed us to establish the final version of the IELIG methodology (García-Cortés et al., 2018) which we herein present in this section. It is important to note that this is not a mere methodological proposal, but one that has already been applied and tested in the inventory of several Spanish geological regions from both the Variscan cycle (Cantabrian Zone, Central-Iberian Zone), Alpine cycle (Iberian System, Prebetic System, and related sedimentary cover of the interior plateaus) or from post-orogenic regions (Tagus-La Mancha Basin). The compilation of these inventories has allowed us to validate the proposed methodology and also to improve it by making the required adjustments.

### 5.1. Inventory model

The IELIG is a systematic inventory (Sharples, 2002) based on classifying the geological setting to obtain the most representative sites of the Spanish geological diversity. The national territory was classified using genetic criteria (Gonggrijp, 2000) to inventory each of the geological domains defined in section 5.2. In addition to classifying the territory into geological regions, contributions from experts in different geological disciplines have given this inventory its systematic character.

The inventory also aims to present a universal compilation, that is, it intends to cover all geological disciplines. Therefore, SGI defined in the inventory are assigned a single primary type of geological interest and, if appropriate for their content, one or more of the secondary types of geological interest indicated in Table 9, and should be grouped according to the corresponding disciplines.

As can be seen, we have differentiated between (1) a site's mining-metallogenic interest, associated with mineralized geological formations or mineral deposits that have been or could be developed by the mining industry (excluding mining constructions and facilities, since these are not part of the natural heritage although they may constitute mining historical and industrial cultural heritage), and (2) its mineralogical interest, which is limited to type localities of mineral species, or mineral deposits, regardless of their economic or mining interest.

**Table 9.** Types of geological interest evaluated in the Spanish Inventory of SGI (IELIG), depending on different geological disciplines.

| |
|---|
| Stratigraphic |
| Sedimentological (includes palaeogeographic and palaeoclimatic) |
| Geomorphological (includes karst and geological hazards) |
| Paleontological |
| Tectonic |
| Petrological-geochemical (includes volcanic) |
| Mining-metallogenic |
| Mineralogical |
| Hydrogeological |
| Others (pedological, etc.) |

### 5.2. Scope of the inventory and establishment of study areas

The IELIG is, by definition, a nation-wide inventory that covers the entire Spanish territory. This does not mean, however, that it has been undertaken globally across Spain. Instead, it has been carried out in each Spanish geological domain in order to explain the geological evolution of these regions and their geological processes. These geological domains, which are used to classify the territory, are those defined in the IGME's continuous digital geological map of Spain (GEODE), and are listed in Table 10.

In compiling the IELIG, therefore, we relied on geological rather than administrative (regional or provincial) divisions. However, given their authority in environmental issues, the inventories previously undertaken and approved by the respective competent bodies in four Spanish regional governments (Catalonia, Andalusia, Basque Country and Aragon) have been acknowledged as official inventories, and as such have been directly incorporated in the IELIG. In 2019, Murcia officially announced the start of its regional inventory. In order to harmonize these different inventories, a single common metadata profile (MAGRAMA, 2013) and a minimum data model (MAPAMA, 2015) for inventories of SGI was prepared and approved by the Committee of the Spanish Inventory of Natural Heritage and Biodiversity (formed of representatives from both the central and the regional governments). Other regions, such as Castile-La Mancha and Galicia, have followed suit and reached agreements with IGME to undertake the inventory in their respective territory.

**Table 10**. Geological domains included in the IELIG, indicating the number of inventoried SGI (underlined), SGI in the process of being inventoried, or SGI to be inventoried in the future (italics).

| Geological domain | Code | Number of SGI planned or already inventoried | Geological domain | Code | Number of SGI planned or already inventoried |
|---|---|---|---|---|---|
| 1. Duero Basin-Almazán | DU | *129* | 2. Balearic Islands | BL | *89* |
| 3. Ebro Basin | EB | *129* | 4. Prebetic System and Sedimentary Cover of the Plateau | PT | <u>188</u> |
| 5. Guadalquivir Basin and Postorogenic Betic Basins | GR | <u>227</u> | 6. Sub-Betic | SB | *177* |
| 7. Guadiana Basin | GA | 32 | 8. Gibraltar | CG | <u>14</u> |
| 9. Tagus-Mancha Basin | TM | <u>168</u> | 10. Betic Internal Zones | BE | 138 |
| 11. Levantine Basins | LV | <u>32</u> | 12. Cantabrian Zone | CA | <u>134</u> |
| 13. Canary Islands | IC | *80* | 14. West Asturian-Leonese Zone | AL | <u>140</u> |
| 15. Iberian System | IB | <u>162</u> | 16. Galicia Tras-os-Montes Zone | GM | <u>111</u> |
| 17. Catalan Coastal Range | CT | <u>62</u> | 18. Central Iberian Zone | CI | <u>251</u> |
| 19. Pyrenees | PS | *189* | 20. Ossa-Morena Zone | OM | 113 |
| 21. Basque System and Basin | CV | *165* | 22. South Portuguese Zone | SP | <u>31</u> |
| **Total number of SGI planned or already inventoried** | | | | | **2,761** |

Because the identified SGI illustrate the evolution of the inventoried geological domain, these SGI will have, at least, a regional and possibly also a national or international, relevance. Local SGI, which are of little scientific value, have been excluded from the IELIG. The study of these particular sites should be reserved for inventories that are carried out at the local or municipal level, or for other detailed inventories such as those carried out in natural protected areas. However, as Elízaga and Palacio (1996) pointed out, the level of "national" relevance of a site will not be definitive until the entire Spanish national inventory has been completed, and its "international" relevance can be no more than a proposal until a European inventory, such as the Global Geosites project (Wimbledon, 1998), has been compiled. This is why such qualifiers are not used in the IELIG, and each SGI has been awarded a numerical score that denotes its value, as will be explained below.

### 5.3. First phase of the inventory. Identification of SGI

Once the geological domain to be inventoried has been selected, the work can be divided into two consecutive phases, which are summarized in Figure 2. The aim of the first phase is to select and identify the SGI to be included in the inventory. In the second phase, the selected SGI are described, delineated, evaluated and uploaded to the IELIG database.

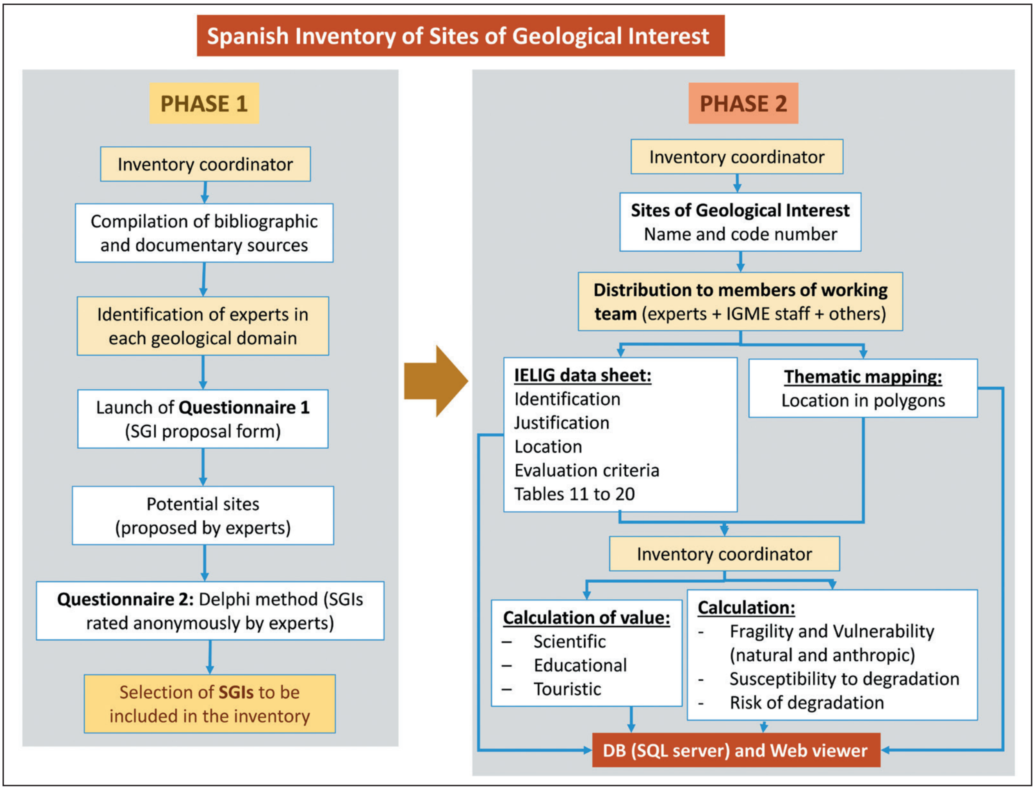


**Figure 2.** Outline of the IELIG methodology, structured in two phases: a preliminary phase for selecting and identifying SGI, and a second phase for describing, delineating and evaluating SGI.

### *5.3.1. Bibliographic and documentary compilation*

Once the geological domain for the SGI inventory has been selected, the first task faced by the working team is to review the bibliographic and documentary evidence. This review should focus on three fundamental themes:

- Information on the geological characteristics and geodynamic evolution of the area under study, published by experts in various different fields. This should include national or other more detailed geological maps that will raise awareness of the elements that should be represented in the IELIG, and guide the work of the team of scientists chosen to select these sites.
- The existence of earlier projects to inventory geological sites in the area. This will allow the working team to make use of any studies previously conducted in the area.

- Information on natural protected areas and other elements of interest, both natural and historical and/or cultural heritage, as well as their corresponding legal regulations. This will give the working team insight into the level of protection of the SGI included in the inventory, and the non-geological values that can enhance the recreational use of the inventoried elements.
- Guidebooks on scientific fieldtrips and conferences organised in the region, as well as other scientifically-rigorous guides on the surrounding nature or natural protected areas.

#### *5.3.2. Creation of the working group and appointment of experts*

As mentioned above, the IELIG is intended to be a universal multidisciplinary inventory. Given the complexity and variety involved in recording the geology of a particular region in terms of geochronology, and the geological disciplines and geographical space involved, the working group obviously needs to include several experts in various branches of geology who, together with the inventory coordinating team, will be in charge of selecting the most representative sites for each geological domain. The working group must include experts in all the disciplines corresponding to the different types of geological interests listed in Table 9 (Stratigraphy, Sedimentology, Geomorphology, Palaeontology, Structural Geology, Petrology and Geochemistry, Metallogeny, Mineralogy and Hydrogeology), depending on the corresponding geological domain.

The members of this panel of experts are selected by the coordinating team after analysing the bibliography referring to each geological region. Experts will be sent Questionnaire number 1 and invited to participate in the inventory project (Appendix I). Experts must have foresight and extensive knowledge of the subject consulted (Astigarraga, 2003), that is, they must be able to propose the most relevant geological sites based on their geological discipline and their relevant publications in the region being inventoried. Prior papers and publications of the entire team of experts must adequately cover all or most of the geological region considered.

According to the existing bibliography, the panel should consist of at least seven experts, since the likelihood of error decreases markedly for each expert added until reaching that number. In any event, most studies recommend forming a panel of around thirty experts (Norman et al., 1970). Given that nine specialties are required, and that seven experts are required per specialty, the panel should ideally consist of 63 experts. This is rarely possible due to unavailability of experts, but at least three of them should be appointed per specialty. Either way, the number of experts will not only depend on availability, but also on the extension and geodiversity of the geological region under study.

Each expert is expected to devote the equivalent of three and a half working days (which may include a small test trip lasting one and a half days), and therefore each expert will receive the equivalent of five sitting fees for tribunal members.

The working group will also include members of the IGME coordinating team and researchers who have worked in the geological inventory region.

### *5.3.3. Criteria for proposing a SGI*

A SGI must be proposed and selected using three different criteria (Cendrero, 1996):

- criteria related to its intrinsic value,
- criteria related to its potential use, and
- criteria related to the need for protection.

Table 11 presents and briefly describes the selection criteria that experts can or should consider when proposing an SGI.

From a scientific point of view, the intrinsic value criteria should be prioritised. However, other criteria, such as beauty, educational or outreach potential, accessibility or fragility, may add weight to a particular proposal. Although these criteria are more subjective, they should not be ignored, since though they are less important than intrinsic value, they will allow the working group to include sites with more capacity for public use (recreational or educational) than scientific value.

**Table 11.** Selection criteria for SGI.

| TYPE | SELECTION CRITERIA | DESCRIPTION |
|---|---|---|
| CRITERIA FOR INTRINSIC VALUE | Representativeness | Reports the site's capacity to adequately illustrate the characteristics of the region |
| | Type locality or reference | Provides information about the quality of the site as a stratigraphic, palaeontological, mineralogical reference, etc. |
| | Degree of scientific knowledge of the site | Indicates that the site's geological relevance and scientific interest make it the subject of scientific studies and publications |
| | State of conservation | Reports the existence of physical deterioration of the feature |
| | Visibility | Indicates the extent to which the surroundings facilitate the visibility of the feature |
| | Rarity | Reports the shortage of features similar to that described |
| | Geological diversity | Reports the existence of several different geological elements of interest in the same site |

| TYPE | SELECTION CRITERIA | DESCRIPTION |
|---|---|---|
| CRITERIA FOR INTRINSIC VALUE AND USAGE | Spectacularity or beauty | Reports the visual quality of the feature |
| | Outreach potential | Indicates whether the feature lends itself more or less easily to interpretation or is already used for this purpose |
| | Educational possibilities | Indicates whether the feature lends itself more or less easily to education or is already used for this purpose |
| | Potential for recreational activities | Reports whether the site fulfils the requirements for leisure or recreational activities, or if it is already used for this purpose. Also linked to the potential for use |
| CRITERIA FOR POTENTIAL USE | Logistic infrastructures | Reports on the existence of accommodation and restaurants |
| | Social and economic setting | Reports on the social and economic conditions of the region, which can show the potential of the site as a factor of local development |
| | Association with other elements of natural or cultural heritage | Reports whether the site also contains other elements of non-geological interest, which may attract a greater number of visitors |
| CRITERIA FOR POTENTIAL USE AND NEED FOR PROTECTION | Population density | Linked to the potential number of visitors on the one hand, and the greater likelihood of vandalism on the other. |
| | Accessibility | As above, linked to the potential number of visitors on the one hand, and the greater likelihood of vandalism on the other. |
| | Fragility | It indicates the site's susceptibility to degradation due to its intrinsic characteristics (lithology, nature, size) |
| | Proximity to recreational areas | Indicates the presence of recreational or touristic areas near the site. Linked to the potential number of visitors on the one hand, and the greater likelihood of vandalism on the other. |

#### *5.3.4. Launch of a preliminary round of consultations with the panel of experts and processing of the information received*

Delphi methodology is used to perform the preliminary selection of the SGI to be included in the inventory. The process is conducted in stages, as follows:

The project coordinators email the questionnaire shown in Appendix I to members of the panel of experts previously appointed. In this first phase, the experts are contacted and asked to confirm their participation in the project. The consultation procedure is explained, underlining the importance of anonymity as a means of preventing distortions caused by the "group process" (influence due to the leadership of some experts over others). If the experts contacted do not respond to the request for information before the established deadline, they may be replaced by other experts.

Section 1 of the questionnaire in Appendix I aims to assess the expert's geoconservation sensitivity (from a scientific, educational and touristic-recreational point of view) and assess its coherence (questions 3 and 5). Once all the questionnaires have been completed and returned, section 2 will enable project coordinators to draw up a list of possible geological sites of interest that will be analysed in the second round of consultations with the panel of experts. Finally, section 3, together with the expert's self-assessed degree of knowledge of block 2, aims to ascertain the expert's personal knowledge of the sites he or she proposes, and their relevance at the national and international level.

The first-stage questionnaire is always the most extensive, since it provides most of the information required. For this reason, it is essential that this questionnaire is correctly designed, since any information missing from a subject related to the general objectives of the inventory could invalidate the subsequent stages (Grande and Abascal, 2003).

After receiving the questionnaire, the experts complete it within the established period, which is usually two months. Once completed, it is returned to the coordinators, who, after compiling and analysing the responses, prepare a list of all the sites proposed, unifying the denominations and, where appropriate, grouping or splitting proposals. A summary description of the sites, their location, and the reasons why they have been proposed, should be added to the list.

### *5.3.5. Launch of the second round and information processing: identification of the SGI*

The aims of the second round are to:

– provide all participating experts with a list of the SGI proposed for the geological domain under study.
– consolidate the results obtained in the first round.
– obtain an ordered list of those sites most highly scored by the experts, which will allow them to select those SGI to be considered in successive phases of the project.

The procedure is as follows:

– Each expert is sent a data file with the answers to the non-personal questions included in the first questionnaire (list of sites, summary description and reasons for selection). The second questionnaire is included in Appendix II.
– The experts are asked to rate all the proposed sites they have personal knowledge of (with a score of 20, 15, 10, 5 or 0 points, according to Appendix II). Any sites they are not personally familiar with are rated “S” to avoid a score of 0 in these cases.
– The experts are also told that they can argue against the inclusion of certain sites proposed.

- Once the second round of questionnaires has been received, the lists of proposed sites is re-compiled and the statistical values of the scores are calculated.
- A final report is drawn up with the conclusions obtained and the selection of SGI, divided into three groups: one group formed of all sites scoring above a pre-established cut-off score (average scores greater than 5), which will become part of the definitive IELIG; a second group consisting of sites that have not obtained sufficient support (average scores below 5), and are therefore ruled out; and a third group of sites that, without having reached the cut-off score for inclusion in the IELIG, have not been ruled out, and are included in a list of local sites of interest. The highest scoring group is selected taking into consideration both the highest total score (representing SGI reasonably well scored by a large number of experts) and the highest average score (which includes SGI that, though not known by most experts, are very highly rated by the experts that do, provided these latter comprise 10% of the panel or at least 50% of the experts of the same specialty).

The deadline for completing the second survey is one month.

### *5.3.6. Validation of the results*

It is important to note that, once the preliminary selection or identification of SGI is complete, the inventory coordinating team, in the light of the regional knowledge of the inventoried region, must analyse the validity of the results based on a series of criteria. These include the adequate representation of all the evolution and geological record of the region, a balanced representation of the main lithological groups in the territory, and a proportionate representation of the different types of interest of the selected SGI. This analysis will reveal whether sites that could be representative of an important part of the geological record of the inventory region are missing, and as such is an essential validation process.

When such gaps are detected, the coordinating team will proceed to include in the group of selected SGI some sites of so-called local interest that maybe essential to complete the representativeness of the final list of SGI. These SGI, however, should not exceed 5% of the total amount of SGI selected by the panel of experts.

## 5.4. Second phase of the inventory. Description, delineation and evaluation of SGI

### *5.4.1. Study and description of the SGI. IELIG data sheets*

Once all the information from the second round of expert consultations has been received and processed, the working team will proceed to compile the bibliography and documentation specific to the selected SGIs. This information will not be limited to the site's geological characteristics, but will also include its situation in the urban planning of each municipality and the land ownership system, together with the demographic situation and logistic infrastructure of the surroundings. This will be complemented with information on the natural or cultural heritage, of natural protected areas, and other elements of interest already obtained in the initial phases of the inventory, as well as the legal regulations related to all these elements.

A field visit will be made to each SGI selected in order to complete the characterization and description of the site. These data will be collected in the data sheet included in Appendix V, which was designed following the previous Inventory of Geological Points of Interest of the IGME (Duque et al., 1979a and b; García-Cortés and Fernández-Gianotti, 2005), the Inventory of Hydrogeological Sites of Interest of Andalusia (Durán et al., 2008), the inventories compiled by the regional governments of Andalusia and Catalonia (Villalobos, 2004; Druguet et al., 2004; Herrero et al., 2004), as well as of France, Italy, the United Kingdom and Switzerland, and the *Global Geosites* Project of the IUGS (Wimbledon, 1996; Grandgirard and Berger, 1997; UKRIGS, 2001; De Wever et al. 2006; Bruschi, 2007).

Sections 1 to 11 of the fact sheet include the data considered important for identifying, using and monitoring the SGI, after comparing the information with that included in existing inventories. These data are complemented by the information needed to calculate the scientific, educational and touristic/recreational value of the SGIs, as well as their vulnerability, conservation status and degradation risk. Sections 12 to 20 of the fact sheet (which should be filled in, as appropriate, according to the nature of the SGI) describe in detail the igneous, metamorphic and sedimentary materials and formation processes, together with deformation or modelling processes, mineralogical or palaeontological deposits, and a section for museums.

All the information contained in the data sheet is uploaded to a database with unrestricted access (except for confidential information) on both the IGME website in the IELIG viewer (http://info.igme.es/ielig/) and on the Ministry for the Ecological Transition's Inventory of Natural Heritage and Biodiversity website, and the website of the Spatial Data Infrastructure of Spain (IDEE).

### *5.4.2. Criteria for evaluating SGIs*

According to Carcavilla et al. (2007), the evaluation of a SGI is based on three fundamental premises:

1) Not all geological elements have a heritage value,
2) not all outcrops or elements that do have heritage value are equally interesting, and
3) a series of parameters may be defined to calculate the level of geological interest of the site.

In the IELIG methodology, according to Cendrero (1996b), UKRIGS (2001), Villalobos (2004) and Bruschi & Cendrero (2005), the intrinsic or scientific value of the SGI and its potential for use are assessed separately, differentiating in the latter, as does Villalobos (2004), between the educational and touristic-recreational value. This will facilitate management of inventoried SGIs, since differentiating between the scientific, educational and recreational value makes it possible to obtain distinct groups of SGI, which are likely to overlap, with different potential use. The management of a SGI with the highest scores for scientific value should focus on conservation, while those with high educational or touristic scores should focus on facilitating this usage. Evaluating sites independently for their scientific, educational and recreational merits also prevents certain sites of great scientific interest from being excluded from the inventory because their lack of spectacularity or accessibility would have earned them low scores for touristic-recreational or educational interest. And conversely, it prevents the exclusion of sites of great touristic or educational interest from being excluded when their scientific value is particularly low.

Based on the previous experiences of the JNCC (1993), and those mentioned in the preceding paragraph, the following parameters have been used to evaluate the scientific value of the SGI: the representativeness of the site, the degree of scientific knowledge, its rarity, its state of conservation or integrity, its visibility, its locality-type or reference value, and the geological diversity that it contains. However, some parameters used by some of these authors, such as the surface area of the SGI, its age or association with cultural values, have not been included, since we consider the first two to be irrelevant from a scientific point of view, and the third is not an intrinsic parameter but instead is linked to its potential use.

