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Suitability of Valleys of Cantabria Area for a UGGp Proposal

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Abstract: UNESCO-designated geoparks, intended for conservation, seek to drive economic development via geological heritage education and tourism. Since 2018, within the framework of the European project Atlantic Geoparks (Interreg Atlantic area program), the Valleys of Cantabria project has been promoted to declare a UNESCO Global Geopark (UGGp) in the Cantabria region (northern Spain). The Valles de Cantabria proposal, aligning with UNESCO objectives, evaluates the region's geopark potential, emphasizing sustainable development and societal education. Covering 600 km^2 in eastern Cantabria, the territory involves 19 municipalities and has a population of 60,600. The geological context, ranging from the Triassic to the Quaternary periods, reflects the complex evolution of this territory, which has been influenced by tectonic forces, geomorphological processes, and sea-level changes. Detailed reviews and fieldwork performed by experts, including university researchers, have identified 66 sites of geological interest (SGI). The geosites, which have different geological–geomorphological significances, have been assessed according to their scientific value (including educational importance), potential of use (mainly geotouristic use), and vulnerability or risk of degradation. The geological heritage is directly related to the high biodiversity of the area. The challenges of this territory, such as depopulation and the low income of the inhabitants, can be improved with the declaration of a geopark, which would help to create new job opportunities related to geotourism and sustainable development. UNESCO recognition could catalyse scientific research, address socioeconomic challenges, and foster rural revitalization, strengthening the symbiotic relationship between geoconservation and local economic growth. Collaboration with other Atlantic geoparks has enabled the exchange of experiences that will hopefully deepen in the future. Consequently, the aim of this work is to explore the potential of this territory in terms of high-quality geological features and biological and cultural heritage, as well as to evaluate the socioeconomic context that makes the territory potentially suitable for promoting a UGGp.

Keywords: UNESCO geopark; sites of geological interest (geosites); geotourism; Valles de Cantabria; northern Spain

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1. Introduction

A geopark is an area designated for nature conservation declared by UNESCO to contribute to the economic development of a territory through the dissemination of its geological heritage by means of education and tourism activities [1,2]; this also relies on the biological and cultural heritage of the area.

Geoparks are the cornerstone of geotourism, a concept first defined in 1995 in England [3] as the development of tourism based on visiting the best examples of the geological values of a territory [4]. Geotourism, or geologically based tourism, deals with natural and built abiotic environments [5], combining geological values with other natural values of a biological or sociocultural nature; this can act as a tool for the development of rural environments affected by depopulation.

The UNESCO Global Geoparks Network totals 195 territories spread over 48 countries. Spain, with 16 geoparks, is the largest contributor at the European level and second only to China (41 geoparks) at international level. The last Spanish territory to join the UNESCO Global Geoparks Network was Cabo Ortegal [6]. In 2018, the project Atlantic Geoparks was launched under the auspices of the European Commission, framed in the Interreg Atlantic Area Cooperation Program through the "Transnational promotion and cooperation of the Atlantic Geoparks for sustainable development". This project involved partners from different countries, including eight geoparks in the European Atlantic area (Portugal, United Kingdom, Ireland, and Spain) and two aspiring territories (France and Spain). Despite the significant number of geoparks declared in Spain and due to the great potential that geological values offer to relaunch the economy of depopulated rural areas, a great social interest in promoting new geopark projects persists. Thus, Volcanes de Calatrava [7] is under consideration for declaration in 2024 and three other candidacies (Huellas de dinosaurio de La Rioja [8], Costa Quebrada [9], and Valles de Cantabria [10]) have been working over the last few years to become UGGps. In the present work, we analyse the Valles de Cantabria proposal.

All of the areas must harmonise with the requirements of the National Strategic Plan for Natural Heritage and Biodiversity approved by the Spanish government under the Law 42/2007, on Natural Heritage and Biodiversity. In addition, they have to contribute to the 17 Sustainable Development Goals (SDGs) of UNESCO's 2030 Agenda through the strategy designed by establishing synergies with other geoparks.