In the IELIG, the touristic interest of the SGI is evaluated using the same parameters as the scientific value (except for the degree of scientific knowledge), with the addition of its educational potential and logistic infrastructures, the population density, accessibility, association with eco-cultural values, and its aesthetic value. The last six parameters, together with the visibility of the site, are taken into account to evaluate the touristic interest of the SGI, along with other parameters specific for this type of interest, such as the surface area, its outreach potential, its recreational potential, its proximity to recreational areas, and the social and economic level of the setting.

### *5.4.3. Calculation of the value and definitive selection of SGI*

Once all the information has been collected and the field work completed, the SGI selected in the preceding phase are evaluated. In the IELIG, this is done using a quantitative procedure involving numerical algorithms. It is important to emphasise that quantitative methods are not used to achieve greater accuracy, but to reduce subjectivity by establishing mechanisms to guarantee, or at least facilitate, the repeatability and reproducibility of the assessments. Each preselected site is scored according to the parameters described in section 5.3.3 and weighted using the coefficients shown in Table 12, in order to calculate their value for scientific, educational and touristic-recreational purposes. Each parameter receives a score from 0 to 4, according to the scales indicated in Appendix III.

**Table 12**. Summary of the weighting coefficients used for each parameter, depending on the type of value calculated (scientific, educational, and touristic or recreational). More details in Appendix III.

| Parameter / Value | Scientific | Educational | Touristic or recreational |
|---|---|---|---|
| | **weight** | **weight** | **weight** |
| Representativeness **(R)** | **30** | **5** | 0 |
| Degree of scientific knowledge of the site **(K)** | **15** | 0 | 0 |
| Rarity **(A)** | **15** | **5** | 0 |
| Type locality **(T)** | **10** | **5** | 0 |
| State of conservation **(C)** | **10** | **5** | 0 |
| Visibility **(O)** | **10** | **5** | **5** |
| Geological diversity **(D)** | **10** | **10** | 0 |
| Educational content/educational use **($C_{DD}$)** | 0 | **20** | 0 |
| Logistic infrastructures **($I_L$)** | 0 | **15** | **5** |
| Population density **($D_P$)** | 0 | **5** | **5** |
| Accessibility **($A_C$)** | 0 | **10** | **10** |
| SGI size (load capacity) **(E)** | 0 | **5** | **15** |
| Association with eco-cultural elements **(NH)** | 0 | **5** | **5** |
| Spectacularity or beauty **(B)** | 0 | **5** | **20** |
| Outreach content/ use **($C_{DV}$)** | 0 | 0 | **15** |
| Potential for activities **($P_{TR}$)** | 0 | 0 | **5** |
| Proximity to recreational areas **($Z_R$)** | 0 | 0 | **5** |
| Social and economic environment **($E_S$)** | 0 | 0 | **10** |
| **Total weights** | **100** | **100** | **100** |

According to the coefficients shown in Table 12, the scientific ($V_C$), educational ($V_D$) and touristic-recreational ($V_T$) values will be expressed by the following algorithms (divided by 40 to obtain a figure between 0 and 10):

$$V_C = 1/40 \times [30 \times R + 15 \times (K + A) + 10 \times (T + C + O + D)]$$

$$V_D = 1/40 \times [20 \times C_{DD} + 15 \times I_L + 10 \times (D + A_C) + 5 \times (R + A + T + C + O + D_P + E + NH + B)]$$

$$V_T = 1/40 \times [20 \times B + 15 \times (E + C_{DV}) + 10 \times (A_C + E_S) + 5 \times (O + I_L + D_P + NH + P_{TR} + Z_R)]$$

As can be seen, the parameters can be either intrinsic or linked to the site's potential use, and may or may not coincide in each category of use; however, if they coincide, they are affected by different weighting coefficients.

As a general rule, subject to specific reconsiderations, SGI obtaining scores over 6.65 points are considered extremely valuable, SGI obtaining a score between 3.33 and 6.65 points are highly valuable, and finally, SGI with scores less than 3.33 points are considered average value. The inclusion of any SGI with a score of less than 1.25 points would need to be reconsidered, although this has not so far been necessary.

The objective, as indicated above, is to obtain three groups of SGI arranged according to their value in each category of use (scientific, educational and touristic), in each geological domain, and even in each geological discipline. The total number of SGI selected in each geological domain will vary, but around 2,800 are expected to be included in the IELIG.

### *5.4.4. Assessment of vulnerability*

Once the scientific, educational and touristic value of the SGI has been evaluated, the site's vulnerability, susceptibility to degradation and, finally, risk of degradation must be assessed to determine whether protection should be prioritised. For this purpose, the parameters associated with the need for protection described by Cendrero (1996b), Bruschi & Cendrero (2005) and De Wever et al. (2006) have been used, with the addition of the concepts discussed in section 2 of this document, where fragility, vulnerability (natural, intrinsic and anthropic), and susceptibility to degradation (natural or anthropic) were defined, according to Carcavilla et al. (2017 and in press). These concepts should be correctly reported in the inventory, as they provide basic information to facilitate the management and conservation of SGI, since although fragility and natural threats cannot usually be mitigated, the identification and quantification of anthropic threats can guide protection measures.

Vulnerability due to natural causes, or natural vulnerability ($\mathbf{Vu}_N$), will depend on the intensity of the active geological processes affecting the SGI, and the biological processes (bioturbation) that can alter it. The more vulnerable the site, the more intense the deterioration caused by these geodynamic or biological processes. Therefore, natural vulnerability is expressed as:

$$\mathbf{Vu}_N = F \times A_N$$

where F is fragility, which will be greater the more alterable the lithology of the SGI, and $A_N$ is the natural threat to the SGI. Fragility and natural threats are assigned the values indicated in Table 13, so natural vulnerability $Vu_N$ is rated on a scale of 1 to 400.

**Table 13.** Points for fragility (F) and natural threats ($A_N$).

| **Fragility (F)** | **Value** |
|---|---|
| Very hard lithologies (quartzites or similar), with little fracturing and no weathering | 1 |
| Hard or very hard lithologies, but with extensive fracturing and/or weathering | 5 |
| Soft consolidated lithologies, with little fracturing and/or weathering | 10 |
| Unconsolidated lithologies, or consolidated but soft and heavily fractured and/or weathered lithologies | 20 |
| **Natural threats ($A_N$)** | |
| SGI not significantly affected by natural processes (geological or biological) | 1 |
| SGI affected by natural processes (geological or biological) of little relevance | 5 |
| SGI affected by natural processes (geological or biological) of moderate relevance | 10 |
| SGI affected by highly intense natural processes (geological or biological) | 20 |

Vulnerability due to anthropic threats or anthropic vulnerability (**$Vu_A$**) will be broken down into the following types, depending on the nature of anthropic pressure:

- Vulnerability of the SGI due to mining or water supply (**$Vu_M$**)
- Vulnerability of the SGI due to its interest for collectors and plounderers (**$Vu_{EX}$**).
- Vulnerability of the SGI due to its proximity to infrastructures (**$Vu_I$**), which is due to the proximity of the key elements of the SGI to towns, industrial estates or roads.
- General anthropic vulnerability (**$Vu_{AG}$**) of the SGI due simply to the influx of people who can voluntarily or involuntarily destroy or damage the SGI. This anthropic pressure is generally increased by ease of access, influx of visitors, and population density, and decreased by other factors, such as legal or physical protection, access regime, etc.

Unlike general anthropic pressure, pressure due to mining interest or the extent to which the site can attract plundering depend on the lithology of the SGI and its fossiliferous or mineralogical content, which, like fragility, are intrinsic qualities. However, due to human involvement, it is preferable to include these pressures under anthropic vulnerability. They should, moreover, be considered individually, because mining interest and attractiveness for pillagers and collectors depends less on factors such as population density, accessibility and proximity to roads, etc., which have been included under general anthropic pressure.

Based on the above, we can express **$Vu_A$** anthropic vulnerability as:

$$\mathbf{Vu_A = Vu_M + Vu_{EX} + Vu_I + Vu_{AG}}$$

This equation will be calculated using the parameters shown in Table 14. Some of these, such as accessibility or population density, have already been discussed above as parameters for calculating the value of the SGI. Here, however, they have a different purpose, and in some cases, such as the SGI size parameter, an opposite effect: the smaller the size of the

SGI, the lower its potential and value for recreational or touristic use, but the greater its vulnerability and, therefore, the need for protection.

**Table 14.** Parameters for evaluating vulnerability of SGI due to anthropogenic threats and weighting coefficients of each parameter. These are explained in more detail in Appendix IV.

| Parameter | | Description | Weight | Points |
|---|---|---|---|---|
| Mining or water supply interest **($Vu_M$)** | | Vulnerability of the site due to the interest it may have for mining exploitation or water supply | 25 | 0 to 4 |
| Vulnerability to pillage **($Vu_{EX}$)** | | Vulnerability of the site due to its palaeontological or mineralogical contents and its heritage value | 25 | 0 to 4 |
| Proximity to activities or infrastructure **($Vu_I$)** | | Vulnerability of key elements of the SGI to anthropic threats due to the proximity of infrastructure in general | 15 | 0 to 4 |
| **$Vu_{AG}$** | Accessibility **(Ac)** | Due to the fact that acts of vandalism or unintentional damage are more likely to occur in more easily accessible SGIs | 10 | 0 to 4 |
| | Protection measures **(P)** | Rates the need for measures to protect the site, depending on its location inside or outside a protected area | 5 | 0 to 4 |
| | Physical or indirect protection **($P_F$)** | Rates the physical difficulties of accessing the site | 5 | 0 to 4 |
| | Land ownership and access regime **($T_S$)** | Rates the access regime (free or restricted) and ownership of the site (private or public) | 5 | 0 to 4 |
| | Population density **($D_P$)** | Due to the fact that population density increases the likelihood of vandalism or unintentional damage | 5 | 0 to 4 |
| | Proximity to recreational areas **($Z_R$)** | Indicates the presence of recreational or tourist areas near the site. Linked to the need for protection (greater likelihood of acts of vandalism) | 5 | 0 to 4 |
| | | | **100** | |

According to Table 14, **$Vu_A$** anthropic vulnerability is calculated using the following formula, and rated on a scale of 0 to 400.

$$\mathbf{Vu_A = [25 \times (Vu_M + Vu_{EX}) + 15 \times Vu_I + 10 \times Ac + 5 \times (P + P_F + T_S + D_P + Z_R)]}$$

Unlike natural vulnerability, anthropic vulnerability is less dependent on the fragility or alteration of the lithology of the SGI (if necessary, there are more than enough resources to excavate harder rocks), so these parameters are not included in the equation.

### 5.4.5. *Susceptibility to degradation*

The susceptibility of the SGI to degradation, $\mathbf{S_D}$, will depend on its vulnerability, and this, in principle, will be lower the larger the SGI, since the potential for damage can be limited to part of its surface. Therefore, the following equation is used:

$$\mathbf{S_D = Vu \times E_F}$$

Where **Vu** is vulnerability and $\mathbf{E_F}$ is a factor inversely proportional to the size of the SGI. This, however, is open to interpretation, because in the case of stratigraphic cross sections, for example, the deterioration of a part of the site (the so-called critical areas) renders the SGI valueless as a stratigraphic column. These circumstances must be taken into account when quantifying the size factor, which applies not only to the SGI, but also to its features of interest.

The SGI susceptibility to degradation due to both natural causes ($\mathbf{S_{DN}}$) and anthropic causes ($\mathbf{S_{DA}}$) must be considered and calculated using the following equation:

$$\mathbf{S_{DN} = E_F \times Vu_N}$$

$$\mathbf{S_{DA} = E_F \times Vu_A}$$

Table 15 shows the values of the size factor ($E_F$) used in the IELIG, which, as mentioned above, will be smaller the larger the size of the SGI. Since the value of a SGI is rated on a scale of 0 to 10, the results of the $\mathbf{S_D}$ equation will be within the same range. For this reason, the size factor is awarded the point scheme shown in the table, so that multiplying them by the vulnerability score gives a score of between 0 and 10. This parameter is explained in more detail in Appendix IV.

**Table 15.** Points for size factor ($E_F$).

| SGI Size Factor ($E_F$) | |
|---|---|
| Metric features (vulnerable due merely to visits, such as speleothems, poorly consolidated geological structures, etc.). | 10/400 |
| Decametric features (not vulnerable due merely to visits but sensitive to more aggressive anthropic activities, such as stratigraphic sections, etc.) | 6/400 |
| Hectometric features (may suffer some damage due to human activities) | 3/400 |
| Kilometric features (hardly damageable by human activities) | 1/400 |

It is important to note that the parameters related to anthropic threats and, to a lesser extent, threats due to natural causes may evolve over time, so it would be advisable to update them periodically. Updating the inventory every ten years, as described in section 7.1, will facilitate the incorporation of new SGI in the inventory, but it is insufficient to monitor the conservation status of sites that have already been inventoried or the aforementioned parameters related to anthropic threats. Under Act 42/2007, however, these factors must be monitored and included in the Report on the State of Conservation of Natural Heritage and Biodiversity. For this reason, the $\mathbf{S_{DN}}$ and $\mathbf{S_{DA}}$ scores can be used to prioritise monitoring of the conservation status of these sites, thus ensuring that the few resources available are allocated correctly,

### *5.4.6. Risk of degradation*

Once the SGI's **V** and $\mathbf{S_D}$ (susceptibility to degradation) scores have been obtained, its **risk of degradation ($\mathbf{R_D}$)** can be calculated. Since the objective of every manager must be to minimise degradation of the site and its consequences, the risk of degradation is indicative of the need to protect the site and the level of protection required, and is probably the best indicator for prioritizing conservation measures. The risk of degradation, as defined in section 2, is calculated using the following equation:

$$\mathbf{R_D = V \times S_D}$$

which is divided by 10 to obtain a number from 0 to 10, and where **V** is the value of the site and $\mathbf{S_D}$ its susceptibility to degradation. Now, every SGI has a scientific ($\mathbf{V_C}$), educational ($\mathbf{V_D}$) and touristic ($\mathbf{V_T}$) value, and its susceptibility to degradation can be natural ($\mathbf{S_{DN}}$) or anthropic ($\mathbf{S_{DA}}$). It may be interesting to ascertain the risk of degradation of a SGI's scientific ($\mathbf{R_{DC}}$), educational ($\mathbf{R_{DD}}$) and touristic ($\mathbf{R_{DT}}$) value, but the IELIG takes the risk of degradation of a SGI ($\mathbf{R_D}$) to be the greatest, not the mean, of these three factors.

Before implementing geoconservation measures, site managers will need to know to what extent this risk of degradation is due to anthropic or natural causes, and in the latter case, whether or not the intrinsic vulnerability of the site determines its degradation. As discussed above, intrinsic vulnerability occurs when the same active geological processes that characterise or have created the site are responsible for the changes or damage occurring to the site. In these cases, there is little justification for implementing geoconservation measures to mitigate this deterioration. Therefore, it is useful to ascertain not only the risk of global degradation $\mathbf{R_D}$, but also the risk of degradation due to natural $\mathbf{R_{DN}}$ and anthropic $\mathbf{R_{DA}}$ causes:

$$\left.\begin{aligned} \mathbf{R_{DNC}} &= \mathbf{V_C \times S_{DN}} \\ \mathbf{R_{DND}} &= \mathbf{V_D \times S_{DN}} \\ \mathbf{R_{DNT}} &= \mathbf{V_T \times S_{DN}} \end{aligned}\right\} \qquad \mathbf{R_{DN}} = \text{MAX}\,(\mathbf{R_{DNC}, R_{DND}, R_{DNT}})$$

$$\left.\begin{aligned} \mathbf{R_{DAC}} &= \mathbf{V_C \times S_{DA}} \\ \mathbf{R_{DAD}} &= \mathbf{V_D \times S_{DA}} \\ \mathbf{R_{DAT}} &= \mathbf{V_T \times S_{DA}} \end{aligned}\right\} \qquad \mathbf{R_{DA}} = \text{MAX}\,(\mathbf{R_{DAC}, R_{DAD}, R_{DAT}})$$

In this way, the results of the inventory can help the competent government bodies to prioritise protection measures for certain sites. These protection measures may be based on natural heritage laws, urban planning regulations (in both cases for all types of geological heritage elements), or on regulations for protecting cultural assets, in the case of SGI with palaeontological interest. However, not all SGI need to be protected legally, and the competent authorities must take steps to rapidly study SGI that merit priority protection and implement the most appropriate conservation measures. In addition to, or instead of, giving the site special conservation status, these may consist of drainage works to prevent the erosion of a slope with elements of interest, changes in planning, modification of a restoration program, removal of vegetation or waste, or any other measure deemed relevant within the corresponding legal framework.

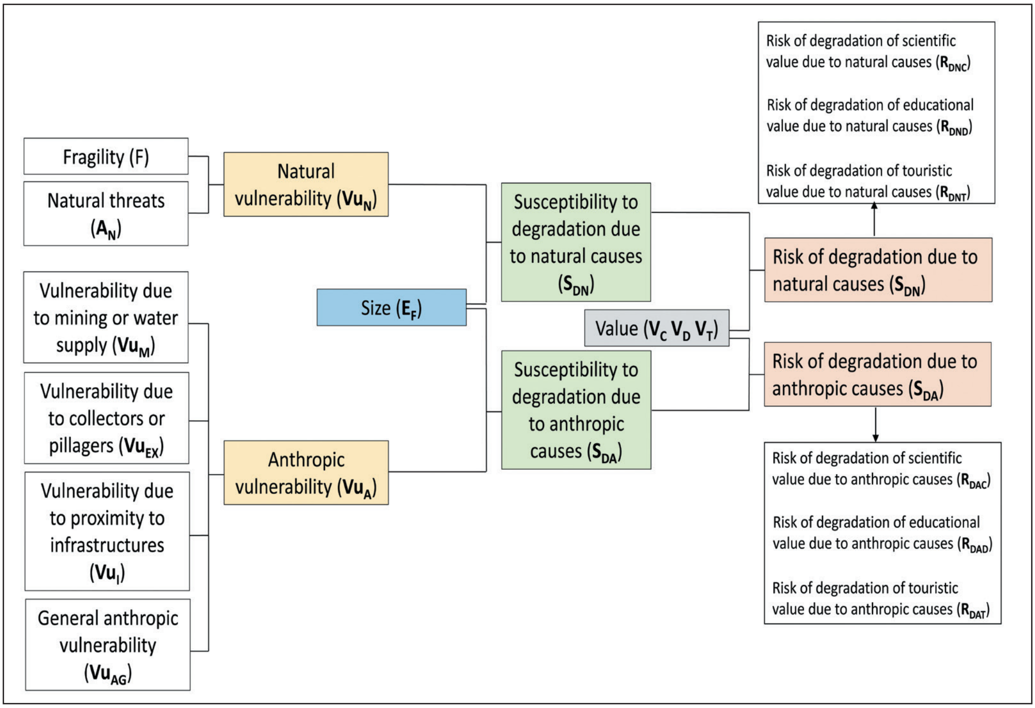


**Figure 3.** Outline of the IELIG methodology for calculating risk of degradation (**$R_D$**).

### *5.4.7. Levels of Susceptibility and Risk of Degradation*

Based on the experience so far accumulated with the IELIG, the cut-off thresholds shown in Table 16 have been used to define different levels of susceptibility and risk of degradation.

**Table 16.** Cut-off thresholds defining Low, Medium, High and Very High levels of Susceptibility and Risk of Degradation in SGI.

| | **Susceptibility to degradation** | **Risk of degradation** |
|---|---|---|
| **Levels** | **Cut-off threshold** | **Cut-off threshold** |
| High/very high | **3.5** | **2.5** |
| Medium/High | **1.5** | **1** |
| Low/Medium | **0.75** | **0.5** |

Since the risk of degradation is the best indicator of the need to protect an SGI, as a general rule, subject to timely re-evaluations, SGI with a $R_{DA}$ greater than 2.5 should receive urgent protection measures (very high risk of degradation), those with an $R_{DA}$ of between 1 and 2.5 should receive short-term protection measures (high risk of degradation), and those with an $R_{DA}$ of between 0.5 and 1 may, at the discretion of site manager, receive long-term protection measures (medium risk of degradation) or be left unprotected. SGI with a lower $R_{DA}$ (low or non-significant risk of degradation) would not, in principle, need specific protection measures. This same criterion can be followed for the risk of degradation due to natural causes ($R_{DN}$), although in this case site managers must consider whether measures are worth taking, particularly in the case of a site with high intrinsic vulnerability, as discussed above.

### *5.4.8. Naming and mapping of geological sites*

The naming of SGIs included in the different inventories compiled in Spain has so far been highly heterogeneous: names were chosen at the discretion of the author proposing the SGI, without regard for rules or standards. As a result, in many cases the names of the SGI reveals little about its interest value and basic characteristics. For this reason, the IELIG uses a unified nomenclature system consisting of a name formed of three terms that include: (1) the age of the feature (period), (2) a description of the site's primary type of geological interest, and (3) the geographical reference (Vegas et al., 2011). This system must be flexible, and exceptions can be made when the rules would create excessively long or cumbersome names. In fact, in the case of Quaternary geomorphological elements, the age parameter is usually left out as evident (e.g., Cascada de la Cola de Caballo [Pony Tail Waterfall]).

Similarly, each SGI should be identified by a code, and a 6-digit system has been developed for this purpose. The first two digits correspond to the acronym of the geological region, as shown in Table 10. The following three digits are correlative, from 001 to 999, and identify each of the inventoried SGIs, and finally, a sixth alphabetic digit (b, c, d…) is included when more than one outcrop must be identified for a particular SGI because the uniqueness of the formation merits an independent description. An example is the SGI IB034 Icnitas de dinosaurio del Weald de Cameros (Soria) [Early Cretaceous dinosaur footprints of Cameros], which has ten main outcrops. When these outcrops do not present significant differences and are all described under a single code, no sixth digit is required.

Local SGI, that is, those that have been excluded from the selection process, are coded with another six digits: the first two correspond to the acronym of the geological region, as shown in Table 10, the second is a lower case "s" (indicative of the secondary importance of the site), and the last three digits are correlative, from 001 to 999, to identify each site.

Another essential element for ensuring the protection of the SGI under the Spanish Natural Heritage Act is an accurate description of its location and demarcation. In the IELIG, SGI are delineated according to their surface area, in accordance with the minimum criteria shown in Table 17.

**Table 17.** Relationship between SGI surface area, mapping medium, scale and map accuracy.

| SGI SURFACE AREA | MEDIUM | SCALE | ACCURACY |
|---|---|---|---|
| ≤ 0.5 $km^2$ | Orthophoto | 1:5,000 | 2.5 m |
| 0.5 $km^2$ < S ≤ 10 $km^2$ | Topographic map | 1:25,000 | 12.5 m |

Experience with IGME projects has shown the importance of including the most advantageous observation viewpoints in these maps (Lozano et al., 2011). These are chosen by the experts conducting the study as the best viewpoints for observing the characteristics of the SGI. These viewpoints are the ideal site for placing explanatory panels, and for stopping to view and photograph the feature, and as such help in the management of the SGI. The coordinates of the best viewpoints are also included in the SGI data sheets.

## 5.5. Validation of the methodology in a pilot geological region

Before finalising this methodology, it was necessary to validate it in a pilot geological region. For this purpose, an inventory of the Geological Sites of the Iberian System was compiled between 2009 and 2011, and the Enguídanos Geological Heritage Inventory (Cuenca) was compiled to adapt the IELIG methodology at the municipal (township) level. The results of these pilot projects allowed us to make some corrections and modifications to the methodology published in 2009. The Iberian System was chosen for several reasons. Firstly, it spans five regional administrations (Aragon, Castile-La Mancha, Castile and León, Valencia, and La Rioja), and was therefore useful to test the IELIG's capacity to coordinate and work together with regional environmental agencies. The response at this level was mixed: technicians from some regional councils participated actively in the projects, while others were almost totally uninterested. Secondly, the Iberian System has the advantage of relative proximity to Madrid, which facilitated the displacement of IGME personnel. Finally, the region has already been extensively studied by researchers from various universities (University of Zaragoza, Complutense University of Madrid, Technical University of Madrid, University of Alcalá de Henares, University of Valencia, etc.) and by IGME personnel. Corrections and modifications have been made to the formulas used to calculate the value of SGI, their susceptibility to degradation and risk of degradation, and also to the data files, but overall the methodology was shown to be both practical and effective. In García-Cortés et al. (2014) the report of the IELIG pilot project for the Iberian System can be consulted.

# 6. IELIG DATABASE

## 6.1. Introduction

This section presents the general characteristics of the institutional database of the Geological Survey of Spain (IGME) that has been used to compile the Spanish Inventory of Sites of Geological Interest (IELIG), one of the components of the Spanish Natural Heritage Inventory, pursuant to the provisions of Act 42/2007, of December 13, on Natural Heritage and Biodiversity.

The Relational Database Management System used to store and manage the database is Microsoft SQL Server.

As of June 30, 2019, the database includes information on 3,852 SGI, including 904 local SGI that, strictly speaking, are not part of the Inventory. The database is intended to cover the entire country. Currently, it covers approximately 80%. It is updated by means of bulk uploads or Access forms, though not on a regular basis.

The database stores the delineation of the SGI. The location of SGI are stored in the database according to type: points (LOC_PNT table) and polygons (LOC_POL table) in the EPSG reference system: 4326 (WGS84).

There is also a LOCATION table where the planar coordinates of the centroid of the SGI are stored. Depending on the area, coordinates can be stored in Universal Transverse Mercator (UTM) and in the ETRS89 or REGCAN datum and corresponding zone.

## 6.2. Overall structure of the database

The database organizes the information in 230 tables. The main table is called identification. It contains basic information including, among other things, the SGI, such as its code, name, its Global Geosite code (as applicable), its confidentiality code (if it is not open to the public), or whether it is shown on the Website. The other tables are embedded in this table. Some of the tables use the SGI code as their primary key (for example, the table containing the data that identify the SGI or its interest), but there are also dictionary tables or controlled lists that have been created to complement the foregoing table and are intended to improve referential consistency and fast information retrieval.

In addition to the detailed thematic information on the main interest of the SGI and, where appropriate, secondary information, the database contains information for identifying and locating the SGI, physiographic information, the geological status of the site, and other information necessary for evaluating the state of conservation, degree of scientific knowledge, representativeness, rarity, geological diversity, spectacularity, use and monitoring, protection, degradation and available equipment, etc.

In addition to the basic information, a number of photographs, maps, documents, etc. are linked to the database (with file path). The files are stored on an IGME server called INFOSERVIDOR using the following folder structure path: /<zone>/<SGIcode>/<type>/<file>

Given the number of different tables and links, Figure 4 provides a simplified overview of the structure in the database.

### 6.3. IELIG viewer and WMS services

The IGME has created a web viewer to display the information in the database on any device. Figure 5 shows the homepage of the application.

The application for searching the Inventory of Geological Sites of Interest is a *mashup* (uses APIs supplied by different providers, Leaflet, ASPX, JQuery, CSS3 and Bootstrap). It allows the user to select different base maps from different sources, such as OpenStreetMap, IGN, ESRI and PNOA and works on any device and web browser.

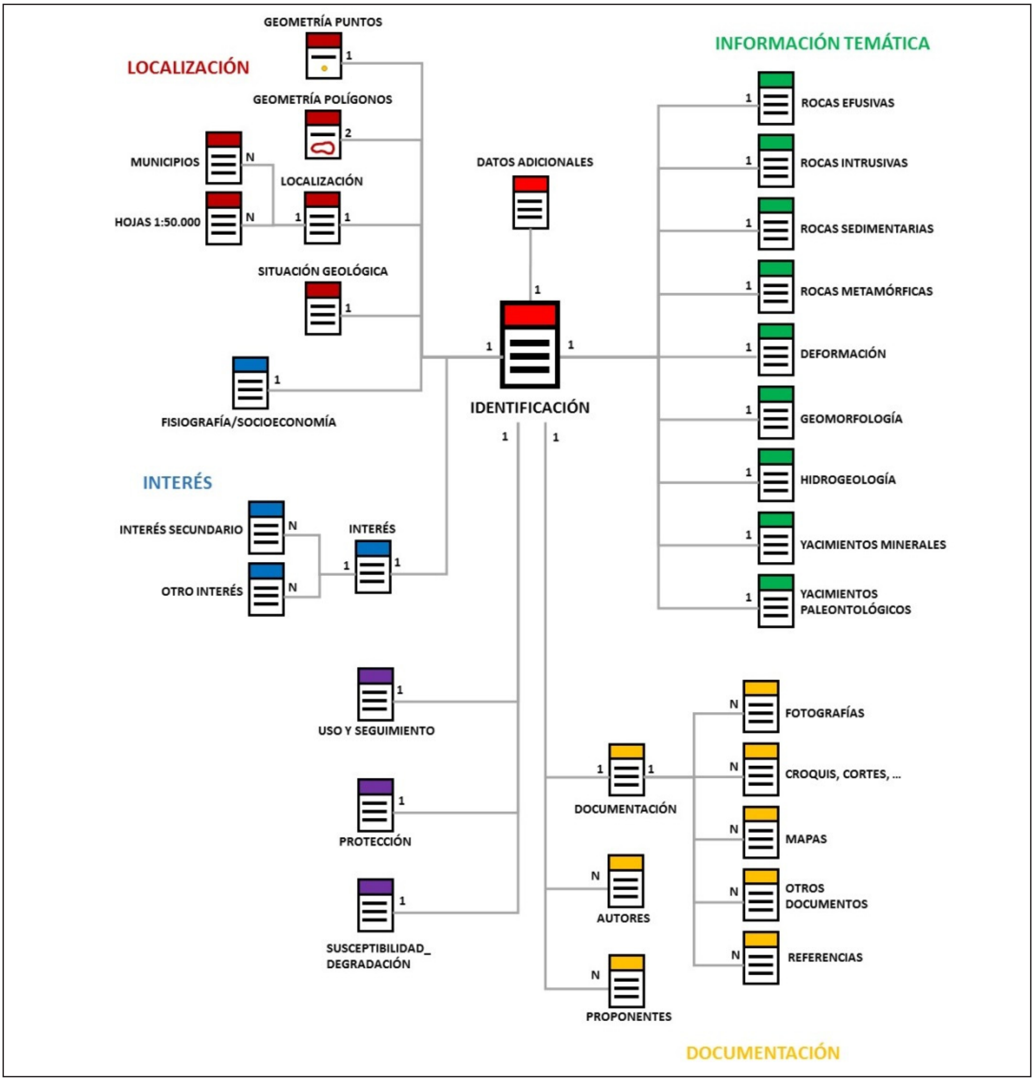


**Figure 4.** Simplified structure of the IELIG database.

The architecture is based on three layers:

- data (the database, with its tables, links, restrictions, views and stored procedures, and the files with the attached information),
- services (that facilitate the exchange of information between the user interface and the data layer. A map service is used to show the SGI, and a WCF service is used for alphanumeric queries)
- presentation (interface that allows users to search for and view information).

The map services include a WMS service, the OGC standard that allows any user to view, search and download reports of the SGI contained in the database. The access URL to the WMS service is: http://mapas.igme.es/gis/services/BasesDatos/IGME_IELIG/MapServer/WMSServer

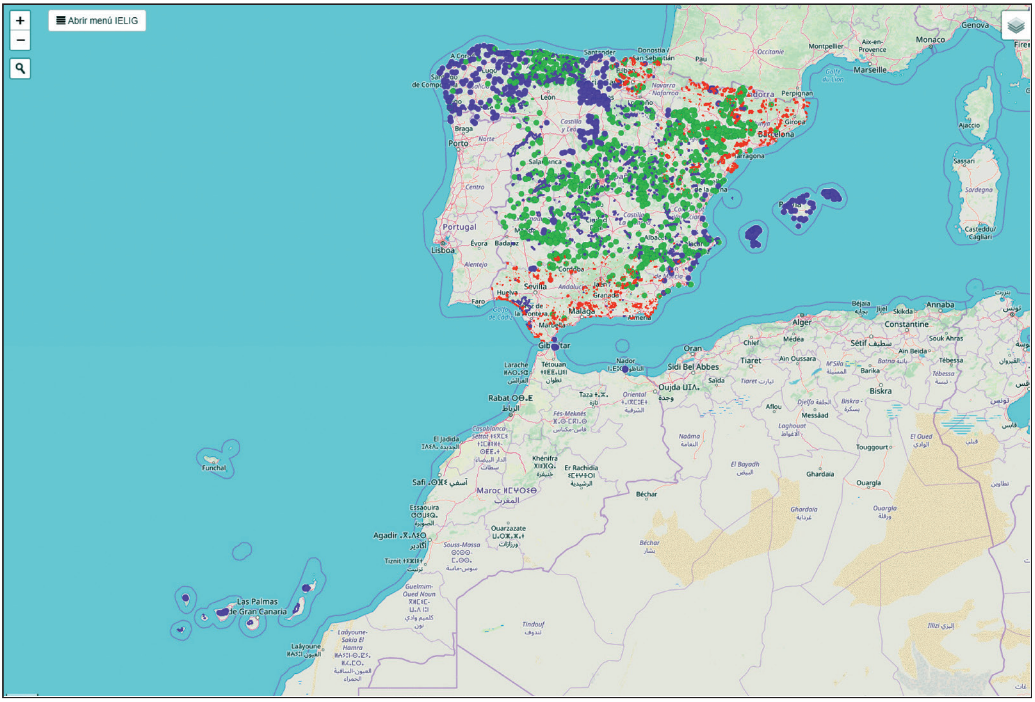


**Figure 5:** Homepage of the IELIG information access web viewer.

## 7. PLANNING

### 7.1. Update of the Spanish Inventory of Geological Sites of Interest (IELIG)

The IELIG database is not a complete, definitive compilation, but is open to the addition of new SGI in the future. There are two mechanisms for updating the inventory. The first of these is a continuous update mechanism by which any individual or institution can submit specific proposals for new SGIs to the department of Geological and Mining Heritage, which is in charge of coordinating the IELIG. These proposals will be submitted on a form that can be downloaded from the IGME web site. Once completed by any expert, the form is sent to the email address indicated. The coordinating team will apply the IELIG methodology for evaluating SGI, and on this basis will either accept or reject the proposal. In the latter case, the sender will receive due justification for the decision. If the proposal is accepted, however, inclusion of the SGI in the inventory does not imply its validation; instead, it will remain in a status similar to that of SGI of local interest until it is definitively included in the inventory as a result of the second mechanism described herewith.

The second update mechanism is performed at an institutional level, and consists of re-evaluating all the geological regions studied to obtain the new SGIs in each region, using the methodology described in section 5. This makes it possible to remove SGIs previously included in the IELIG, and to incorporate new SGIs that have come to light since the inventory was compiled. This second update mechanism should be performed every 10 years, in accordance with Royal Decree 556/2011, of April 20, for the development of the Spanish Inventory of Natural Heritage and Biodiversity.

### 7.2. Complementary projects

As indicated in chapter 5.9., the conservation status of inventoried SGI must be monitored using appropriate indicators that can be applied to SGI, at least to those with the greatest risk of degradation. A simple system of indicators that can be incorporated in the IELIG data model is currently being used for this purpose.

A very useful initiative to monitor the conservation status of inventoried SGI is the Sponsor a Rock program (Vegas et al., 2018), launched by IGME at the end of 2017, and accessed from http://www.igme.es/patrimonio/ApadrinaUnaRoca.htm. This project invites individuals to sponsor, free of charge, inventoried SGI. Sponsors voluntarily undertake to report, at least once a year, on the conservation status and conditions of observation of their SGI, and alert IGME of any incidents or activities undertaken in the physical surroundings of the SGI that could threaten its integrity. The initiative is based on the figure of the Inventory Volunteer provided in Royal Decree 556/2011, of April 20, for the development of the Spanish Inventory of Natural Heritage and Biodiversity.

Another interesting project involves identifying large areas that are unique because of their high geological diversity, and can be classified as parks (defined in art. 30.1 of Act 42/2007 as *natural areas, which, due to their beauty, the representativeness of their ecosystems, the uniqueness of their flora, fauna or geological diversity, including their geomorphological* *formations, have ecological, aesthetic, educational and scientific values that merit preferential conservation measures*) and/or geoparks. For this purpose, the maps and databases of the SGI and other geo-thematic maps will be managed using the tools and criteria defined below. This will allow these areas of high geodiversity, which might include a number of related SGI, to be identified and mapped.

## 8. CONCLUSIONS

In 2007, nearly thirty years after the first geological heritage inventory was started in Spain, the Natural Heritage and Biodiversity Act was passed, calling for the compilation of the Spanish Inventory of Sites of Geological Interest (IELIG) to be included in the Spanish Inventory of Natural Heritage and Biodiversity. As a result, IGME has updated the methodology used to compile the 1978 inventory by reviewing both the Spanish and international bibliography on the subject. The project was completed in 2009 and published on IGME's website, and was accordingly included in Royal Decrees RD 556/2011 for the development of the Spanish Inventory of Natural Heritage and Biodiversity, and RD 1274/2011, which entrusted the Geological Survey of Spain (IGME) with the completion of the IELIG.

The IELIG is in practice a systematic inventory, since Spain is classified, according to its geotectonic evolution, into 22 different geological domains. Within each domain, SGI are identified by groups of experts in each of the 10 geological disciplines contemplated in the methodology.

Once selected, the SGI are evaluated to quantitatively determine their scientific, educational, and touristic-recreational value. The evaluation also determines the fragility, vulnerability, both anthropic and natural, susceptibility to degradation and risk of degradation of each SGI in order to establish priorities for the protection of the geological heritage of each geological domain.

The quantitative evaluation system developed for the IELIG is not designed to obtain exact values for each parameter, but rather to reduce subjectivity, increase the repeatability and reproducibility of the results, and thus obtain different rating ranges that will facilitate the comparison of SGI in all the geological domains inventoried.

This methodology was tested in a pilot project to compile a geoheritage inventory for the Iberian System. This region was chosen because it spans five regional administrations, and was therefore ideal for testing the extent to which the regional authorities would be able to coordinate and collaborate with the inventory. In addition, it is relatively close to Madrid, and has already been extensively studied by researchers from various universities and by the IGME itself. The results of the pilot project showed the need for minor changes in the methodology, following which it was finally adopted in 2014, and work was started on compiling the Spanish Inventory of Sites of Geological Interest in the Cantabrian Zone, Central-Iberian Zone, the Iberian and Prebetic systems, the Sedimentary Cover of the Plateau and the Tagus-La Mancha Basin. The inventories for the Galicia-Tras-os-Montes Zone, the West Asturian Leonese Zone and the Duero Basin have recently been started.

The results obtained after implementing the methodology in 58% of Spanish territory (about 294,000 km$^2$) has shown that the system is no longer a proposal, but a proven and robust methodology. The project, coordinated by IGME, has been enriched by contributions from the official inventories compiled to date (Catalonia, Andalusia, Basque Country, Aragon and Murcia). The Committee of the Spanish Inventory of Natural Heritage and Biodiversity approved a common metadata profile and a minimum data model that allows these different inventories to be integrated into the Spanish Inventory of Sites of Geological Interest. This contribution has widened the scope of the IELIG to 80% of Spain.

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## REFERENCES

Águeda J, Elízaga E, González-Lastra JA, Palacio J, Sánchez de la Torre L, Suárez de Centi C & Valenzuela M (1985) Puntos de Interés Geológico de Asturias. Volumen I. Ministerio de Industria y Energía. IGME, Madrid. 132 p.

Aguirre E, Goy A, Comas-Rengifo MJ, Hernán Sanz J & Morales J (1974) Informe sobre conservación de sitios de interés geológico y paleontológico en la Región Central. Base para el Plan Especial de Protección del Medio Físico de la Provincia de Madrid. Informe para COPLACO, 83 pp. Madrid (inéd).

Alcalá L & Morales J (1991) The paleontological heritage of the Community of Madrid. Mém. Soc. Géol. Fr. Nouvelle Série, 165. 13-16. Paris.

Arana R, Rodríguez-Estrella T, Mancheño MA, Guillén F, Ortiz R, Fernández Tapia T & Del Ramo A (1999) El Patrimonio Geológico de la Región de Murcia. Fundación Séneca, Murcia. 399 p.

Astigarraga E (2003) El método Delphi. Documento en línea: https://s3.amazonaws.com/academia.edu.documents/50762750/Metodo_delphi.pdf?AWSAccessKeyId=AKIAI-

WOWYYGZ2Y53UL3A&Expires=1532007536&Signature=Q8LDVT3LOyRFGS3T-boBY%2FoUJYV8%3D&response-content-disposition=inline%3B%20filename%-3DEl_Metodo_Delphi._Universidad_de_Deusto.pdf

Barba FJ, Remondo J & Rivas V (1997) Propuesta de un procedimiento para armonizar la valoración de elementos del patrimonio geológico. Zubía 15, 11-20. Logroño.

Bartolomé C, Álvarez Jiménez J, Vaquero J, Costa M, Casermeiro MA, Giraldo J & Zamora J (2005) Los tipos de hábitat de interés comunitario de España. Ministerio de Medio Ambiente. Dirección General para la Biodiversidad. 281 p.

Bertacchini M, Coltellacci MM, Coratza P, Malmusi S, Piacente S & Poli G (2003) Censimento dei Geositi in Emilia-Romagna. In Piacente S & Poli G (eds) La Memoria della Terra, la Terra della Memoria. Collana Naturalistica del Servizio Parchi e Risorse Forestali. 41-48. Regione Emilia Romagna – Universita degli Studi di Modena e Reggio Emilia. L'Inchiostroblu Editore.

Bertacchini M, Betelli G, Bonazzi U, Capedri S, Capitani M, Castaldini D, Conti S, Corradini D, Fioroni C, Fontana D, Fregni P, Gasperi G, Giusti C, Lugli S, Marchetti M, Panini F, Panizz M, Pellegrini M, Piacente S, Rossi A, Soldati M & Tosatti G (1999) I Beni Geologici della Provincia di Modena. Universita degli Studi di Modena e Reggio Emilia e Provincia di Modena. Asesorato Difensa di suolo e Tutela dell'Ambiente. Artiole Editore.

Bolner-Takàcs K, Cserny T & Horwath G (2012) Hungary. In Wimbledon, W.A.P. and Smith-Meyer, S. (Eds.) Geoheritage in Europe and its conservation. ProGEO. Oslo, 158-169.

Bonachea J, Bruschi VM, Remondo J, González-Díez A, Salas L, Bertens J, Cendrero A, Otero C, Giusti C, Fabbri A, González-Lastra JR & Aramburu JM (2005) An approach for the incorporation of geomorphologic factors into EIA of transportation infrastructures; a case study in northern Spain. Elsevier, Geomorphology, 66, 95-117.

Bostick VB, Niles WE, McClellan WA, Oakes EH & Wilbanks JR (1975) Inventory of Natural Landmarks of the Great Basin. Complied for the Natural Park Service, United States Department of the Interior. 686 p y apéndice. The University of Nevada. Las Vegas.

Brancucci G & Burlanco M (2001) La salvaguardia del patrimonio geologico. Scelta strategica per il territorio. L'esperienza della Liguria. 96 p. Franco-Angeli. Milano.

Brilha J (2010) Geoconservation in Portugal. An updated perspective about geosites inventory, legal setting, conservation and educational issues. Geoevents. Geological Heritage and the role of the IGCP. Caravaca de la Cruz. 18-24.

Brilha J, Andrade C, Azevedo A, Barriga FJAS, Cachao M, Couto H, Cunha PP, Crispim JA, Dantas P, Duarte LV, Freitas MC, Granja HM, Henriques MH, Henriques P, Lopes L, Madeira J, Matos JMX, Noronha F, Pais J, Piçarra J, Ramalho MM, Relvas JMRS, Ribeiro A, Santos A, Santos VF, Terrinha P (2005) Definition of the Portuguese frameworks with international relevance as an input for the European geological heritage characterisation. Episodes 28(3):177–186.

Bruschi VM (2007) Desarrollo de una metodología para la caracterización, evaluación y gestión de los recursos de la geodiversidad. 355 p. Tesis Doctoral. Universidad de Cantabria. Santander.

Bruschi VM & Cendrero A (2005) Geosite evaluation; can we measure intangible values? Il Quaternario 18, 1. Italian Journal of Quaternary Sciences, 293-306.