The present work analyses the reasoning used by the team who drafted the proposal for the Valles de Cantabria candidacy as a geopark. Are there elements of geological heritage with sufficient scientific value and quality to make them worthy of conservation? Are there other complementary biological and/or sociocultural natural heritage elements? Do the existing elements possess didactic capacities with potential for geotourism? Does the territory need the geopark for its socioeconomic development, as established by UNESCO? Is the proposed territory complementary to other nearby geoparks so that together they can show the geological evolution of the planet? This article intends to provide answers to some of these questions.

The remainder of this manuscript is organised as follows. The first part presents a description of the study area, especially with regard to its geological and geomorphological characteristics. Next, the methodology used to collect and examine the information is presented. This section is followed by the results, with examples of the main geosites identified, their relationship with other natural and cultural values, and the socioeconomic context, highlighting the needs and potentials of the aspiring geopark territory. Finally, within the discussion section, the connections among the aforementioned aspects are illustrated.

1.1. Study Area

The aspiring area is located in eastern Cantabria (Figure 1), bordering the provinces of Burgos (Castile–Leon) and Vizcaya (Basque Country). Its surface covers approximately 600 km^2 and is characterised by steep slopes with heights ranging from 0 to 1600 m above sea level. The distance in a straight line between the coast and the summit areas (to the south) does not exceed 35 km. The proposal includes the participation of 19 municipalities, with a total population of 60,600 inhabitants that increases during summer. The predominant economic activity in the coastal and urban areas is the hospitality and tourism industry, livestock farming still plays a major role in rural environments, and the fishing and the canning industries are predominant in the fishing port areas.