Bruschi VM, Cendrero A & Cuesta Albertos JA (2011) A Statistical Approach to the Validation and Optimisation of Geoheritage Assessment Procedures. Geoheritage 2011. 3:131–149.

Carcavilla L, López-Martínez J, Durán JJ (2007) Patrimonio geológico y geodiversidad: investigación, conservación, gestión y relación con los espacios naturales protegidos. Instituto Geológico y Minero de España, Madrid.

Carcavilla L, García Cortés A, Díaz-Martínez E (2008) The Spanish Global Geosites Project and its influence on recent legislation for the conservation of natural heritage. Abstracts 33th International Geological Congress, p 114.

Carcavilla L, Durán JJ, García-Cortés A & López-Martínez J (2009). Geological heritage and geoconservation in Spain: past, present and future. Geoheritage, Volume 1, Issue 2, 75-91. DOI:10.1007/s12371-009-0006-9.

Carcavilla, L., Díaz-Martínez, E., Erikstad, L. & García-Cortés, A (2013). *Valuation of geoheritage in Europe. Boletim Paranaense de Geociências,* 70:28-40.

Carcavilla L, Díez-Herrero A, Vegas J, Díaz-Martínez E, García-Cortés Á., Baeza E, Rábano I, Martín-Serrano Á, Gutiérrez Marco JC & Gómez-Heras M (2017). Proyecto INDICAGEOPAR. Memoria final. Documento inédito. 26 pp.

Carcavilla L, Díez-Herrero A, Vegas J, Díaz-Martínez E, García-Cortés Á., Baeza E, Rábano I, Martín-Serrano Á, Gutiérrez Marco JC & Gómez-Heras M (en prensa). Geoindicadores para la evaluación del estado de conservación y el uso público del patrimonio geológico. Aplicación al Parque Nacional de Cabañeros. 2019. Memorias de proyectos de investigación en parques nacionales. Organismo Autónomo de Parques Nacionales.

Casto L & Zarlenga F (1992) I Beni Culturali a carattere geologico nella Media Valle del Tevere. ENEA. Area Ambiente. Dipartimento Monitoraggio ambientale. Regione Lazio. Assessorato Alla Cultura. CRD. 163 p. Roma.

Cendrero A (1996a) El Patrimonio Geológico. Ideas para su protección, conservación y utilización. In: MOPTMA (ed.) El patrimonio geológico. Bases para su valoración, protección, conservación y utilización, 17-27. Serie Monografías 112 p. Ministerio de Obras Públicas, Transportes y Medio Ambiente, Madrid.

Cendrero A (1996b) Propuesta sobre criterios para la clasificación y catalogación del patrimonio geológico. In MOPTMA (ed) El Patrimonio Geológico. Bases para su valoración, protección, conservación y utilización, 29-38. Serie Monografías. 112 p. Ministerio de Obras Públicas, Transportes y Medio Ambiente, Madrid.

Cowie JW (1993) Report of working on geological and paleobiological sites. 34 p. IUGS. Trondheim.

Crowther PR and Wimbledon WAP (eds) (1988) The use and conservation of Palaeontological sites. Spec. Papers in Palaeontology, 40. 1-200. London.

Daly D (ed) (1990) The conservation of Earth Science areas of scientific interest. Irish Assoc. for Quaternary Studies. Geol. Surv. of Ireland. 68 p. Dublin.

De Lima FF, Brilha JB & Salamuni E (2010) Inventorying geological heritage in large territories: a methodological proposal applied to Brazil. Geoheritage, DOI 10.1007/s12371-010-0014-9.

Delvene G, Vegas J, Jiménez R, Rábano I & Menéndez S (2018). From the Field to the Museum: Analysis of Groups-Purposes-Locations in relation to Spain's Moveable Palaeontological Heritage. Geoheritage 10, 451-462

Departamento de Desarrollo Rural & Sostenibilidad (2015). Decreto 274/2015, de 29 de septiembre, del Gobierno de Aragón, por el que se crea el Catálogo de Lugares de Interés Geológico de Aragón y se establece su régimen de protección. Boletín Oficial de Aragón, nº 213. 33278-33551.

De Wever P, Le Nechet Y & Cornée A (2006) Vade-mecum pour l'inventaire du patrimoine géologique national. Mém. H.S. Soc. Géol. Fr. 12 - 162 p.

Díaz-Martínez E, Vegas J, Carcavilla L & García-Cortés A (2016) Base conceptual, estado de la cuestión y perspectivas de la gestión y conservación del patrimonio paleontológico. G. Meléndez, A. Núñez y M. Tomás (eds.). Actas de las XXXII Jornadas de la Sociedad Española de Paleontología. Cuadernos del Museo Geominero, nº 20. Instituto Geológico y Minero de España, 159-163.

Dingwall PR (2000) Legislation and international agreements: the integration of the geological heritage in nature conservation policies. In: Barettino D, Wimbledon WAP & Gallego E (eds) Geological heritage: its conservation and management. Book Lectures. III International Symposium ProGEO on the Conservation of the Geological Heritage. Madrid, 1999. 15-28.

Dingwall P, Weighell T & Badman T (2005) Geological world heritage: a global framework. A Contribution to the Global Theme Study of World Heritage Natural Sites. Protected Area Programme. 51 p.

Duque LC, Abril J, García Salinas F & Elízaga E (1979b). Desarrollo de la metodología del inventario de puntos de interés geológico en el Sector Oriental de la Cordillera Cantábrica. Centro de documentación IGME. 107 p. Madrid.

Duque LC, Murcia V, Abril J, García Salinas F & Elízaga E (1979a). Proyecto previo Puntos de Interés Geológico. Centro de documentación IGME. 82 p Madrid.

Duque LC, Elízaga E & Vidal Romaní JR (1983) Puntos de Interés Geológico de Galicia. Instituto Geológico y Minero de España, Madrid. 103 p.

Durán JJ, Carcavilla L & López-Martínez J (2005) Patrimonio geológico: una panorámica de los últimos 30 años en España. Boletín de la Real Sociedad Española de Historia Natural (Sección Geológica) 100 (1-4), 277-287.

Durán JJ, Robledo PA, de la Hera A (Coords.) (2008) Lugares de Interés Hidrogeológico de Andalucía. 1 CD: son.,col.;12 cm + 1folleto 20 p. IGME-Agencia Andaluza del Agua, Madrid.

Druguet E, Carreras J & Herrero N (2004) Inventario de espacios de interés geológico de Catalunya. 2. Bases de datos y perspectivas de desarrollo. Libro de Actas de la VI Reunión Científica de la Comisión de Patrimonio Geológico de la Sociedad Geológica de España. 27-36.

Elízaga E (1988) Georrecursos culturales. En: Geología Ambiental, 85-100. ITGE. Madrid.

Elizaga E, Abril J, Duque LC, García Salinas F & Murcia V (1980) Los puntos geológico-mineros de interés singular como patrimonio natural. Su inventario y metodología de estudio. I Reunión Nacional de Geología Ambiental y Ordenación del Territorio. Volumen de Comunicaciones, 21. Santander.

Elízaga E, Gallego E & García-Cortés A (1994) Inventaire National des sites d'Intérêt Géologique en Espagne: Méthodologie et Déroulement. Mém. Soc. Géol. Fr. n. s. 165. 103-110. Paris.

Elízaga E & Palacio J (1996) Valoración de puntos y/o lugares de interés geológico. En: El Patrimonio Geológico. Bases para su valoración, protección, conservación y utilización. Cendrero, A. Ed., págs. 61-79. Ministerio de Obras Públicas, Transportes y Medio Ambiente, Madrid.

Ellis NV (ed), Bowen DQ, Campbell S, Knill JL, McKirdy AP, Prosser CD, Vincent MA & Wilson RCL (1996) An Introduction to the Geological Conservation Review. GCR Series 1. 131 p. Joint Nature Conservation Committee, Peterborough.

Erikstad L (1984) Registration and conservation of sites and areas of geological significance in Norway. Norsk. Geogr. Tidskr. 38. 199-204. Oslo.

Fassoulas C, Mouriki D, Dimitriou-Nikolakis P & Iliopoulos G (2012) Quantitative Assessment of Geotopes as an Effective Tool for Geoheritage Management. Geoheritage 4. 177–193.

Fuertes I. (2013) Patrimonio geológico y ordenación del territorio. Tesis doctoral. Universidad de León. 507 p.

Fuertes-Gutiérrez I & Fernández-Martínez E (2010) Geosites Inventory in the Leon Province (Northwestern Spain): A Tool to Introduce Geoheritage into Regional Environmental Management. Geoheritage 2. 57–75.

Fuertes-Gutiérrez I, Fernández-Martínez E & García-Ortiz E (2013) Propuesta de términos en castellano sobre conceptos relacionados con el riesgo de degradación del patrimonio geológico. In Vegas J, Salazar A, Díaz-Martínez E y Marchán C (eds.) Patrimonio Geológico, un recurso para el desarrollo. Publicaciones del Instituto Geológico y Minero de España. Serie Cuadernos del Museo Geominero nº 15. 195-206. Madrid.

Gallego Valcarce E & García-Cortés A (1996) Patrimonio Geológico y Espacios Naturales Protegidos. Geogaceta19. 202-206. Sociedad Geológica de España. Madrid.

García-Cortés A (ed) (2008) Contextos geológicos españoles: una aproximación al patrimonio geológico español de relevancia internacional. Instituto Geológico y Minero de España, Madrid.

García-Cortés A (ed) (2009) Spanish Geological Frameworks. An approach to Spanish Geological heritage of internacional relevance. Instituto Geológico y Minero de España.

García-Cortés A & Carcavilla L (2009) Documento metodológico para la elaboración del Inventario Español de Lugares de Interés Geológico (IELIG). Versión 12. 61 p. http://www.igme.es/patrimonio/descargas.htm

García-Cortés A, Carcavilla L, Díaz-Martínez E & Vegas J (2012). Inventario de Lugares de Interés Geológico de la Cordillera Ibérica. Informe Final. Instituto Geológico y

Minero de España (Servicio de Documentación del IGME). 147 p. http://www.igme.es/patrimonio

García-Cortés A, Carcavilla L, Díaz-Martínez E & Vegas J (2018) Documento metodológico para la elaboración del Inventario Español de Lugares de Interés Geológico (IELIG). Versión Versión 5/12/2014, Actualización 12/07/2018. 65 p http://www.igme.es/patrimonio/descargas.htm

García-Cortés A, Rábano I, Locutura J, Bellido F, Fernández-Gianotti J, Martín-Serrano A, Quesada C, Barnolas A, Durán JJ (2001) First Spanish contribution to the Geosites Project: list of the geological frameworks established by consensus. Episodes 24–2:79–92.

García-Cortés A & Fernández-Gianotti J (2005) Estrategia del Instituto Geológico y Minero de España para el estudio y protección del Patrimonio Geológico y la Geodiversidad. En M.A. Lamolda (Ed.). Geociencias, recursos y patrimonio geológicos. 59-72. Serie Geología y Geofísica, 3. Instituto Geológico y Minero de España. 210 p.

García-Ortiz E, Fuertes-Gutiérrez I, Fernández-Martínez E (2014) Concepts and terminology for the risk of degradation of geological heritage sites: fragility and natural vulnerability, a case study. Proceedings of the Geologists' Association. Volume 125, Issue 4, September 2014, Pages 463–479. http://dx.doi.org/10.1016/j.pgeola.2014.06.003

Gonggrijp GP (1988) Earth Science Conservation: the GEA Project – Ann. Rep. Res. Inst. Nature Management (1987) 93-101. Arnheim/Leersum/Texel.

Gonggrijp GP (2000) Planificación y gestión para la conservación. En Barettino, D. Wimbledon, W.A.P. y Gallego, E. (Eds.). Patrimonio Geológico: conservación y gestión, 31-49. Instituto Tecnológico Geominero de España. Madrid.

Grande I & Abascal E (2003) Fundamentos y Técnicas de Investigación Comercial, 7ª edición, ESIC, Madrid.

Grandgirard V (1995) Méthode pour la réalisation d'un inventaire de geotopes géomorphologiques. UKPIK Cahiers de l'Institut de Géographie de l'Université de Fribourg 10:121–137

Grandgirard V (1996) Gestion du patrimoine naturel, l'inventaire de géotopes géomorphologiques. Ukpik, Rapports de recherches, 8. 181-195. Institut de Géographie. Université de Fribourg.

Grandgirard V & Berger JP (1997) Inventario dei Geotopi d'importanza nazionale – Groupe de Travail pour la protection des géotopes en Suisse, Académie Suisse des Sciences Naturelles.

Haff B (1995) A research methodology on geomorphological assets in the Vosges (France). In: Marchetti M, Panizza M, Soldati M & Barani D (eds.) Geomorphology and environmental impact assessment. Quaderni di Geodinamica Alpina e Quaternaria, 3. 181-185.

Hayward B (1989) Earth Science conservation in New Zealand. Earth Science Conservation 26. 4-6.

Herrero N, Druguet E & Carreras J (2004) Inventario de espacios de interés geológico de Cataluña.1. Antecedentes y metodología. Actas de la VI Reunión Nacional de la Comisión de Patrimonio Geológico. Sociedad Geológica de España. Salardú. 17-26.

JNCC (1993) Guidelines for selection of earth science SSSIs. Joint Nature Conservation Committee. 11 p. http://jncc.defra.gov.uk/pdf/earthscienceSSSI.pdf

Jódar G, Ortega F, León M & Castellano A (2012) Valoración del Patrimonio Geológico. Diagnóstico sobre los posibles impactos. 115 p y anexo. Agencia del Medio Ambiente y Agua. Junta de Andalucía.

Joyce EB (2010) Australia's Geoheritage: History of Study, A New Inventory of Geosites and Applications to Geotourism and Geoparks. Geoheritage 2. 39–56.

Junta de Andalucía (2002) Propuesta de Estrategia Andaluza de Conservación de la Geodiversidad. Consejería de Medio Ambiente. Sevilla. 103 p.

Junta de Andalucía (2008) Estrategia Andaluza de Gestión Integrada de la Geodiversidad. Documento borrador. Consejería de Medio Ambiente. Sevilla. 138 p., Anejos y 1 Cd.

Junta de Andalucía (2011) Estrategia Andaluza de gestión Integrada de la geodiversidad. Consejería de Medio Ambiente. Sevilla 187 p.

Kananoja T, Suominen V & Neromen K (2012) Finland. In: Wimbledon, W.A.P. & Smith-Meyers, S. (Eds) Geoheritage in Europe and its conservation. ProGEO, Oslo, 115-123.

Look ER (ed) (1996) Geotope Conservation in Germany. Guidelines of the Geological Surveys of the German Federal States. Final Report. 105 + XVI p. Ad-hoc Geotope Conservation Working Group. Angewandte Landschaftsökologie. Bundesamt für Naturchutz. Bonn-Bad Godesberg.

Lozano G, Vegas J & García-Cortés A (2011) Representación cartográfica de los lugares de interés geológico: consideraciones de cara a la gestión, Enguídanos (Cuenca). Avances y retos en la conservación del patrimonio geológico en España. 152-155. Universidad de León.

MAGRAMA (2013) Informe 2012 sobre el estado del patrimonio natural y de la biodiversidad. Ministerio de Agricultura, Alimentación y Medio Ambiente. Madrid. 315 p. http://www.mapama.gob.es/es/biodiversidad/temas/inventarios-nacionales/informe_iepnb_2012_tcm30-196689.pdf

MAPAMA (2015) Informe 2014 sobre el estado del patrimonio natural y de la biodiversidad. Ministerio de Agricultura, Pesca, Alimentación y Medio Ambiente. http://www.mapama.gob.es/es/biodiversidad/temas/inventarios-nacionales/iepnb_2014_tcm30-196687.pdf

Master LL, Faber-Langendoen D, Bittman R, Hammerson GA, Heidel B, Ramsay L, Snow K, Teucher A & Tomaino A (2012). NatureServe Conservation Status Assessments: Factors for Evaluating Species and Ecosystem Risk. NatureServe, Arlington, VA. 64 p.

Mendía M, Aramburu A, Carracedo M, González MJ, Monge-Ganuzas M & Pascual A (2010) Lugares de interés geológico de la Reserva de la Biosfera de Urdaibai. Departamento de medio Ambiente, Planificación Territorial, Agricultura y Pesca. Gobierno Vasco. 180 p. (http://www.euskadi.net/geodibertsitatea).

Mendía M, Hilario A, Apellaniz E, Aramburu A, Carracedo M, Cearreta A, Eguíluz L, Gil Crespo P, González MJ, López-Horgue M, Martínez-Torres LM & Mugerza

I (2013) El inventario de lugares de interés geológico de la comunidad autónoma del País Vasco (CAPV). In Vegas J, Salazar A, Díaz-Martínez E y Marchán C (eds.) Patrimonio Geológico, un recurso para el desarrollo. Publicaciones del Instituto Geológico y Minero de España. Serie Cuadernos del Museo Geominero nº 15. 457-466. Madrid.

Metaseria D, Asfawossen A & Mogessie A (2004) Contribution of geology to the growth of the tourism industry in Ethiopia. 20th Colloquium African Geology, Abstr. Vol., 131. Orleans.

Morales J (1996) El patrimonio paleontológico. Bases para su definición, estado actual y perspectivas futuras. En: El Patrimonio Geológico. Bases para su valoración, protección, conservación y utilización, Cendrero A Ed. pp. 39-51. Ministerio de Obras Públicas, Transportes y Medio Ambiente, Madrid.

Morales J, Gómez E & Azanza B (2002) El patrimonio paleontológico español: marco legal, titularidad, gestión y conservación. En: El patrimonio paleontológico de Teruel, Meléndez, G. y Peñalver E (Coords.), pp. 53-62. I Jornadas sobre el patrimonio de la provincia de Teruel. Paleontología. Instituto de Estudios Turolenses. Diputación de Teruel.

NCC (1991) Earth Science Conservation in Great Britain. A Strategy. 84 p. Nature Conservancy Council. Peterborough.

Oxford University Press (2014) Oxford dictionaries. http://www.oxforddictionaries.com/es

Palacio J (Coord.) (2000) Jornadas sobre Patrimonio Geológico y Desarrollo Sostenible. Serie Monografías. Ministerio de Medio Ambiente. Sociedad Española de Geología Ambiental y Ordenación del Territorio. Madrid. 91 p.

Panizza M. (2001) "Geomorphosites: concepts, methods and examples of geomorphological survey". Chinese Science Bulletin, vol. 46, Supp. December.

Parkes MA & Morris JHM (2002) Earth Science conservation in Ireland: The Irish Geological Heritage Programme. Irish Journal of Earth Sciences 19 (2001) 79-90.

Pralong JP (2005) A method for assessing the touristic potential and use of geomorphological sites. Géomorphologie: relief, processus, environment. 3. 189-196.

Reynard E, Fontana G, Kozlik L, Scapozza C (2007) A method for assessing "scientific" and "additional values" of geomorphosites. Geographica Helvetica 62(3):148–158

Rivas V, Rix C, Francés E, Cendrero A & Brunsden D (1995) The use of indicators for the assessment of environmental impacts on geomorphological features. In: Marchetti M, Panizza M, Soldati M, Barani D (Eds.) Geomorphology and Environmental Impact Assessment. Quaderni di Geodinamica Alpina e Quaternaria, 3, 157-180.

Rivas V, Rix K, Frances E, Cendrero A & Brunsden D (1997) Geomorphological indicators for environmental impact assessment: consumable and non consumable geomorphological resources. Geomorphology, 18, Issues 3-4, 169-182.

Romero Sánchez G (2004): El Patrimonio Paleontológico de la Región de Murcia. Tesis doctoral, Univ. de Murcia. Inédita.

Servicio Geológico Colombiano (2019) Inventario geológico y paleontológico inmueble. https://www2.sgc.gov.co/patrimonio/Paginas/inventario-inmmueble.aspx

Sharples C (ed) (2002) Concepts and principles of geoconservation. Tasmanian Parks & Wildlife Service website. 81 p. http://dpipwe.tas.gov.au/Documents/geoconservation.pdf.

Schlüter T, Kibunja M & Kohring R (2001) Geological Heritage in East Africa. Its Protection and Conservation. Documenta Naturae 136, 39-49. Munich.

Strasser A, Heitzmann P, Jordan P, Stapfer A, Stürm B, Vogel A & Weidmann M (1995) Géotopes et la protection des objets géologiques en Suisse : un rapport stratégique. 27 p. Groupe de travail suisse pour la protection des géotopes. Fribourg.

Tamés P, Mendiola I & Pérez C (Coords.) (1991) Puntos de interés geológico de Guipúzcoa. Diputación Foral de Guipúzcoa, San Sebastián. 167 p.

UKRIGS (2001) Notes to accompany RIGS recording, assessment, designation and notification sheets. UKRIGS Conference.

Vegas J, Lozano G, García-Cortés A, Carcavilla L & Díaz-Martínez E (2011) Adaptación de la metodología del Inventario Español de Lugares de Interés Geológico a los inventarios locales de patrimonio geológico: municipio de Enguídanos (Cuenca). Avances y retos en la conservación del Patrimonio Geológico en España. Actas de la IX Reunión Nacional de la Comisión de Patrimonio Geológico (Sociedad Geológica de España). Universidad de León. 271-276.

Vegas J, Cabrera A, Prieto A, García-Cortés A & Díez Herrero A (2018) Apadrina una Roca. Un programa de voluntariado para la conservación del patrimonio geológico en España. Enseñanza de las Ciencias de la Tierra AEPECT 23.2. 122-124.

Vegas J., Delvene G, Menéndez S, Cabrera A, García-Cortés Á, Díaz-Martínez E, Carcavilla L & Rábano I (2019). Metodología y estado actual del patrimonio paleontológico en el Inventario Español de Lugares de Interés Geológico. Spanish Journal of Palaeontology, 34 (1), 79-96.

Vegas J, Delvene G, Menéndez S, Rábano I, García-Cortés Á, Díaz-Martínez E & Jiménez R (2017) El patrimonio paleontológico en España: una necesidad de consenso sobre su gestión y marco legal. Perspectivas Revista ph Instituto Andaluz del Patrimonio Histórico nº 94. 326-329.

Viljoen MJ & Reimold WU (1999) An Introduction to South Africa’s Geological and Mining Heritage. 193 p. Mintek, Randburg.

Villalobos M, Braga JC, Guirado J & Pérez Muñoz AB (2004) El inventario andaluz de georrecursos culturales: criterios de valoración. De Re Metallica 3: 9-21.

Wild R (1986) The protection of fossils as cultural monuments in West Germany. Geological Curator 4. 275-280.

Wimbledon WAP (1996) GEOSITES, a new IUGS initiative to compile a global comparative site inventory, an aid to international and national conservation activity. Episodes. 19:87–88.

Wimbledon WAP & Smith-Meyer S (eds) (2012) Geoheritage in Europe and its conservation. ProGEO. 405 p. Oslo.

Zouros N (2007) Geomorphosite assessment and management in protected areas of Greece. Case study of the Lesvos Island-coastal geomorphosites. Geographica Helvetica 62(3):69–180.

# APPENDIX I

## PRELIMINARY SURVEY QUESTIONNAIRE

## INFORMATION ON THE INVENTORY OF THE GEOLOGICAL HERITAGE OF REGION X FOR WHICH YOUR COLLABORATION IS REQUESTED

**AIMS OF THE PROJECT:**

Act 42/2007 on Natural Heritage and Biodiversity, requires the Ministry of the Environment to work with regional governments and scientific institutions to compile the Spanish Inventory of Natural Heritage, which includes the inventory of Sites of Geological Interest (SGI). Royal Decree 1274/2011 approved the Strategic Plan for Natural Heritage and Biodiversity 2011-2017, entrusting IGME with objective 2.8.6.: "Finalise the Spanish Inventory of Sites of Geological Interest", with the collaboration of the Directorate General for Environmental Quality and Evaluation. IGME works with the Ministry of the Environment to inventory and evaluate SGI, which are areas that contain homogeneous, uninterrupted examples of one or several notable and significant characteristics of the geological heritage of a region. Geological heritage is defined as all natural geological resources of scientific, cultural and/or educational value, be they formations and geological structures, landforms, minerals, rocks, meteorites, fossils, soils and other geological features that facilitate the understanding, study and interpretation of (a) the origin and evolution of the Earth, (b) the processes that have modelled it, (c) the climates and landscapes of the past and present, and (d) the origin and evolution of life (Act 42/2007).

Under the inventory methodology developed by IGME, the first phase consists of a Delphi-type round of questionnaires.

**METHODOLOGY OF THE EXPERT SURVEY:**

+ Selection of the panel of experts.

+ **The personal details of the experts will not be disclosed in order to avoid professional influence bias. After the second round of questionnaires, the author of the proposed site of geological interest can be named.**

+ A preliminary questionnaire is sent to each expert.

+ The experts complete the questionnaire and return it to the Project Manager.

+ The information is studied and processed.

+ Experts are sent a second (simplified) questionnaire.

+ The experts complete the questionnaire and return it to the Project Manager.

+ The information is processed and analysed statistically.

+ Conclusions are drafted.

**TECHNICAL COORDINATION OF THE PROJECT:**

The project will be coordinated on a technical level by the Geological Survey of Spain through the following email:

**x.x@igme.es**

**DETAILS OF THE EXPERT:**

SURNAME(S)/FAMILY NAMES:
FIRST (GIVEN) NAME(S):
DEGREE/QUALIFICATIONS:
OCCUPATION:
POSTAL ADDRESS:
TELEPHONE:
EMAIL:

## QUESTIONNAIRE

**TIPS ON HOW TO COMPLETE THE QUESTIONNAIRE**

(1) Complete in the questionnaire, tables and attached fact sheets. **This will take** between **one to five hours, depending on the number of geological sites propose**d. We recommend proposing no more than 20 sites, although this is not mandatory.

(2) If you have any questions about completing the questionnaire, please contact the project manager:

**x.x@igme.es**

**(3) IMPORTANT**:

Once you have completed the questionnaire, **DON'T FORGET TO SAVE the Word Document**. To do this, in the option "Save as" assign it the following name:

**Surnames_Specialist field_X.doc**

For example, if your name is José Gutiérrez, you are an expert in Stratigraphy of the Iberian System, and this is the first round of this project, your document would be saved as:

Gutiérrez_Stratigraphy_Iberian.doc

(4) Send an email to the project manager **(x.x@igme.es)** WITHOUT FORGETTING to attach the saved Word document.

(5) Once your questionnaire has been received, the project manager will reply to your email to inform you that the process has been successfully completed. If any corrections are required, you will be informed as soon as possible.

**THANK YOU VERY MUCH FOR YOUR HELP!**

## SECTION 1 IMPORTANCE OF GEOLOGICAL HERITAGE

**EXPLANATION** The questions in this first section are intended to estimate the degree of importance the panel of experts attaches to geological heritage.

1. Indicate with an "x" the degree of importance you attach to geological heritage in general

| | |
|---|---|
| Very important | |
| Quite important | |
| Important | |
| Not so important | |
| Irrelevant | |

2. Indicate with an "x" the degree of importance you attach to geological heritage in the geological region to be inventoried.

| | |
|---|---|
| Very important | |
| Quite important | |
| Important | |
| Not very important | |
| Irrelevant | |

3. Indicate with an "x" whether you consider that geological domain x contains SGI of greater relevance, in general terms, than in other geological domains in Spain.

| | |
|---|---|
| Clearly more relevant than in the rest of Spain | |
| More relevant in specific cases | |
| Equally relevant | |
| Less relevant, except for specific cases | |
| Clearly less relevant than in the rest of Spain | |

4. What importance do you attach to promoting (planning and management of educational, interpretive and/or touristic-recreational use) geological heritage as an alternative to economic development in geological region x? Choose an option.

| | |
|---|---|
| Very important | |
| Quite important | |
| Important | |
| Not very important | |
| Irrelevant | |

5. In terms of Spanish geological heritage, which 10 sites of interest would you highlight, in general?

| | |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |

## SECTION 2 PROPOSED SITES OF GEOLOGICAL INTEREST IN GEOLOGICAL REGION X

<table>
<tr><td colspan="2">EXPLANATION<br>– Using the evaluation parameters shown in the right column, propose and list in order of decreasing importance up to 20 geological sites in geological region X.<br>– In the lower right hand box, indicate the extent of your knowledge of the site.</td></tr>
<tr><th>SITES OF GEOLOGICAL INTEREST</th><th>EVALUATION PARAMETERS THAT CAN BE CONSIDERED</th></tr>
<tr><td>1</td><td rowspan="20">• Representativeness<br>• Type locality or reference<br>• Degree of scientific knowledge of the site<br>• State of conservation<br>• Visibility<br>• Rarity<br>• Geological diversity<br>• Spectacularity or beauty<br>• Informative content/Informative use<br>• Educational content/educational use<br>• Potential for recreational activities<br>• Association with other elements of natural or cultural heritage</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td></tr>
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<tr><td>10</td></tr>
<tr><td>11</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td></tr>
<tr><td>14</td></tr>
<tr><td>15</td></tr>
<tr><td>16</td></tr>
<tr><td>17</td></tr>
<tr><td>18</td></tr>
<tr><td>19</td></tr>
<tr><td>20</td></tr>
<tr><td>RATE from 1 to 5 the extent of your knowledge of the geological heritage in geological region X</td><td></td></tr>
</table>

<table>
<tr><th colspan="7">PROPOSAL OF SITE OF GEOLOGICAL INTEREST I (*)</th></tr>
<tr><td>Name of the SGI</td><td colspan="6"></td></tr>
<tr><td>Short description</td><td colspan="6"></td></tr>
<tr><td>Justification of interest</td><td colspan="6"></td></tr>
<tr><td colspan="7">Parameters that justify your choice (check the box of the parameters that apply):</td></tr>
<tr><td colspan="3">☐ Representativeness</td><td colspan="4">☐ Spectacularity or beauty</td></tr>
<tr><td colspan="3">☐ Type locality or reference value</td><td colspan="4">☐ Informative content/informative use</td></tr>
<tr><td colspan="3">☐ Extent of knowledge of the site</td><td colspan="4">☐ Educational content/educational use</td></tr>
<tr><td colspan="3">☐ State of conservation</td><td colspan="4">☐ Potential for recreational or leisure activities</td></tr>
<tr><td colspan="3">☐ Visibility</td><td colspan="4">☐ Association with other elements of natural or cultural heritage</td></tr>
<tr><td colspan="3">☐ Rarity</td><td colspan="4">☐ Geological diversity</td></tr>
<tr><td rowspan="5">Location</td><td colspan="2">Province</td><td colspan="4">Town/City</td></tr>
<tr><td colspan="6">Site</td></tr>
<tr><td rowspan="2">UTM coordinates (**)</td><td rowspan="2">X:</td><td rowspan="2">Y:</td><td colspan="3">Zone:</td></tr>
<tr><td colspan="2">Datum: ED50 ☐</td><td>ETRS89 ☐</td></tr>
<tr><td colspan="5">Check the box if it is advisable to maintain the confidentiality of the site and hide its coordinates.</td><td>☐</td></tr>
<tr><td>Driving/walking directions</td><td colspan="6"></td></tr>
<tr><td>Diagram of the site with proposed delineation (***)<br><br>(insert or attach a separate map fragment or SIGPAC orthophoto file)</td><td colspan="6"></td></tr>
</table>

(*) The data provided will be treated as proposals that may be modified in later phases of the inventory.
(**) From the geometric center of the SGI. (***) Optional delimitation.

| PROPOSAL OF SITE OF GEOLOGICAL INTEREST (II) | |
|---|---|
| **Photograph(s) of the site**<br><br>(can be attached in separate files) | |
| **References** | |
| **Author of the proposal** | |
| **<u>IMPORTANT</u>: Check the box** if, in the second phase of the project, you would be willing to describe and propose the demarcation of this SGI. You will be compensated for any expenses. | ☐ |
| **Please add or attach any additional information and documentation you believe will facilitate the subsequent field work and evaluation.** | |

## SECTION 3 EXPERT SELF-ASSESSMENT

**EXPLANATION**
Mark with an "x" the sources of the arguments put forward to defend your choice(s), indicating their importance (High, Average, Low).

| SOURCES OF ARGUMENTS | HIGH | AVERAGE | LOW |
|---|---|---|---|
| Your experience (professional, researcher, etc.) in the subject. | | | |
| Studies on the subject published by Spanish researchers. | | | |
| Studies on the subject published by researchers from other countries. | | | |

**Comments:**

**THANK YOU VERY MUCH FOR YOUR HELP**
**Please**
**DON'T FORGET to send your questionnaire**
**to the project MANAGER: x.x@igme.es**

# APPENDIX II

## SECOND-ROUND QUESTIONNAIRE

**SPANISH INVENTORY OF SITES OF GEOLOGICAL INTEREST (IBERIAN SYSTEM)**
**SECOND QUESTIONNAIRE**

The following is a list of all the sites of interest proposed by the experts taking part in the first round. The aim of this second round is to allow the experts who have responded to the first questionnaire to formulate their opinion, evaluating all the sites proposed according to the following scale:

– **20 points:** exceptional site for understanding, studying and interpreting the origin and geological or paleobiological evolution of the Iberian System, or the processes that have modelled it.
– **15 points:** very important for these purposes
– **10 points:** important for these purposes
– **5 points:** unimportant for these purposes (it is interesting, but in the wider context of the Iberian System it is unrepresentative or insignificant, at least compared to other SGI included in the list)
– **0 points:** irrelevant for these purposes; should not be included in the Spanish Inventory of Geological Sites of Interest
– **S:** Insufficient information to evaluate the site

**RECOMMENDATIONS**

In this process, it is very important to remember that the sites should be evaluated in respect of the entire Iberian System. To facilitate the review, please:

– Read the description of each site carefully, putting an S against any site you will not evaluate
– It appears to be easier to evaluate sites whose relevance is exceptionally high. Therefore, we recommend going through the list again and giving maximum points to those sites that are, without a doubt, outstanding examples within the scope of the Iberian System, and even on a national level.
– Next, rate the remaining categories.
– Then, assign a score of 0 to those sites you believe are irrelevant and should not therefore be included in the list.
– Finally, arrange the SGIs in order of importance in order to group sites with a score of 0, 5, 10, 15 and 20 to facilitate comparison.

This will take between 2 and 4 hours

Once you have evaluated all the sites, save the excel file using the **Surnames_Specialist field_Iberian2.xls** format and email it to **x.x@igme.es**

Again, thank you very much for your help.

| Sites | Score | Description |
|---|---|---|
| | | |
| | | |
| | | ... |

## APPENDIX III

## CRITERIA FOR RATING PARAMETERS FOR CALCULATING THE SCIENTIFIC, EDUCATIONAL AND TOURISTIC-RECREATIONAL VALUE OF THE SGI

Each SGI is evaluated according to its interest (scientific, educational and touristic-recreational) using the parameters indicated for each type of interest and their weighting coefficients (Table 5.8.1), **scoring each of these parameters according to the following criteria (when the SGI can be assigned more than one type of interest, choose the one with the highest score):**

| EVALUATION | | | | |
|---|---|---|---|---|
| **Representativeness (R)** | **Points** | **Scientific value** | **Educational value** | **Touristic-recreational value** |
| Little use as a model to represent, even partially, a feature or process | 0 | X 30 | X 5 | X 0 |
| Useful as a model to represent part of a feature or process | 1 | X 30 | X 5 | X 0 |
| Useful as a model to represent an entire feature or process | 2 | X 30 | X 5 | X 0 |
| Best known example of an entire feature or process in the geological region inventoried. | 4 | X 30 | X 5 | X 0 |
| **Type locality (T)** | | | | |
| It does not meet, by default, the following three criteria | 0 | X 10 | X 5 | X 0 |
| Regional reference site | 1 | X 10 | X 5 | X 0 |
| Reference site (metallogenic, petrological, mineralogical, tectonic, stratigraphic etc.) used internationally, or type locality of fossils, or biozones of wide scientific use | 2 | X 10 | X 5 | X 0 |
| Stratotype accepted by the IUGS, or IMA type locality | 4 | X 10 | X 5 | X 0 |
| **Degree of scientific knowledge of the site (K)** | | | | |
| There are no published studies or doctoral theses on the site | 0 | X 15 | X 0 | X 0 |
| There are published studies and/or doctoral theses on the site | 1 | X 15 | X 0 | X 0 |
| The site has been studied by several scientific teams and is the subject of doctoral theses and published papers cited in national scientific journals | 2 | X 15 | X 0 | X 0 |
| The site has been studied by several scientific teams and is the subject of doctoral theses and published papers cited in international scientific journals | 4 | X 15 | X 0 | X 0 |

| | Points | Scientific value | Educational value | Touristic-recreational value |
|---|---|---|---|---|
| **State of conservation (C)** | | | | |
| Strongly degraded: the site is practically destroyed | 0 | X 10 | X 5 | X 0 |
| Degraded: the site shows significant deterioration | 0 | X 10 | X 5 | X 0 |
| Altered: the site has damage that prevents the observer from appreciating some characteristics of interest | 1 | X 10 | X 5 | X 0 |
| Good with alterations: some damage that does not decisively affect the value or interest of the SGI | 2 | X 10 | X 5 | X 0 |
| Good: the SGI in question is practically intact and is well preserved. | 4 | X 10 | X 5 | X 0 |
| **Visibility (O)** | | | | |
| Has elements that almost entirely obscure the characteristics of interest | 0 | X 10 | X 5 | X 5 |
| Has elements that obscure the SGI and prevent the observer from appreciating some characteristics of interest | 1 | X 10 | X 5 | X 5 |
| Has the occasional element that does not prevent the observer from appreciating the entire SGI | 2 | X 10 | X 5 | X 5 |
| Almost the entire SGI is perfectly and easily observable | 4 | X 10 | X 5 | X 5 |
| **Rarity (A)** | | | | |
| There are several similar sites in the geological domain | 0 | X 15 | X 5 | X 0 |
| One of the few known examples in the geological domain | 1 | X 15 | X 5 | X 0 |
| Only known example in the geological domain | 2 | X 15 | X 5 | X 0 |
| Only known example in Spain (or worldwide) | 4 | X 15 | X 5 | X 0 |
| **Diversity (D)** | | | | |
| The SGI only presents the primary type of interest | 0 | X 10 | X 10 | X 0 |
| The SGI presents another type of interest in addition to the primary type, but it is not relevant | 1 | X 10 | X 10 | X 0 |
| The SGI presents 2 other types of interest in addition to the primary type, or only 1, but relevant | 2 | X 10 | X 10 | X 0 |
| The SGI presents 3 other types of interest in addition to the primary type, or only 2, but relevant | 4 | X 10 | X 10 | X 0 |
| **Educational content ($C_{DD}$)** | | | | |
| It does not meet, by default, the following three criteria | 0 | X 0 | X 20 | X 0 |

| | Points | Scientific value | Educational value | Touristic-recreational value |
|---|---|---|---|---|
| Illustrates university teaching content | 1 | X 0 | X 20 | X 0 |
| Illustrates teaching content for any educational level | 2 | X 0 | X 20 | X 0 |
| It is routinely used in teaching activities for any educational level | 4 | X 0 | X 20 | X 0 |
| **Logistic infrastructure ($I_L$)** | | | | |
| It does not meet, by default, the following three criteria | 0 | X 0 | X 15 | X 5 |
| Accommodation and catering for groups of up to 20 people within 25 km | 1 | X 0 | X 15 | X 5 |
| Accommodation and catering for groups of up to 40 people within 25 km | 2 | X 0 | X 15 | X 5 |
| Accommodation and catering for groups of up to 40 people within 5 km | 4 | X 0 | X 15 | X 5 |
| **Population density (immediate potential demand) ($D_P$)** | | | | |
| Less than 200,000 inhabitants within a radius of 50 km | 1 | X 0 | X 5 | X 5 |
| Between 200,000 and 1,000,000 inhabitants within a radius of 50 km | 2 | X 0 | X 5 | X 5 |
| More than 1,000,000 inhabitants within a radius of 50 km | 4 | X 0 | X 5 | X 5 |
| **Accessibility ($A_C$)** | | | | |
| It does not meet, by default, the following three criteria (paved road without parking, path or dirt road, 4x4 track, boat access, etc.) | 0 | X 0 | X 10 | X 10 |
| Direct access by dirt road suitable for cars | 1 | X 0 | X 10 | X 10 |
| Direct access by paved road with parking for cars | 2 | X 0 | X 10 | X 10 |
| Direct access by paved road with parking for buses | 4 | X 0 | X 10 | X 10 |
| **SGI Size (E)** | | | | |
| Metric features (vulnerable to visits, such as speleothems, etc.) | 0 | X 0 | X 5 | X 15 |
| Decametric features (not vulnerable to visits but sensitive to more aggressive anthropic activities) | 1 | X 0 | X 5 | X 15 |
| Hectometric features (could suffer some damage due to human activities) | 2 | X 0 | X 5 | X 15 |
| Kilometric features (hardly damageable by human activities) | 4 | X 0 | X 5 | X 15 |
| **Association with other elements of natural or cultural heritage (NH)** | | | | |

| | Points | Scientific value | Educational value | Touristic-recreational value |
|---|---|---|---|---|
| There are no elements of natural or cultural heritage within a radius of 5 km | 0 | X 0 | X 5 | X 5 |
| There is 1 element of natural or cultural heritage within a radius of 5 km | 1 | X 0 | X 5 | X 5 |
| There are various elements of natural or cultural heritage within a radius of 5 km | 2 | X 0 | X 5 | X 5 |
| There are several elements of both natural and/or cultural heritage within a radius of 5 km | 4 | X 0 | X 5 | X 5 |
| **Spectacularity or beauty (B)** | | | | |
| It does not meet, by default, the following three criteria | 0 | X 0 | X 5 | X 20 |
| 1) High relief, or 2) Large rivers/lakes (or ice) or 3) Notable variety of colours. Also fossils and/or colourful minerals | 1 | X 0 | X 5 | X 20 |
| Presence of two of the first three characteristics. Also fossils and/or colourful minerals | 2 | X 0 | X 5 | X 20 |
| Presence of the first three characteristics. | 4 | X 0 | X 5 | X 20 |
| **Informative content ($C_{DV}$)** | | | | |
| It does not meet, by default, the following three criteria | 0 | X 0 | X 0 | X 15 |
| Clearly and expressively instructs people with a certain level of culture | 1 | X 0 | X 0 | X 15 |
| Clearly and expressively instructs groups with any level of culture on the importance or usefulness of geology | 2 | X 0 | X 0 | X 15 |
| It is regularly used for informative activities | 4 | X 0 | X 0 | X 15 |
| **Potential for touristic and recreational activities ($P_{TR}$)** | | | | |
| No potential for either touristic or recreational activities | 0 | X 0 | X 0 | X 5 |
| Potential for either tourism or recreational activities | 1 | X 0 | X 0 | X 5 |
| Potential for both tourism and recreational activities | 2 | X 0 | X 0 | X 5 |
| Activities are already organized at the site | 4 | X 0 | X 0 | X 5 |
| **Proximity to recreational areas (immediate potential demand) ($Z_R$)** | | | | |
| Located more than 5 km from recreational areas (campsites, beaches, etc.) | 0 | X 0 | X 0 | X 5 |
| Located less than 5 km and more than 2 km from recreational areas | 1 | X 0 | X 0 | X 5 |

| | Points | Scientific value | Educational value | Touristic-recreational value |
|---|---|---|---|---|
| Located less than 2 km and more than 500 m from a recreational area | 2 | X 0 | X 0 | X 5 |
| Located less than 500 m from a recreational area | 4 | X 0 | X 0 | X 5 |
| **Social and economic environment ($E_S$)** | | | | |
| Area with per capita income, education and employment rates above the regional average | 0 | X 0 | X 0 | X 10 |
| Site located in a district with per capita income, education and employment similar to the regional average but below the national average | 1 | X 0 | X 0 | X 10 |
| Site located in a district with per capita income, education and employment rates below the regional average | 2 | X 0 | X 0 | X 10 |
| Site located in a district in social and economic decline | 4 | X 0 | X 0 | X 10 |
| **TOTAL** | | $\Sigma_C$ | $\Sigma_D$ | $\Sigma_T$ |
| **VALUE (over 10)** | | $V_C = \Sigma_C/40$ | $V_D = \Sigma_D/40$ | $V_T = \Sigma_T/40$ |