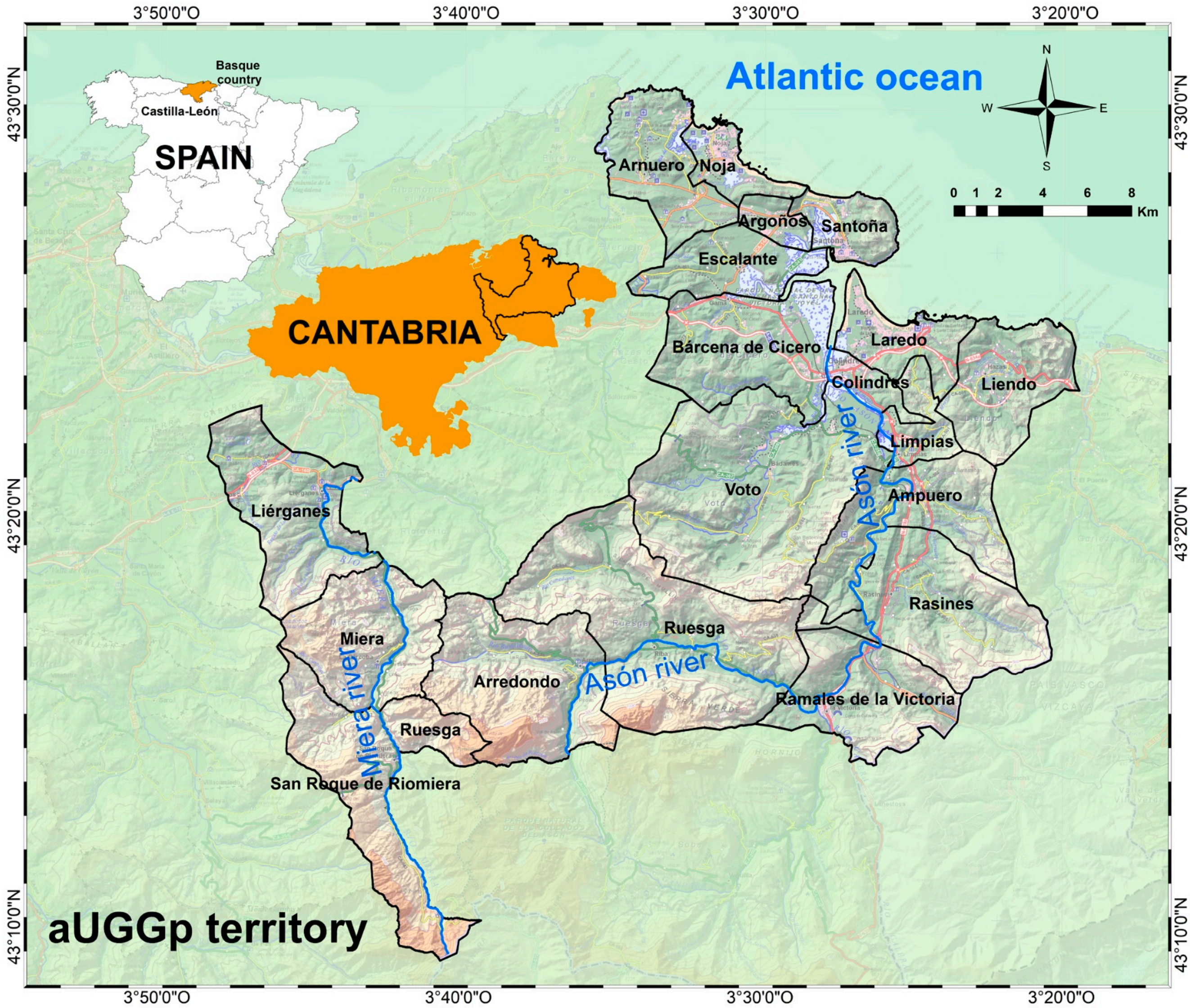


Figure 1. Location of the applicant territory, including municipalities, rivers, and main roads.

1.2. Geological Setting

The aspiring territory is located in the eastern sector of the Cantabrian Mountain Range in the Basque–Cantabrian Basin [11–14], where crop out materials from the Mesozoic (Triassic, Jurassic, and Cretaceous, with ages ranging from 230 to 94 Ma) emerge overlapped by a wide variety of Quaternary deposits (Figure 2).

At the upper Permian (Lopingian) and Lower Triassic, the Atlantic Ocean and the Bay of Biscay began to open. It is in the last stage of the Triassic when the sedimentation of clay and evaporite (Keuper facies) from the Upper Triassic (Norian–Rhaetian, 227–201.3 Ma) takes place, which gave rise to the formation of salt diapirs and constituted the take-off area for the dipping faults originating during the Alpine Orogeny. Volcanic activity during this period is revealed by the intrusion of ophite [15].

During the Lower–Middle Jurassic (ages Pliensbachian, Toarcian, and Aalenian, 190.8–170.3 Ma), the opening of the Atlantic Ocean continued, the Bay of Biscay opened up, and a marine transgression took place, contributing to the deposition of marine sediments (limestones, dolomites, lime-dolomitic breccias, and microcrystalline limestone). The geotectonic evolution changes of the Upper Jurassic modified the sedimentation regime, allowing terrigenous deposits to appear [16]. With the opening of the Bay of Biscay, a large sedimentary basin was created and the Basque–Cantabrian Basin compartmentalised into blocks with horsts and grabens, in which currently a differential accumulation of Mesozoic sediments is present, with an average thickness of up to 15 km.

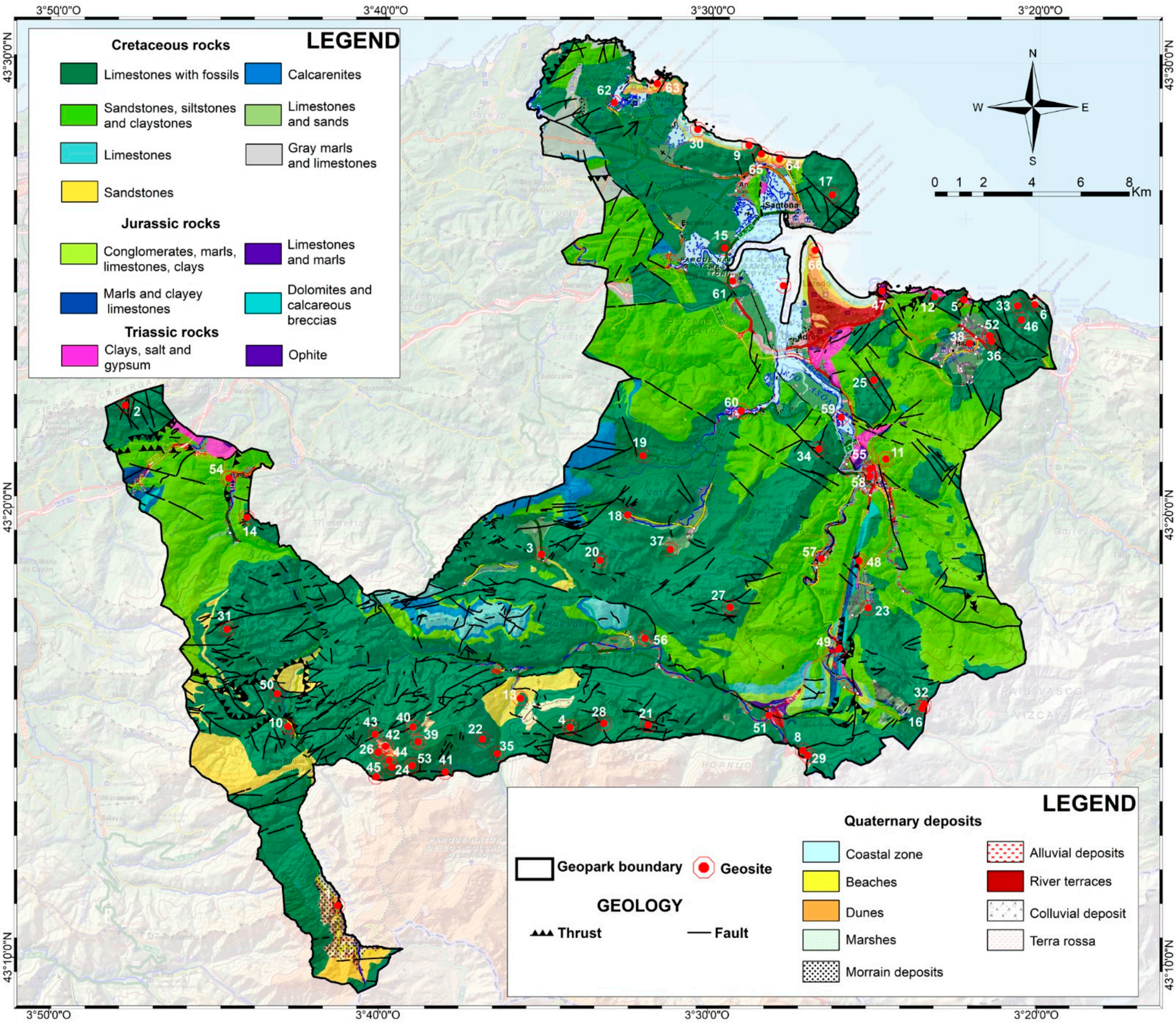


Figure 2. Geological map of the aspiring UNESCO Global Geopark (aUGGp), with the location of the sites of geological importance (SGIs).

The Cretaceous succession [17–22] can be divided into three large groups or complexes that cover, from bottom to top, the following periods: Late Upper Jurassic–Lower Cretaceous, Lower Cretaceous, and Lower Upper Cretaceous (Albian–Cenomanian, 105–93 Ma), with the last two predominating. The first group (Tithonian–Aptian, 152–125 Ma) is mainly composed of detrital materials of continental origin corresponding to alluvial fans that gradually filled up the basin, although, on some occasions, these could also have been deposited in coastal areas (Purbeck–Weald facies). This sedimentation was strongly conditioned by the action of the W–E (Cabuérniga fault) and N–S (Ubierna fault) faults. In the second group (Aptian–Albian, 125–100 Ma), sedimentation is mainly marine, although it is characterised by its lithological variability, with frequent lateral changes of facies (Urgonian complex). This sedimentation was controlled by a series of faults that originated during the rift stage and led to the opening of the Bay of Biscay and by a shallow sea that favoured the development of large reefs on the raised blocks formed by bivalve molluscs, mainly rudists, among which the endemic *Pseudotoucasia santanderensis* stands out. Although carbonates dominate, terrestrial detrital intercalations are frequent and linked to deltaic, coastal, or platform environments. The third group (Albian–Cenomanian; 105–93 Ma) is characterised by variations in the thickness and facies of sediments in a deltaic environment of detrital materials (sandstone and shale); these sediments overlap laterally on the previous group, producing sediment thicknesses greater than 2000 m (Supraurgonian complex).