According to this table, the value can be shown as an algorithm using the following expressions (divided by 40 to obtain a number between 0 and 10):

$$V_C = 1/40 \times [30 \times R + 15 \times (K + A) + 10 \times (T + C + O + D)]$$

$$V_D = 1/40 \times [20 \times C_{DD} + 15 \times I_L + 10 \times (D + A_C) + 5 \times (R + T + C + O + A + D_P + E + NH + B)]$$

$$V_T = 1/40 \times [20 \times B + 15 \times (E + C_{DV}) + 10 \times (A_C + E_S) + 5 \times (O + I_L + D_P + N_H + P_{TR} + Z_R)]$$

# APPENDIX IV

# CRITERIA FOR RATING PARAMETERS FOR CALCULATING THE SUSCEPTIBILITY TO DEGRADATION (NATURAL AND ANTHROPIC) OF THE SGI

## SUSCEPTIBILITY TO NATURAL DEGRADATION ($S_{DN}$)

To calculate the susceptibility of the SGI to degradation by natural causes ($S_{DN}$), the size of the site ($E_F$ is multiplied by its natural vulnerability ($V_N$). Natural vulnerability is obtained, in turn, by multiplying fragility (**F**) by natural threats ($A_N$):

$$S_{DN} = E_F \times Vu_N = E_F \times F \times A_N$$

Where $E_F$, **F** and $A_N$ take the values shown below, depending on the case. **When the SGI is susceptible to more than one factor, choose the one with the highest score.** $S_{DN}$ will be a number between 0 and 10, depending on the values of $E_F$, L and $V_N$, which are shown in the following table:

| **SGI Size Factor ($E_F$)** | **Score** |
|---|---|
| Metric features (vulnerable to visits, such as speleothems, poorly consolidated geological structures, etc.). | 10/400 |
| Decametric features (not vulnerable to visits but sensitive to more aggressive anthropic activities, such as stratigraphic sections, etc.) | 6/400 |
| Hectometric features (could suffer some damage due to human activities) | 3/400 |
| Kilometric features (hardly damageable by human activities) | 1/400 |
| **Fragility (F)** | **Score** |
| Very hard lithologies (quartzites or similar), with little fracturing and no weathering | 1 |
| Hard or very hard lithologies, but with extensive fracturing and/or weathering | 5 |
| Soft consolidated lithologies, with little fracturing and/or weathering | 10 |
| Unconsolidated lithologies, or consolidated but soft and heavily fractured and/or weathered lithologies | 20 |
| **Natural threats ($A_N$)** | **Score** |
| SGI not significantly affected by natural processes (geological or biological) | 1 |
| SGI affected by natural processes (geological or biological) of little relevance | 5 |
| SGI affected by natural processes (geological or biological) of moderate relevance | 10 |
| SGI affected by highly intense natural processes (geological or biological) | 20 |

## SUSCEPTIBILITY TO ANTHROPIC DEGRADATION ($S_{DA}$)

Susceptibility to degradation due to anthropogenic threats ($S_{DA}$) is calculated by multiplying the size of the SGI ($E_F$) by the weighted sum of the parameters listed below, with the values corresponding to the following criteria **(when the SGI is susceptible to more than one factor, choose the one with the highest score).**

| EVALUATION OF VULNERABILITY TO ANTHROPIC THREATS | | | |
|---|---|---|---|
| **Mining or water supply interest ($Vu_M$)** | **Points** | **Weight** | **Score** |
| Substance with no interest or scant interest, not exploited in the area | 0 | X 25 | |
| Substance with scant or moderate interest, already exploited in the area | 1 | X 25 | |
| Substance with considerable interest, already exploited in the area | 2 | X 25 | |
| Substance with considerable interest, not already exploited in the area[1] | 4 | X 25 | |
| **Vulnerability to pillage ($Vu_{EX}$)** | | | |
| There are no palaeontological or mineralogical deposits, or they are difficult to pillage | 0 | X 25 | |
| Palaeontological or mineralogical deposits of low value, easily pillaged | 1 | X 25 | |
| Palaeontological or mineralogical deposits of considerable value, abundant, easily pillaged | 2 | X 25 | |
| Palaeontological or mineralogical deposits that are rare and easily pillaged | 4 | X 25 | |
| **Proximity to anthropic activities (infrastructure) ($Vu_I$)** | | | |
| No threat | 0 | X 15 | |
| Site located less than 100 m from a main road, 1 km from industrial or mining activity, less than 2 km from urban land in cities with less than 100,000 inhabitants or less than 5 km in larger towns | 1 | X 15 | |
| Site adjacent to an industrial or mining activity, with undeveloped urban land or located less than 25 m from a main road. | 2 | X 15 | |
| Site located in a mine, on urban land, or bordering a main road | 4 | X 15 | |
| **Accessibility (potential aggression) (Ac)** | | | |
| It does not meet, by default, the following three criteria (e.g., paved road without parking, path or dirt road, 4x4 track, boat access, etc.) | 0 | X 10 | |
| Direct access by dirt road suitable for cars | 1 | X 10 | |
| Direct access by paved road with parking for cars | 2 | X 10 | |
| Direct access by paved road with parking for buses | 4 | X 10 | |
| **Site protection regime (P)** | | | |
| Site located in a national or natural park, nature reserve, or other area with a management plan and guards | 1 | X 5 | |
| Protected site not subject to a management plan and with no guards. Also, an asset of cultural interest due to its palaeontological/archaeological content | 2 | X 5 | |
| Site located on rural land protected from urbanization by territorial and urban planning laws, or unprotected site | 4 | X 5 | |

[1] In the Mediterranean climate, this score will always be applied to SGIs in which water plays a fundamental role.

| **Physical or indirect protection ($P_F$)** | | | |
|---|---|---|---|
| Site not easily accessible | 0 | X 5 | |
| Site located in a prohibited area and protected with high security fences. | 1 | X 5 | |
| Site located in a prohibited area, with no fences or low security fences. | 2 | X 5 | |
| Site with no kind of physical or indirect protection | 4 | X 5 | |
| **Land ownership and access regime ($T_S$)** | | | |
| Site located in areas with restricted access, public property | 1 | X 5 | |
| Site located in areas with restricted access, private property | 2 | X 5 | |
| Site located in areas with unrestricted access (public or private property) | 4 | X 5 | |
| **Population density (potential damage) ($D_P$)** | | | |
| Less than 100,000 inhabitants within a radius of 50 km | 0 | X 5 | |
| More than 100,000 but less than 200,000 inhabitants within a radius of 50 km | 1 | X 5 | |
| Between 200,000 and 1,000,000 inhabitants within a radius of 50 km | 2 | X 5 | |
| More than 1,000,000 inhabitants within a radius of 50 km | 4 | X 5 | |
| **Proximity to recreational areas (potential damage) ($Z_R$)** | | | |
| Site located more than 5 km from recreational areas (campsites, beaches, etc.) | 0 | X 5 | |
| Site located less than 5 km and more than 2 km from recreational areas | 1 | X 5 | |
| Located less than 2 km and more than 500 m from a recreational area | 2 | X 5 | |
| Located less than 500 m from a recreational area | 4 | X 5 | |
| | | **100** | |

Therefore, the $S_{DA}$ would be calculated using the following equation:

$$S_{DA} = E_F \times Vu_A$$

$$S_{DA} = E_F \times [25 \times (Vu_M + Vu_{EX}) + 15 \times Vu_I + 10 \times Ac + 5 \times (P + P_F + T_S + D_P + Z_R)]$$

## APPENDIX V

## SITES OF GEOLOGICAL INTEREST DATA SHEETS

| **GENERAL INFORMATION** | | | |
|---|---|---|---|
| **1. IDENTIFICATION** | | | |
| Code: | | | |
| Origin of the SGI: | | | |
| Name | | | |
| Description: | | | |
| **Data confidentiality** | | | |
| ☐ Public | | ☐ Restricted | ☐ Confidential |
| **Has it provided collections to museums or research centres?** YES ☐ NO ☐ | | | |
| Where are these collections? **(name of institution)** | | | |
| **Is it related to traditional habits, customs and knowledge of the environment?** | | | |
| ☐ Pottery and ceramics | | ☐ Dyes and paints | ☐ Traditional architecture |
| ☐ Lime and plaster | | ☐ Salt production | ☐ Traditional thermal baths |
| ☐ Local traditions/festivals | | ☐ Legends | ☐ Traditional water resource |
| ☐ Historic/prehistoric mining resource | | ☐ Munition | ☐ Animal husbandry |
| **2. LOCATION (coordinates of the centroid. Use at least one of the two)** | | | |
| UTM X: | UTM Y: | Zone | ETRS89 |
| UTM X: | UTM Y: | Zone | REGCAN95 |
| Sheet(s) 1: 50,000 | | | |
| Site(s) | | | |
| Town/City | | Island (as applicable) | |
| Province(s) | | | |
| Autonomous community(ies) | | | |
| Driving/walking directions: | | | |

| 3. PHYSIOGRAPHY/SOCIAL ECONOMIC STATUS | | | |
|---|---|---|---|
| **Height** | Max. | Min. | Mean |
| **Type of surface** | ☐ Moun-tainous | ☐ Coastal | ☐ Woodland |
| ☐ Scrub | ☐ Pas-tureland | ☐ Rocky | ☐ Agricultural |
| ☐ Urban or settle-ment | ☐ Bare | ☐ Body of water | |
| **Social and economic environment (choose one)** | | | |
| ☐ Region with per capita income, education and employment rates above the regional average | | | |
| ☐ Region with per capita income, education and employment rates similar to the regional average | | | |
| ☐ Region with per capita income, education and employment rates below the regional average | | | |
| ☐ Region in social and economic decline | | | |

| 4. GEOLOGICAL SITUATION | | |
|---|---|---|
| Geological region (GEODE): | | |
| Second order geotectonic unit | | |
| Geological framework (Act 42/2007) | | |
| Geological unit (Act 42/2007) | | |
| **Age of the feature or process** | Lower limit | Upper limit |
| **Age of the enclosing rocks** | Lower limit | Upper limit |
| **Geologic column (if applicable):** attach image in jpg format | | |

| 5. INTEREST | | | |
|---|---|---|---|
| **Primary geological interest (choose one)** | | | |
| ☐ Stratigraphic | ☐ Sedimentological | ☐ Geomorphological | ☐ Paleontological |
| ☐ Tectonic | ☐ Petrological-geochemical | ☐ Geotechnical | ☐ Mining-metallogenic |
| ☐ Mineralogical | ☐ Hydrogeological | ☐ History of geology | ☐ Edaphological/pedologic |
| **Justification:** | | | |
| **Secondary geological interest (may be more than one)** | | | |
| ☐ Stratigraphic | ☐ Sedimentological | ☐ Geomorphological | ☐ Paleontological |
| ☐ Tectonic | ☐ Petrological-geochemical | ☐ Geotechnical | ☐ Mining-metallogenic |

| | | | |
|---|---|---|---|
| ☐ Mineralogical | ☐ Hydrogeological | ☐ History of geology | ☐ Edaphological/ pedologic |
| **Justification:** | | | |
| **NON-geological interest (may be more than one)** | | | |
| ☐ Mining-industrial | ☐ Mining-medicinal | ☐ Botanical/Faunistic | ☐ Landscape/scenic |
| ☐ Architectural | ☐ Archaeological | ☐ Ethnological | ☐ Historical or cultural |
| **Justification of non-geological interest:** | | | |
| **Representativeness (choose one)** | | | |
| ☐ Little use as a model to represent, even partially, a feature or process | | | |
| ☐ Useful as a model to partially represent a feature or process | | | |
| ☐ Useful as a model to represent an entire feature or process | | | |
| ☐ Best known example of an entire feature or process in the geological domain | | | |
| **Type locality (choose one )** | | | |
| ☐ Does not fulfil these criteria | | | |
| ☐ Regional type locality | | | |
| ☐ International type locality, or widely used type locality for fossils or biozones | | | |
| ☐ Stratotype accepted by the IUGS, or mineralogical type locality recognized by the IMA | | | |
| **Degree of scientific knowledge of the site (choose one)** | | | |
| ☐ There are no published studies or doctoral theses on the site | | | |
| ☐ There are published studies and/or doctoral theses on the site | | | |
| ☐ The site has been studied by several scientific teams and is the subject of papers published in national scientific journals | | | |
| ☐ The site has been studied by several scientific teams and is the subject of papers published in international scientific journals | | | |
| **Visibility (choose one)** | | | |
| ☐ With elements that almost entirely obscure the characteristics of interest | | | |
| ☐ Has elements that obscure the SGI and prevent the observer from appreciating some characteristics of interest | | | |
| ☐ Has occasional elements that do not prevent the observer from appreciating the entire SGI, albeit with difficulty | | | |
| ☐ The entire SGI is perfectly and easily observable | | | |
| **Rarity (choose one)** | | | |
| ☐ There are several similar sites in the region | | | |
| ☐ One of the few known examples in the region | | | |
| ☐ Only known example in the region | | | |
| ☐ Only known example in Spain (or worldwide) | | | |

| **Diversity (choose one)** |
|---|
| ☐ The SGI only presents the primary type of interest |
| ☐ The SGI presents another type of interest in addition to the primary type, but it is not relevant |
| ☐ The SGI presents 2 other types of interest in addition to the primary type, or only 1, but relevant |
| ☐ The SGI presents 3 other types of interest in addition to the primary type, or only 2, but relevant |
| **Educational content/educational use (choose one)** |
| ☐ Does not fulfil these criteria |
| ☐ Illustrates university teaching content |
| ☐ Illustrates teaching content for any educational level or is routinely used in university teaching activities |
| ☐ It is routinely used in teaching activities for any educational level |
| **Spectacularity or beauty (choose one)** |
| ☐ Does not fulfil these criteria |
| ☐ High relief or large river/large expanse of water (or ice), or notable variety of colours. Also fossils and/or colourful minerals |
| ☐ Presence of two of the first three characteristics. Also fossils and/or colourful minerals |
| ☐ Presence of the first three characteristics. |
| **Informative content/informative use (choose one)** |
| ☐ Does not fulfil these criteria |
| ☐ Clearly and expressively instructs groups with a certain level of culture on the importance or usefulness of Earth sciences |
| ☐ Clearly and expressively instructs groups with any level of culture on the importance or usefulness of Earth sciences |
| ☐ It is regularly used for public outreach activities |
| **Potential for touristic and recreational activities (choose one)** |
| ☐ No potential for either touristic or recreational activities |
| ☐ Potential for either touristic or recreational activities |
| ☐ Potential for both touristic and recreational activities |
| ☐ Activities are already organized at the site |
| **Justification for touristic, recreational, educational and informative interest:** |
| **Proximity to recreational areas (choose one)** |
| ☐ Located more than 5 km from recreational areas (campsites, beaches, etc.) |
| ☐ Located less than 5 km and more than 2 km from recreational areas |
| ☐ Located less than 2 km and more than 500 m from a recreational area |
| ☐ Located less than 500 m from a recreational area |

| **Population density (choose one)** |
|---|
| ☐ Less than 100,000 inhabitants within a radius of 50 km |
| ☐ Between 100,000 and 200,000 inhabitants within a radius of 50 km |
| ☐ Between 200,000 and 1,000,000 inhabitants within a radius of 50 km |
| ☐ More than 1,000,000 inhabitants within a radius of 50 km |
| **Conservation status (choose one)** |
| ☐ Strongly degraded: the site is practically destroyed |
| ☐ Degraded: the site shows significant deterioration |
| ☐ Altered: with damage that prevents the observer from appreciating some characteristics of interest |
| ☐ Good, with alterations: some damage that does not decisively affect the value or interest of the SGI |
| ☐ Good: the SGI in question is practically intact and is well preserved. |
| **Association with other elements of natural and/or cultural heritage (choose one)** |
| ☐ There are no elements of natural or cultural heritage within a radius of 5 km |
| ☐ There is one element of natural or cultural heritage within a radius of 5 km |
| ☐ There are several element of either natural or cultural heritage within a radius of 5 km |
| ☐ There is one or more elements of both natural and cultural heritage within a radius of 5 km |

| **6. PROTECTION** |
|---|
| Does it appear in an existing inventory? YES ☐ NO ☐ |
| Which? |
| **Obviously, if known.** |
| **Existing legal protection measures** |
| Reference and date: |
| URL link: |
| **Protection measures (choose one)** |
| ☐ Site located in a national or natural park, nature reserve, or other area with a management plan and guards |
| ☐ Protected site not subject to a management plan and with no guards. Also, an asset of cultural interest due to its palaeontological/archaeological content |
| ☐ Site located on rural land protected from urbanization by territorial and urban planning laws |
| ☐ Unprotected site |
| **Physical or indirect protection (choose one)** |
| ☐ Site not easily accessible |
| ☐ Site easily accessible, but located far from foot paths and hidden by vegetation |
| ☐ Site easily accessible, near to paths, and only hidden by vegetation |
| ☐ Site with no kind of physical or indirect protection |

| 7. SUSCEPTIBILITY TO DEGRADATION | | |
|---|---|---|
| **Land ownership** | Public (%) | Private (%) |
| **Current land use** | Forest (%) | Livestock (%) |
| Agricultural (%) | Urban development (%) | Other (specify) (%) |
| **Zone status** | Rural land protected from urban development (%) | Rural land not protected from urban development (%) |
| Urban land (%) | | |
| **Land ownership and access regime (choose one)** | | |
| ☐ Site located in areas with unrestricted access | | |
| ☐ Site located in areas with restricted access, private property | | |
| ☐ Site located in areas with restricted access, public property | | |
| **Anthropic threats (choose one)** | | |
| ☐ The key elements of the SGI are not threatened | | |
| ☐ The key elements of the site are located less than 100 m from a main road, 1 km from industrial or mining activity, less than 2 km from urban land in cities with less than 100,000 inhabitants or less than 5 km in larger towns | | |
| ☐ The key elements of the site are adjacent to an industrial or mining activity, with undeveloped urban land or located less than 25 m from a main road. | | |
| ☐ The key elements of the site are located in a mine, on urban land, or bordering a main road | | |
| **Mining or water supply interest (choose one)** | | |
| ☐ No interest or scant interest, not exploited in the area | | |
| ☐ Substance with scant or moderate interest, already exploited in the area | | |
| ☐ Substance with great interest, already exploited in the area | | |
| ☐ Substance with considerable interest, already exploited in the area[2] | | |
| Comments on current or potential anthropic threats: | | |
| **Vulnerability to pillage (choose one)** | | |
| ☐ Palaeontological or mineralogical deposits of low value, easily pillaged | | |
| ☐ Valuable palaeontological or mineralogical deposits, abundant, easily pillaged | | |
| ☐ Valuable palaeontological or mineralogical deposits that are rare and easily pillaged | | |
| ☐ There are no palaeontological or mineralogical deposit, or they are difficult to pillage | | |
| **Natural threats (choose one)** | | |
| ☐ Site not significantly affected by natural processes (geological, biological and/or meteorological) | | |
| ☐ Site affected by natural processes (geological, biological and/or meteorological) of little relevance | | |
| ☐ Site affected by natural processes (geological, biological and/or meteorological) of moderate relevance | | |

[2] In arid areas, if water plays a decisive role in the value of the SGI, check the last box

| | | |
|---|---|---|
| ☐ Site affected by natural processes (geological, biological and/or meteorological) of great intensity | | |
| **Lithological factor (choose one)** | | |
| ☐ Very hard lithologies (quartzites or similar) with little fracturing | | |
| ☐ Resistant or very resistant lithologies, but with extensive fracturing | | |
| ☐ Soft consolidated lithologies, with little fracturing | | |
| ☐ Unconsolidated lithologies, or consolidated but soft and heavily fractured lithologies | | |
| **Size factor (choose one)** | | |
| ☐ Metric features (vulnerable to visits, trampling or human breathing, such as tuffs, speleothems, etc.). | | |
| ☐ Decametric features (not vulnerable to visits, but sensitive to more aggressive anthropic activities, such as stratigraphic sections, etc.) | | |
| ☐ Hectometric features (could suffer some damage due to human activities) | | |
| ☐ Kilometric features (hardly damageable by human activities) | | |
| Intrinsic vulnerability: Yes☐ | No ☐ | Some ☐ |

| **8. USE AND MONITORING** | |
|---|---|
| ☐ No problems for educational use | |
| ☐ Some disadvantages for educational use (comment): | |
| ☐ No problems for touristic or recreational use | |
| ☐ Some disadvantages for touristic or recreational use (comment): | |
| Is fossil collection compatible with site conservation? | ☐ NO ☐ YES |
| For research purposes? ☐ NO ☐ YES | For educational purposes? ☐NO ☐ YES |
| For recreational, non-profit purposes? ☐NO ☐ YES | |
| Is mineral collection compatible with site conservation? | ☐ NO ☐ YES |
| For research purposes? ☐ NO ☐ YES | For educational purposes? ☐NO ☐ YES |
| For recreational, non-profit purposes? ☐NO ☐ YES | |
| Number of visitors per year, if data are available: | |
| Recommendations for the preservation of the SGI as a cultural asset | |
| Recommendations for the recuperation of the SGI as a cultural asset (of special interest for quarries and abandoned mines) | |
| Monitoring: | |

| **9. ADDITIONAL DATA FOR THE ORGANIZATION OF VISITS** | | |
|---|---|---|
| ☐ Lookout | ☐ Tables, benches, etc. | ☐ Marked trails |
| Is it dangerous for visitors? YES ☐ NO ☐ | Specify the danger, if applicable. | |

| | | | |
|---|---|---|---|
| Is there a source of drinking water in the immediate vicinity (<250 m)? YES ☐ NO ☐ | | | |
| **Physical difficulty of the trail** | ☐ Low | ☐ Mean | ☐ High |

| | |
|---|---|
| **Type of access (choose one)** | |
| ☐ No path or trail | ☐ Footpath |
| ☐ Dirt road, requires 4x4 | ☐ Dirt road, accessible by car |
| ☐ Paved road without parking | ☐ Paved road with parking for cars |
| ☐ Paved road with parking for buses | ☐ Tourist train |
| ☐ Boat access | |
| **Wheelchair access:** YES ☐ NO ☐ | |
| **Distance from the site to a paved road (in km):** | |
| **Approximate duration of the trail in hours and minutes, normal speed (in hours):** | |
| **Logistic infrastructures (choose one)** | |
| ☐ Accommodation and catering for groups of up to 20 people within 25 km | |
| ☐ Accommodation and catering for groups of up to 40 people within 25 km | |
| ☐ Accommodation and catering for groups of up to 40 people within 5 km | |
| ☐ Does not fulfil these criteria | |

## 10. DOCUMENTS

| | |
|---|---|
| ☐ Photos with comments | ☐ Sketch with trails, if applicable |
| ☐ Geological Map | ☐ Detailed topographical map |
| ☐ Topographical site map, scale 1: 5,000 to 1: 200,000 | |
| ☐ Field data acquisition | ☐ Bibliographic data acquisition |
| **Author(s) of the site proposal:** | |
| **Author(s) of the data sheet:** | |

## 11. REFERENCING (style guide, pdf document)

a) Journal articles: Heredia, M. and Baltuille, J.M. 1997. Las posibilidades mineras de Cuba en el sector de las Rocas Ornamentales. *Boletín Geológico y Minero*, 108 (6), 47-52.

b) Books: Didier, J. 1973. *Granites and their enclaves*. Elsevier, Amsterdam, 393 pp.

c) Chapters in books: Quesada, C. 1983. El Carbonífero de Sierra Morena. In: Martínez, C. (ed.), *Carbonífero y Pérmico de España*. Instituto Geológico y Minero de España, Madrid, 243-278.

d) Conference papers & proceedings: Delgado, F., Ovejero, G. y Jacquin, J.P. 1971. Localización estratigráfica y medio paleogeográfico de las mineralizaciones (galena y fluorita) de Sierra de Baza (Granada, Spain). *I Congreso Hispano-Luso-Americano de Geología Económic*a, Madrid, 2, 119-128.

e) Unpublished sources: Author or authors, year produced, location.

f) Websites: Title of the website, authors, name of publisher of site and location of the server, date accessed and full URL or Internet address. Example: Kluwer Academic Publishers Information Service (KAPIS), Holland, 24/03/99, http://www.wkap.nl.

- **<u>DEPENDING ON THE NATURE OF THE SGI</u>, fill in one of sections 12 to 15, and the corresponding section 16 to 20.**

| **12. DESCRIPTION: EFFUSIVE IGNEOUS MATERIAL AND PROCESSES** | | | |
|---|---|---|---|
| **Context/Area** | | | |
| ☐ Distensive | ☐ Deep magmatism | ☐ Compressive | ☐ Other |
| **Series:** | | | |
| ☐ Tholeiitic | ☐ Alkaline | ☐ Calc-alkaline | ☐ Other |
| **Lithology:** | | | |
| ☐ Rhyolite | ☐ Dacite | ☐ Trachyte | ☐ Foid bearing trachyte/Ol |
| ☐ Quartz trachyte | ☐ Latite | ☐ Foid bearing latite/ Ol | ☐ Quartz latite |
| ☐ Andesite | ☐ Foid bearing andesite/ Ol | ☐ Qtz andesite | ☐ Basalt |
| ☐ Foid bearing basalt/Ol | ☐ Qtz basalt | ☐ Phonolite | ☐ Basanite/Tephrite |
| ☐ Phonolitic tephrite | ☐ Tephrite/Phonolitic basanite | ☐ Feldspathoidite | ☐ Lamproite |
| ☐ Others (specify): | | | |
| **Textures:** | | | |
| ☐ Aphanitic | ☐ Vitreous | ☐ Porphyritic | ☐ Vesicular |
| ☐ Amygdaloidal | ☐ Fluidal | ☐ Perlitic | ☐ Felsitic |
| ☐ Spherulitic | ☐ Pyroclastic | ☐ Welded | ☐ Others (specify): |
| **Observations on the petrographic and petrogenic profile of effusive rocks** | | | |
| **Lavas:** | | | |
| ☐ Solid (lava flows) | ☐ "Pahoehoe" lavas | ☐ Aa lava flow | ☐ Pillow-lavas |
| **Pyroclastic materials:** | | | |
| ☐ Blocks | ☐ Bombs | ☐ Lapilli | ☐ Coarse ash |
| ☐ Fine ash | ☐ *Tephra* | ☐ Pyroclastic rock | ☐ Tuffite |
| ☐ Epiclastic deposit | ☐ Ignimbrite | ☐ Flows | ☐ *Surges* |
| ☐ Falls | ☐ Others (specify): | | |
| **Associated materials:** | | | |
| ☐ Xenoliths (dragged) | ☐ Gaseous (fumaroles) | ☐ Spatters | ☐ Others (specify): |
| **Observations on the petrographic and petrogenic profile of effusive rocks** | | | |
| **Mineral content** | | | |
| **Fossil content** | | | |

| **13. DESCRIPTION: INTRUSIVE IGNEOUS MATERIAL AND PROCESSES** | | | |
|---|---|---|---|
| **Context/Area** | | | |
| ☐ Distensive | ☐ Compressive | ☐ Anorogenic | ☐ Others (specify): |
| **Series:** | | | |
| ☐ Tholeiitic | ☐ Alkaline | ☐ Calc-alkaline | ☐ Others (specify): |
| **Chemical profile:** | | | |
| ☐ Ultrabasic | ☐ Basic | ☐ Intermediate | ☐ Acidic |
| **Lithology:** | | | |
| ☐ Granite | ☐ Granodiorite | ☐ Tonalite | ☐ Syenite |
| ☐ Qtz syenite | ☐ Foid bearing syenite/Ol | ☐ Monzonite | ☐ Qtz monzonite |
| ☐ Foid bearing monzonite/OI | ☐ Diorite | ☐ Qtz diorite | ☐ Foid bearing diorite/Ol |
| ☐ Gabbro | ☐ Qtz gabbro | ☐ Foid bearing gabbro/Ol | ☐ Norite |
| ☐ Troctolite | ☐ Anorthosite | ☐ Charnockite | ☐ Monzosyenite |
| ☐ Monzodiorite | ☐ Monzogabbro | ☐ Foidolite | ☐ Quartzolite or silexite |
| ☐ Carbonatite | ☐ Lamprophyre | ☐ Peridotite | ☐ Dunite |
| ☐ Hornblende | ☐ Pyroxenite | ☐ Porphyry | ☐ Adamellite |
| **Textures:** | | | |
| ☐ Fine | ☐ Medium | ☐ Coarse | ☐ Porphyritic |
| ☐ Aplitic | ☐ Ophitic | ☐ Pegmatitic | ☐ Doleritic |
| ☐ Cumulative | ☐ Graphic | ☐ Pertitic | ☐ *Rapakivi* |
| ☐ Orbicular | ☐ Ocellar | ☐ Banded | ☐ Gabbroid |
| ☐ Granular | ☐ Poikilitic | ☐ Myrmekitic | |
| **Observations on the petrographic and petrogenic profile of intrusive rocks** | | | |
| **Macrostructure:** | | | |
| ☐ Pluton | ☐ Batholith | ☐ Stock | ☐ Pocket |
| ☐ Laccolith | ☐ Lopolith | ☐ Phacolith | ☐ Conolith |
| ☐ Apophysis | ☐ Lamina | ☐ Layer | ☐ Dam |
| ☐ Sill | ☐ Cone-sheet | ☐ *Ring-dike* | ☐ Others (specify): |
| **Microstructures:** | | | |
| ☐ Augans | ☐ Amygdalas | ☐ Nodules | ☐ Lumps |
| ☐ Xenoliths | ☐ Gabbros | ☐ *Schlieren* | ☐ Phlebites |
| ☐ Breccias | ☐ Stockwork | ☐ Mix | ☐ Other |
| **Observations on intrusive morphologies:** | | | |

| **Facies** | | | |
|---|---|---|---|
| Number | ☐ Normal zonation | ☐ Reverse zonation | ☐ Zonation |
| **Observations on the facies** | | | |
| **Mineral content** | | | |

## 14. DESCRIPTION: SEDIMENTARY MATERIALS AND PROCESSES

| **Continental sedimentary environment** | | | |
|---|---|---|---|
| ☐ Aeolian | ☐ Glacial | ☐ Periglacial | ☐ Fluvial |
| ☐ Alluvial fan | ☐ Lacustrine | ☐ Palustrine | ☐ Slope |

| **Mixed-transitional sedimentary environment** | | | |
|---|---|---|---|
| ☐ Beach-Barrier Island | ☐ Cliff | ☐ Deltaic | ☐ Tidal plain |
| ☐ Estuary | ☐ Lagoon | ☐ Evaporitic | ☐ Coastal |

| **Marine sedimentary environment** | | |
|---|---|---|
| ☐ Reef | ☐ Siliciclastic platform | ☐ Carbonate platform |
| ☐ Sand bank | ☐ Submarine talus - canyon | ☐ Submarine fan |
| ☐ Abyssal-bathyal | ☐ Oceanic basin | ☐ Platform |
| **Observations on sedimentary environments:** | | |

| **Layer geometry:** | | | |
|---|---|---|---|
| ☐ Aggradation | ☐ Progradation | ☐ Retrogradation | ☐ Expansive overlap |
| ☐ Downlap | ☐ Tabular | ☐ Cuneiform | ☐ Other: |

| **Polarity:** | | |
|---|---|---|
| **Continuity:** | ☐ Paraconformity | ☐ Disconformity |
| ☐ Discordance | ☐ Sequence boundary | ☐ Unconformity |
| ☐ Mechanical contact | ☐ Progressive discordance | |

| **Lithological succession:** | | | |
|---|---|---|---|
| ☐ Homogeneous | ☐ Heterogeneous | ☐ Random repetitive | ☐ Rhythmic |
| ☐ Turbiditic | ☐ Cyclic | ☐ Molasse | ☐ Thickening upward |
| ☐ Thickening downward | ☐ Coarsening upward | ☐ Coarsening downward | ☐ Other: |
| Observations on lithological successions: | | | |

| **Sedimentary structures:** | | | |
|---|---|---|---|
| ☐ Fissures | ☐ Raindrop | ☐ Ripple marks | ☐ Dunes |
| ☐ Volcanos | ☐ Hardground | ☐ Flute casts | ☐ Tool marks |

| | | | |
|---|---|---|---|
| ☐ Channels | ☐ D. Granulometry | ☐ Rev. granulometry | ☐ Cross lamination |
| ☐ Cross stratification | ☐ Parallel lamination | ☐ *Chevron* (fishtail) | ☐ Convolute lamination |
| ☐ Sand-waves | ☐ Hummocky | ☐ Olistoliths | ☐ Slumps |
| ☐ Bioturbation-Bioerosion | ☐ Dams | ☐ Travertine | ☐ Supercones |
| ☐ Intraformational breccia | ☐ Bioconstructions and microbial domes | ☐ Other sedimentary structures: | |
| **Origin of sedimentary structures:** | | ☐ Biological origin | |
| ☐ Currents | ☐ Tides | ☐ Waves | |
| ☐ Wind | ☐ Mudflows | ☐ Alluvial flows | |
| ☐ Granular flow | ☐ Fluid flow | ☐ Turbiditic flow | |
| **Observations on the structures and their origin:** | | | |
| **Lithology:** | | | |
| ☐ Conglomerate | ☐ Breccias | ☐ Sand | ☐ Sandstone |
| ☐ Calcareous sandstone | ☐ Silt/Siltstone | ☐ Clay/Argillite | ☐ Marl |
| ☐ Limestone-marl | ☐ Clayey limestone | ☐ Limestone | ☐ Dolomite |
| ☐ Gypsum | ☐ Halite | ☐ Cellular dolomite | ☐ Radiolarite |
| ☐ Diatomite | ☐ Laterite | ☐ Bauxite | ☐ Flint |
| ☐ Phosphate | ☐ Carbon | ☐ Hydrocarbons | ☐ Carbonates |
| ☐ Rudite | ☐ Sandstone | ☐ Mudstone | ☐ Evaporite |
| ☐ Aluminium rich iron ore | ☐ Chemical siliceous | ☐ Organogenic | |
| **Observations on lithologies** | | | |
| **Fossil content:** | ☐ Ammonoids | ☐ Other cephalopods | ☐ Bivalves |
| ☐ Gastropods | ☐ Brachiopods | ☐ Graptolites | ☐ Trilobites |
| ☐ Echinoids | ☐ Bryozoans | ☐ Archaeocyatha | ☐ Cnidarians (corals) |
| ☐ Sponges | ☐ Stromatoporides | ☐ Insects | ☐ Fish |
| ☐ Amphibians | ☐ Reptiles | ☐ Birds | ☐ Ichnites |
| ☐ Mammals | ☐ Hominids | ☐ Ostracods | ☐ Other arthropods |
| ☐ Foraminifera | ☐ Conodonts | ☐ Radiolaria | ☐ Coccolithophores |
| ☐ Microvertebrates | ☐ Mollusca | ☐ Algae | ☐ Other vegetation |
| Observations on fossils: | | | |
| **Mineral content:** | | | |

## 15. DESCRIPTION: METAMORPHIC MATERIALS AND PROCESSES

**Type of metamorphism:**

| | | | |
|---|---|---|---|
| ☐ Orogenic | ☐ Burial | ☐ Ocean floor | ☐ Hydrothermal |
| ☐ Contact | ☐ Dislocation | ☐ Impact | ☐ Regional |
| ☐ Dynamic | ☐ Thermal | | |

**Grade of metamorphism:**

| | | | | |
|---|---|---|---|---|
| ☐ Very low | ☐ Low | ☐ Average | ☐ High | ☐ Very high |

**Metamorphic facies:**

| | | | |
|---|---|---|---|
| ☐ Zeolites | ☐ Green shales | ☐ Albite-epidote-amphibolite | |
| ☐ Almandin amphibolites | ☐ Prehnite-pumpellyite | ☐ Blue shales | ☐ Eclogites |
| ☐ Granulites | ☐ Alb-epi hornfels | ☐ Amphibolite hornfels | ☐ Pyroxene hornfels |
| ☐ Sanidinite | ☐ Amphibolites | | |

**Protolyte:**

| | | | |
|---|---|---|---|
| ☐ Pelitic | ☐ Mafic/Basic | ☐ Quartzitic | ☐ Quartzofeldspathic |
| ☐ Carbonated limestone | ☐ Magnesian | ☐ Calc-silicate | ☐ Ultramafic |
| ☐ Ferruginous | ☐ Carbonaceous | ☐ Bauxitic | ☐ Other |

**Lithology:**

| | | | |
|---|---|---|---|
| ☐ Slate | ☐ Phyllite | ☐ Schist | ☐ Quartz-schist |
| ☐ Mica-schist | ☐ Orthogneiss | ☐ Paragneiss | ☐ Migmatite |
| ☐ Hornfels | ☐ Spotted slate | ☐ Quartzite | ☐ Calcite marble |
| ☐ Dolomitic marble | ☐ Green shales | ☐ Amphibolites | ☐ Granulites |
| ☐ Blue shales | ☐ Eclogites | ☐ Serpentinite | ☐ Chlorite |
| ☐ Talcocite | ☐ Fault breccia | ☐ Cataclasite | ☐ Mylonite |
| ☐ Protomylonite | ☐ Pseudotachylyte | ☐ Rodingite | ☐ Anthracite |
| ☐ Gneiss | | ☐ Metaconglomerates | |

**Observations on lithologies**

**Texture:**

| | | | |
|---|---|---|---|
| ☐ Granoblastic | ☐ Idioblastic | ☐ Hypidioblastic | ☐ Xenoblastic |
| ☐ Lepidoblastic | ☐ Nematoblastic | ☐ Crystalloblastic | ☐ Porphyroblastic |
| ☐ Nodular | ☐ Coronite | ☐ Brecciod | ☐ Cataclastic |
| ☐ Mylonitic | ☐ Vitreous | ☐ Glassy | ☐ Other |

**Texture-structure:**

| | | | |
|---|---|---|---|
| ☐ Spotted | ☐ Grainy | ☐ Phlebitic | ☐ Cataclastic |

| | | | |
|---|---|---|---|
| ☐ Gneissic | ☐ Stromatic | ☐ Foliated | ☐ Crenulated |
| ☐ Agmatitic | ☐ Surreitic | ☐ Schistose | ☐ Reticulate |
| ☐ *Folded* | ☐ Ptygmatic | ☐ Ophthalmic | ☐ Stictolytic |
| ☐ *Schlieren* | ☐ Nebulitic | ☐ Other: | |
| **Observations on textures and texture-structures:** | | | |
| **Mineral content** | | | |
| **Fossil content** | | | |

| **16. DESCRIPTION OF DEFORMATIVE PHENOMENA** | | | |
|---|---|---|---|
| **Style of deformation:** | | | |
| ☐ Rigid | ☐ Plastic | ☐ Gravity-induced | ☐ Combined or mixed |
| **Major deformation structures:** | | | |
| ☐ normal faults | ☐ reverse faults | ☐ mixed faults | ☐ vertical faults |
| ☐ right lateral strike slip fault | ☐ left lat. strike slip fault | ☐ conjugate faults | ☐ undulating faults |
| ☐ fault system | ☐ isolated fault | ☐ other faults | ☐ orientation fault |
| ☐ fault plane | ☐ fault striation | ☐ fault drag | ☐ mineralization |
| ☐ fault rocks | ☐ *roll-over* | ☐ mylonite | ☐ shear |
| ☐ thrust | ☐ fenster | ☐ island thrust | ☐ imbrication |
| ☐ extension joints | ☐ compression joints | ☐ decompression joints | ☐ gash joints |
| ☐ radial joints | ☐ parallel joints | ☐ conjugated joints | ☐ sub-orthogonal joints |
| ☐ joints associated with normal faults | | ☐ reverse joints | ☐ strike slip joints |
| ☐ open joints | ☐ filled joints | ☐ irregular joints | ☐ concentric joints |
| ☐ stylolitic sutures | ☐ anticlinal/antiform | ☐ syncline/synform | ☐ anticlinorium |
| ☐ synclinorium | ☐ *horst* | ☐ graben | ☐ scales |
| ☐ nappe | ☐ diapir | ☐ fold-fault | ☐ folds |
| Orientation of fold axis: | ☐ Isocline angle | ☐ compressed | ☐ closed |
| ☐ open | ☐ gentle angle | ☐ straight axial plane | ☐ inclined axial plane |
| ☐ overturned axial plane | ☐ recumbent axial plane | ☐ Olistostromes | ☐ anisopach folds |
| ☐ isopach-parallel folds | ☐ Gravity folds | ☐ flat folds: | ☐ Other structures: |
| **Minor deformation structures:** | | | |
| ☐ Micro-folds | ☐ Microfractures | ☐ Continuous foliation | ☐ Spatial foliation |

| | | | |
|---|---|---|---|
| ☐ Disjointed foliation | ☐ Crenulation foliation | ☐ Orientation of foliation | ☐ Lineation |
| ☐ Surface lineation | ☐ Penetrative lineation | ☐ Structural lineation | ☐ Mineral lineation |
| ☐ *Boudinage* | | | |
| **Lineation components:** | | Orientation of lineation: | ☐ Mullions |
| ☐ Rods | ☐ Deformed objects | ☐ Other minor structures: | |
| **General observations on deformation structures:** | | | |
| **Land Movements:** | | | |
| ☐ Landslides | ☐ Rockfalls | ☐ Subsidence | |
| ☐ Flooding | ☐ Other land movements: | | |
| **Observations on rock deformation:** | | | |

| **17. DESCRIPTION OF GEOMORPHOLOGICAL FEATURES** | | |
|---|---|---|
| **Element and structural forms** | | |
| ☐ Fault scarp | ☐ Exhumed structural surface | |
| ☐ Fault line scarp | ☐ Substructural surface (erosion/sedimentation) | |
| ☐ Anticline relief | ☐ Escarpment in horizontal layers, rows | |
| ☐ Syncline relief | ☐ Escarpments in monoclinal layers, slopes | |
| ☐ Inverted relief | ☐ Crests, bars | ☐ Other: |
| Observations on structural elements and forms: | | |

| | | | |
|---|---|---|---|
| **Volcanic element and forms** | | ☐ Pyroclastic cone | ☐ Tuff ring |
| ☐ Exogenous/ endogenous dome | ☐ Columnar jointing | ☐ Chimney | ☐ Fumarola, geyser |
| ☐ Explosion crater | ☐ Stratum-volcano | ☐ Piton | ☐ Caldera |
| ☐ Crater with lake | ☐ Malpais lava flow | ☐ Lava flow | ☐ Lava lake |
| ☐ Maar | ☐ Grotto, jameo, tube | ☐ Speleothems in grottos | ☐ Other: |
| Observations on volcanic elements and forms: | | | |

| | | |
|---|---|---|
| **Gravitational morphogenesis** | | |
| ☐ Graded slope | ☐ Ordered alluvium | ☐ Downhill creep |
| ☐ Slope with boulders | ☐ Collapse/Avalanche | ☐ Solifluction |
| ☐ Colluvium | ☐ Landslides | ☐ Terracing |
| ☐ Alluvium cone/talus | ☐ Alluvial flow | ☐ Others: |
| Observations on gravitational morphologies: | | |

| | | | |
|---|---|---|---|
| **Fluvial and runoff morphogenesis** | | | |
| ☐ Ravines | ☐ Rapids | ☐ Valley flow | ☐ Terrace |

| | | | |
|---|---|---|---|
| ☐ Piping | ☐ Waterfall | ☐ Wadi | ☐ Terrace system |
| ☐ Gullies, badlands | ☐ Giant's cauldron | ☐ Flood plain | ☐ Erosive terrace |
| ☐ River scarp | ☐ Braided channels | ☐ Dike, levée | ☐ Non-cyclic terrace |
| ☐ River capture | ☐ Meandriform channel | ☐ Channel runoff | ☐ Travertine terrace |
| ☐ River valley | ☐ Anastomosed channels | ☐ Hanging valley | ☐ Beach pad |
| ☐ Abandoned meander | ☐ Alluvium | ☐ *Rock levees* | ☐ Gorge, canyon |
| ☐ Talweg | ☐ Alluvial fan | ☐ Other: | |
| Observations on fluvial morphologies: | | | |
| **Glacier Morphogenesis** | | | |
| ☐ Glacier/ice sheet | ☐ Sill | ☐ Proglacial cone | ☐ Proglacial cone |
| ☐ Horn | ☐ Glacial boulder | ☐ Proglacial mantle | ☐ Diffluence pass |
| ☐ Cirque | ☐ Striations | ☐ Proglacial terrace | ☐ Transfluence pass |
| ☐ Glacier valley | ☐ Ground moraine | ☐ Lateral/central moraine | ☐ Trough/silted lake |
| ☐ Deepened trough | ☐ Subglacial gorge | ☐ Front moraine | ☐ Erratic boulders |
| ☐ Lake, tarn | ☐ Kame | ☐ Fluvioglacial deposits | |
| Observations on glacial morphologies: | | | |

| | | | |
|---|---|---|---|
| **Periglacial morphogenesis** | ☐ Cirque | ☐ Slope with boulders | ☐ Creep |
| ☐ Padded grass | ☐ Snow moraine | ☐ Rocky ground | ☐ Striated soil |
| ☐ Peat bog | ☐ Stone garlands | ☐ Hydrolaccolith, pingo | ☐ Ploughing boulders |
| ☐ Surface cryoplanation | ☐ Alluvial talus or fan | ☐ Cattle trails, terraces | ☐ Complex movement |
| | | | ☐ Rings, stone circles |
| ☐ Avalanche cones and corridors | ☐ Grèzes litées | ☐ Rock glacier | ☐ Corridor, rock river |
| | | ☐ Gelifluction | ☐ Flows |
| ☐ Polygonal ground | ☐ Others: | | |
| Observations on periglacial morphologies: | | | |

| | | |
|---|---|---|
| **Wind morphogenesis** | | |
| ☐ Wind-weathered rocks | ☐ Parabolic dunes | ☐ Dune field or dune ridge |
| ☐ Deflation troughs | ☐ Barchans | ☐ Dune field with vegetation |
| ☐ Longitudinal dunes | ☐ Transverse dunes | ☐ Fossil dune field |
| ☐ Climbing dunes | ☐ Aeolian mantle | ☐ Interdune furrows |

| | | | |
|---|---|---|---|
| ☐ Ventifacts, pebbles | ☐ Loess | ☐ Ripples | ☐ Other: |
| Observations on wind morphologies: | | | |
| **Lacustrine and endorheic morphosystem** | | | |
| ☐ Permanent pond | ☐ Endorheic area with superficial salinisation, saline beach | | |
| ☐ Seasonal pond | ☐ Swamp | ☐ Water deposits | |
| ☐ Permanent lagoon | ☐ Peat bog | ☐ Lake terrace | |
| ☐ Endorheic area, beach, temporary waterlogging | | ☐ Other: | |
| Observations on lacustrine and endorheic morphologies: | | | |
| **Coastal morphosystem** | | | |
| ☐ Island, islet | ☐ Marine terrace | ☐ Coastal plain | ☐ Submerged or ebb delta |
| ☐ Crag | ☐ Sandspit | ☐ Tidal plain | |
| ☐ Cliff | ☐ Sand bar | ☐ Sandy tidal plain | ☐ Delta Plain, delta |
| ☐ Fossil cliff | ☐ Spit | | ☐ Delta channel |
| ☐ Current abrasion platform | ☐ Tombolo | ☐ Tidal channel | ☐ Abandoned delta channel |
| | ☐ Estuary, marsh | ☐ Abandoned tidal channel | ☐ Delta levée |
| ☐ Boulder or shingle beach | ☐ Schorre | | |
| | ☐ Slikke | ☐ Washover fan | ☐ Channel runoff |
| ☐ Sandy beach | ☐ Low sandy marsh | ☐ Biogenic structure, reef | ☐ Mouth of coastal lagoon, grao |
| ☐ Mud beach | ☐ Coastal lagoon | | |
| ☐ Biogenic beach | | | ☐ Peat bog |
| Observations on coastal morphologies: | | | |
| **Exokarst in saline and carbonate rocks:** | | | |
| | | | |
| ☐ Karst in carbonates | ☐ Doline Field | ☐ Karstic levelling, surface | ☐ Sink hole |
| ☐ Gypsum karst | ☐ Uvalas | | ☐ Upwelling |
| | | | |
| ☐ Other evaporite karsts | ☐ Bare lapiaz | ☐ Semi-bare lapiaz | ☐ Covered lapiaz |
| | ☐ Polje | ☐ Corridor | ☐ Ponor |
| ☐ Canyon, gorge | ☐ Blind valley | ☐ *Hum* | ☐ Natural bridge |
| ☐ *Terra rossa* | ☐ Doline window, sunken | ☐ Karst hills, relief system | ☐ Covered dolina karst, alluvial |
| ☐ Funnel doline | ☐ Flat-bottom doline | ☐ Kamenitzas | ☐ Tuff, travertine mass |
| ☐ Other morphologies: | | | |
| **Endokarst (caves and chasms)** | | **Endopseudokarst** | |

| | | | |
|---|---|---|---|
| ☐ In saline and carbonate rocks: | | ☐ In volcanic rocks | ☐ In other rocks: …………………… |
| Development: | Depth: | No. of mouths: | Main Access: |
| Structure of galleries: | | | |
| Hydrological activity in galleries: | | | |
| General layout: | | | |
| **Difficulty:** | ☐ Easy | ☐ Moderate | ☐ For experts |
| **Classification:** | ☐ Tourist cave | ☐ Controlled access | ☐ Caving |
| ☐ Habitable | ☐ Sink hole | ☐ Resurgence | ☐ Landslides |
| ☐ Simas | ☐ Flood | ☐ Other: | |

| | | | |
|---|---|---|---|
| **Importance of speleothems:** | ☐ Low | ☐ Medium | ☐ High |

| | | |
|---|---|---|
| **Deposits in galleries:** | ☐ Hominids and quaternary vertebrates | ☐ Others |
| **Observations on karstic and pseudokarstic morphologies:** | | |

| | | | |
|---|---|---|---|
| **Chemical weathering morphologies in crystalline and siliceous rocks** | | | |
| ☐ T*or* | ☐ Tafoni | ☐ Altered rocks, alterites | ☐ Ferruginizations |
| ☐ Dome, whaleback | ☐ Tafoni fields | ☐ Lehm | ☐ Argilizations |
| ☐ Gnammas or weathering pits | ☐ Gnamma fields | ☐ Kaolinizations | ☐ Carbonatations |
| ☐ Spheroid weathered rocks | ☐ Ruiniform relief, chaos | ☐ Silicifications | ☐ Salt deposits |
| ☐ Spheroidal jointing | ☐ Polygonal cracks | ☐ Pseudostratification | ☐ Exfoliation |
| ☐ Rocky platform | ☐ Boulder fields | ☐ Rocky doline | ☐ Upwelling |
| ☐ Crestones | ☐ Speleothems (opal, pigotite, evansite, etc.) | | ☐ Other: |
| **Observations on morphologies in crystalline and siliceous rocks:** | | | |

| | | |
|---|---|---|
| **Other forms: polygenic or difficult to assign** | | |
| ☐ Erosion surface | ☐ Flat-topped inselberg | ☐ Depression |
| ☐ Highlands | ☐ Linear Inselberg, ridge, bar | ☐ Exfoliated steptoe |
| ☐ Pediment | ☐ Covered pediment, mixed | ☐ Fanglomerate on foothills |
| ☐ Monadnok | ☐ Conical hill, Mambla | ☐ Sloping glacis, colluvial |
| ☐ Inselberg | ☐ Mound, hill | ☐ Valley of mixed origin |
| ☐ Inselberg with grooving | ☐ Inselberg with alluvium | ☐ Dome |
| ☐ Ruiniform relief, chaos | ☐ Dames coiffés | ☐ Other: |
| **Observations on other morphologies:** | | |

| **18. DESCRIPTION OF HYDROGEOLOGICAL FEATURES** | | | | |
|---|---|---|---|---|
| **Aquifer/Groundwater :** | | | | |
| **Type:** | ☐ Free | ☐ Confined | ☐ Perched | ☐ Mixed |
| **Permeability:** | ☐ porosity | ☐ fracturing | ☐ karstification | |
| **Lithology:** | ☐ Detritic | ☐ Carbonate | ☐ Intrusive igneous | |
| ☐ Volcanic | ☐ Non-carbonate metamorphic | ☐ Permeable materials | | |
| ☐ Mixed or other materials | ☐ Impermeable materials | | | |
| **Infiltration or absorption zone: origin of the water inlet:** | | | | |
| ☐ Precipitation | ☐ Rivers or streams | ☐ Other origins: | | |
| **Lakes and wetlands** | | | | |
| **Genetic classification:** | ☐ Anthropic | ☐ Karstic | ☐ Endorheic | |
| ☐ Glacial | ☐ Tectonic | ☐ Other: | | |
| **Water system:** | ☐ Permanent | ☐ Seasonal | | |
| **Natural springs** | | | | |
| **Type:** | ☐ Spring | ☐ Vauclusian spring | ☐ Diffuse flow | ☐ Brackish |
| **Discharge environment:** | ☐ Subaerial | ☐ Channel | ☐ Lake/wetland | |
| ☐ Coastal subaerial | ☐ Coastal subaqueous | ☐ Other: | | |
| **Estimated flow l/s:** | ☐ Average: | ☐ Maximum: | ☐ Minimum: | |
| **Anthropic work** | | | | |
| ☐ Well | ☐ Excavation | ☐ Drilling | ☐ Artesian | ☐ Mining/gallery |
| **Size:** | Depth | Mean diameter | Length | |
| **Uses:** | ☐ Water supply | ☐ Spa/Thermal | ☐ Recovery/injection | |
| ☐ Mining-industrial | ☐ Mining-medicinal | ☐ Other: | | |
| **Observations on hydrogeological aspects:** | | | | |
| Indicators of former water tables (e.g. old water mills) | | | | |
| Indicators of floods and flood levels: | | | | |
| Other observations: | | | | |

| **19. DESCRIPTION OF MINERAL DEPOSITS AND OCCURRENCES** | | | |
|---|---|---|---|
| Exploited substance(s): | | | |
| Mineral Association: | | | |
| Geology of the deposit or occurrence: | | | |
| Morphology: | | Alterations: | |
| Main Minerals: | | Accessory minerals: | |
| Minerals of interest: | | | |
| **Mineralogical type locality** | ☐ Regional | | ☐ International (IMA) |
| Laws: | | Reserves: | |
| **Status:** | ☐ Active | ☐ Intermittent | ☐ Abandoned |
| **Work:** | ☐ Underground | Strip mining | ☐ Mixed |
| ☐ Waste heaps | ☐ Mining buildings | ☐ Other | |
| **Alternative uses** | current: | | potential: |
| **Observations on mineral deposits and occurrences:** | | | |

| **20. DESCRIPTION OF PALEONTOLOGICAL SITES** | | | |
|---|---|---|---|
| **General characteristics:** | | | |
| Type of site: | | | |
| Size of the outcrop in $m^2$: | | | |
| Length in m: | | | |
| Height in m: | | | |
| ☐ Site with historical significance | | ☐ Existence of characteristic fossils | |
| ☐ Existence of facies fossils | | ☐ Exceptional preservation | |
| ☐ Existence of new taxa | | ☐ Existence of index fossils | |
| ☐ Exceptional density | | ☐ Outstanding diversity | |
| ☐ Paleontological site containing particular species or groups of species | | | |
| ☐ Paleontological site containing local abundance of rare fossils | | | |
| ☐ Paleontological site containing fossils with scientifically important features | | | |
| ☐ Paleontological site where the distribution and orientation of fossils is of extraordinary significance | | | |
| ☐ Paleontological site with sequential changes in fossils | | | |
| ☐ Other interesting paleontological sites: | | | |
| **Fossil content Macrofauna** | | | |
| ☐ Ammonoids | ☐ Other Cephalopods | ☐ Bivalves | ☐ Gastropods |
| ☐ Brachiopods | ☐ Graptolites | ☐ Trilobites | ☐ Echinoids |
| ☐ Bryozoans | ☐ Archaeocyatha | ☐ Cnidarians (Corals) | ☐ Sponges |

| | | | |
|---|---|---|---|
| ☐ Stromatoporides | ☐ Insects | ☐ Fish | ☐ Amphibians |
| ☐ Reptiles | ☐ Birds | ☐ Crustaceans | ☐ Mammals |
| ☐ Hominids | ☐ Others: | ☐ Vertebrate footprints | ☐ Invertebrate footprints |
| ☐ Other icnofossils | | | |
| **Fossil content Microfauna** | | | |
| ☐ Ostracods | ☐ Conodonts | ☐ Radiolaria | |
| ☐ Coccolithophores | ☐ Microvertebrates | ☐ Mollusca | |
| ☐ Benthic foraminifera | ☐ Planktonic foraminifera | ☐ Others: | |
| **Fossil content Macroflora** | | | |
| ☐ Algae | ☐ Lycophytes | ☐ Spheophytes | ☐ Gymnosperms |
| ☐ Angiosperms | ☐ Ferns | ☐ Other vegetation | |
| **Fossil content Microflora** | | | |
| ☐ Carophytes | ☐ Diatoms | ☐ Microbial structures | |
| ☐ Limestone nanoplankton | ☐ Palinomorphs: | ☐ Others: | |
| **Composition** | | | |
| ☐ Aragonite | ☐ Calcite | ☐ Dolomite | ☐ Silica |
| ☐ Sulphides | ☐ Phosphate | ☐ Carbon | ☐ Detritic |
| ☐ Iron hydroxides | ☐ Other: | | |
| **Observations on paleontological sites:** | | | |

## MUSEUM OR COLLECTION FACT SHEET

| 1. IDENTIFICATION OF MUSEUMS AND COLLECTIONS | | | |
|---|---|---|---|
| Code | | | |
| Name | | | |
| **Type of Museum:** | | | |
| ☐ Mineralogical museum | ☐ Palaeontological museum | ☐ Science Museum | ☐ Visitor/ Interpretation centre |
| ☐ Open air museum | ☐ Thematic Museums | ☐ Others: | |
| **Short description:** | | | |
| **Access:** | ☐ Public | ☐ Restricted | ☐ No visitors allowed |

**Mineralogical** museum**:** a museum where mineral collections are mainly exhibited.

**Palaeontological** museum**:** museum where fossil collections are mainly exhibited.

**Science Museum:** museums where aspects related to various experimental sciences are shown.

**Visitor Centre, Interpretation Centre or Classrooms:** centres showing geological or palaeontological material associated with a certain natural space.

**Open air museum:** space where visitors can see materials *in situ*. It often also includes a room where collections of elements taken from the site are exhibited.

**Thematic museums**: museums that exhibit a particular aspect of geology or palaeontology, and include collections of interest. For example, mining museums.

| 2. LOCATION OF MUSEUMS AND COLLECTIONS | | | |
|---|---|---|---|
| UTM X: | UTM Y: | Time zone: | Datum: |
| Address: | | | Post code: |
| Town/City: | | Island (as applicable): | |
| Province: | | Autonomous community: | |
| Geological Region (GEODE): | | | |
| Second order geotectonic unit | | | |

| **3. DESCRIPTION OF MUSEUMS AND COLLECTIONS I** | | | |
|---|---|---|---|
| **Minerals of interest for collections:** | | | |
| ☐ elements | ☐ sulphides and sulfosalts | ☐ halides | ☐ oxides and hydroxides |
| ☐ nitrates | ☐ carbonates | ☐ borates | ☐ sulphates |
| ☐ chromates | ☐ molybdates | ☐ wolframates | ☐ phosphates |
| ☐ arsenate | ☐ vanadates | ☐ silicates | ☐ organic compounds |
| ☐ Others: | | | |

| **Thematic collections** | | |
|---|---|---|
| ☐ From a Spanish mining district | ☐ From several Spanish mining districts | ☐ From almost all Spanish mining districts |

| **Observations on minerals of interest for collections:** | | | |
|---|---|---|---|
| **Minerals of interest for collections:** | | | |
| **Intrusive igneous lithologies:** | | | |
| ☐ Granite | ☐ Granodiorite | ☐ Tonalite | ☐ Syenite |
| ☐ Qtz syenite | ☐ Foid bearing syenite/Ol | ☐ Monzonite | ☐ Qtz monzonite |
| ☐ Foid bearing monzonite/OI | ☐ Diorite | ☐ Qtz diorite | ☐ Foid bearing diorite/Ol |
| ☐ Gabbro | ☐ Qtz gabbro | ☐ Foid bearing gabbro/Ol | ☐ Norite |
| ☐ Troctolite | ☐ Anorthosite | ☐ Charnockite | ☐ Monzosyenite |
| ☐ Monzodiorite | ☐ Monzogabbro | ☐ Foidolite | ☐ Quartzolite or silexite |
| ☐ Carbonatite | ☐ Lamprophyre | ☐ Peridotite | ☐ Dunite |
| ☐ Hornblende | ☐ Pyroxenite | ☐ Porphyry | ☐ Other: |
| **Effusive igneous lithologies** | | | |
| ☐ Rhyolite | ☐ Dacite | ☐ Trachyte | ☐ Traquita with Foides/Ol |
| ☐ Quartz trachyte | ☐ Latite | ☐ Foid bearing latite/Ol | ☐ Quartz latite |
| ☐ Andesite | ☐ Foid bearing andesite/Ol | ☐ Qtz andesite | ☐ Basalt |
| ☐ Foid bearing basalt/Ol | ☐ Qtz basalt | ☐ Phonolite | ☐ Basanite/Tephrite |
| ☐ Phonolitic tephrite | ☐ Tephrite/Phonolitic basanite | ☐ Feldespatoidite | ☐ Lamproite |
| ☐ Others (specify): | | | |

| **Sedimentary lithologies** | | | |
|---|---|---|---|
| ☐ Conglomerate | ☐ Breccias | ☐ Sand | ☐ Sandstone |
| ☐ Calcareous sandstone | ☐ Silt/Siltstone | ☐ Clay/Argillite | ☐ Marl |
| ☐ Limestone-marl | ☐ Clayey limestone | ☐ Limestone | ☐ Dolomite |
| ☐ Gypsum | ☐ Halite | ☐ Cellular dolomite | ☐ Radiolarite |
| ☐ Diatomite | ☐ Laterite | ☐ Bauxite | ☐ Flint |
| ☐ Phosphate | ☐ Carbon | ☐ Hydrocarbons | ☐ Other lithologies: |
| **Metamorphic lithologies** : | | | |
| ☐ Slate | ☐ Phyllite | ☐ Schist | ☐ Quartz-schist |
| ☐ Mica-schist | ☐ Orthogneiss | ☐ Paragneiss | ☐ Migmatite |
| ☐ Hornfels | ☐ Spotted slate | ☐ Quartzite | ☐ Calcite marble |
| ☐ Dolomitic marble | ☐ Green shales | ☐ Amphibolites | ☐ Granulites |
| ☐ Blue shales | ☐ Eclogites | ☐ Serpentinite | ☐ Chlorites |
| ☐ Talcocite | ☐ Fault breccia | ☐ Cataclasite | ☐ Mylonite |
| ☐ Protomylonite | ☐ Pseudotachylyte | ☐ Rodingite | ☐ Anthracite |
| ☐ Other | | | |
| **Observations on rocks of interest for collections:** | | | |
| **Meteorites:** | | | |
| ☐ Stone (lithic) | ☐ Metal (siderites) | ☐ Stony-iron (siderites) | ☐ Tektites |
| **Observations on meteorites:** | | | |

| **4. DESCRIPTION OF MUSEUMS AND COLLECTIONS II** | | | |
|---|---|---|---|
| **Interest for collections. Macrofauna** | | | |
| ☐ Ammonoids | ☐ Other Cephalopods | ☐ Bivalves | ☐ Gastropods |
| ☐ Brachiopods | ☐ Graptolites | ☐ Trilobites | ☐ echinoderms |
| ☐ Bryozoans | ☐ Archaeocyatha | ☐ corals | ☐ Sponges |
| ☐ Stromatoporides | ☐ Insects | ☐ Fish | ☐ Amphibians |
| ☐ Reptiles | ☐ Birds | ☐ crustaceans | ☐ Mammals |
| ☐ Hominids | ☐ Vertebrate footprints | ☐ Invertebrate footprints | ☐ Other icnofossils |
| **Interest for collections. Microfauna** | | | |
| ☐ Ostracods | ☐ Conodonts | ☐ Radiolaria | ☐ Coccolithophores |

| | | | |
|---|---|---|---|
| ☐ Benthic Foraminifera | ☐ Planktonic Foraminifera | ☐ Others: | |
| **Interest for collections. Macroflora** | | | |
| ☐ Algae | ☐ Lycophytes | ☐ Spheophytes | ☐ Gymnosperms |
| ☐ Angiosperms | ☐ Ferns | ☐ Other vegetation | |
| **Interest for collections. Microflora** | | | |
| ☐ Carophytes | ☐ Diatoms | ☐ Microbial structures | |
| ☐ Limestone nanoplankton | ☐ Palinomorphs: | ☐ Other: | |
| **Observations on fossils of interest for collections** | | | |
| **Organic structures of interest for collections** | | | |
| ☐ bioturbation | ☐ stromatolites | ☐ bioerosion | ☐ Other: |
| **Observations on organic structures of interest for collections:** | | | |
| **Sedimentary structures of interest for collections** | | | |
| ☐ *bounce marks* | ☐ *brush cast* | ☐ *crescent marks* | ☐ *groove cast* |
| ☐ *prod marks* | ☐ *roll cast* | ☐ *flute cast* | ☐ *ripples* |
| ☐ *herring bone* | ☐ cross bedding | ☐ flaser bedding | ☐ lenticular bedding |
| ☐ parallel lamination | ☐ convolute lamination | ☐ graded lamination | ☐ ripple lamination |
| ☐ concretions | ☐ nodules | ☐ shrinkage cracks | ☐ raindrops |
| ☐ load marks | ☐ stylolites | ☐ Other: | |
| **Minor tectonic structures of interest for collections** : | | | |
| ☐ microfractures | ☐ lineation | ☐ boudinage | ☐ rods |
| ☐ mullions | ☐ micro-folds | ☐ Other minor tectonic structures: | |
| **Igneous structures of interest for collections** | | | |
| **Metamorphic structures of interest for collections** | | | |
| **Observations on structures of interest for collections:** | | | |
| **Other elements in the museum:** | | | |
| **Best examples:** | | | |
| **Observations regarding exhibiting the collections:** | | | |

| USEFUL INFORMATION FOR CONTINUOUS UPDATES |
|---|
| **Interested museums/collections can submit proposals by completing the form and emailing it to x.x@igme.es**<br><br>**After evaluating the proposal, it may be provisionally included into the IELIG until the next official update process in the corresponding geological region.**<br><br>**If the proposal is not accepted, the sender will be duly informed.** |

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Instituto Geológico
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