At the Early Cretaceous, the Iberian plate, pushed by the African plate, collided with the European plate, initiating a phase of deformation that led to the cessation of sedimentation in the basins and the raising of the Cantabrian Mountain Range during the Alpine Orogeny.

From a structural point of view, the materials are deformed by a series of deformation structures typical of a higher structural level. These are folds with a large radius of curvature and brittle-domain faults with mainly N–S and NW–SE orientations. The whole com-plex is affected by a fracture network of traction character with conjugate conditions to the previous ones. There are three important systems of faults in this area showing recent seismic activity [23]. Besides those previously mentioned, corresponding with the original deformation trends and with the deformation existing tensor there are: the eastward prolongation of the Frente Cabalgante de El Escudo de Cabuérniga W–E, called the Arredondo–Ramales fault; the NE-SW Selaya–Arredondo fault, and the S–N Ramales strip. These fractures condition the layout of the main river valleys.

1.3. Geomorphological Setting

Landforms in the area are the result of the dismantling of preexisting relief due to the erosive activity of external agents, leading to landscapes of different morphogenetic environments, such as glaciers, rivers, the sea, karstic processes, and slope movements. The connection between these morphogenetic features provides evidence of the Quaternary climatic evolution and sea-level changes. Furthermore, the geomechanical properties of the bedrocks condition the morphology of the fluvial and slope features. Consequently, river activity eroded the relief, causing the valleys to recede in favour of areas of structural weakness, helped by eustatic sea-level fluctuations, which also facilitated the shaping of the current coastline [24,25]. Regarding the role of sea-level variations, according to the marine isotopic stages (MIS), the erosive process that led to the excavation of the Asón estuary was originated by the last episode of sea-level decline during MIS2–MIS3, with a much lower sea level and the coastline located a few kilometres away from where the present one stands. This marine descent caused the hydrographic network to become encapsulated and the river valleys to be strongly incised below the current level, in favour, in this case, of materials that are not very resistant (Keuper facies) and are intensely tectonised. During MIS1, the end of the glaciation led to a sea-level rise, resulting in the flooding of coastal lowlands (formed by diapiric depressions) and in the transformation of terminal segments of river mouths into estuaries. This initiated a significant sedimentation process, encompassing contributions from both continental and marine sources, including sand, silt, and mud. The subsequent regression meant the progression of beaches and dunes from sand bars, after which, protected from the waves, in some cases semi-enclosed coastal lagoons were formed and finer sediments began to be deposited, developing muddy plains linked to these low-energy conditions during the latest Quaternary. Within these Quaternary deposits, the following are the most relevant: beach deposits, dunes, marshes, terraces, and river deposits [26].

The higher areas show a more abrupt relief, with considerable slopes and elevations (1300–1600 m.a.s.l.) due to the presence of massive reef limestone and stratified limestone, marl, sandstone, and clay. The intermediate areas, with a gentler slope, are composed of sandstone and clay. In lower areas, there are diapiric structures but also limestone that generates a strong and irregular coastline.

During the Late Glacial Maximum (LGM), dated in the Cantabrian range around 44–29 ka [27], the presence of glaciers at heights between 950 and 600 m originated moraine deposits and erosive forms, such as U-shaped valleys and glacial cirques, in the landscape. Within this environment, identifiable glacial forms still remain, both depositional (moraine ridges, closures, dam lakes, glacio-lacustrine deposits, snow-capped moraines, etc.) and erosive features (cirques, snow-capped niches, over-excavation basins, edges, etc.). The moraine front reached the lowest level in Spain [28,29]. Its eastern moraine (very well preserved) serves as a barrier to a group of five very well preserved dam lakes. The western moraine allows the connection of the main moraine chains with those corresponding to five smaller cirques built during the retreat phases towards the headwaters of the valley. The lower moraines (550–600 m) are attributed to the MIS5–6 stages and related to Alpine-type glaciers; the second ones correspond to the MIS2–4 and are related to Pyrenean-type glaciers (900–1000 m). All these morphologies are being partially dismantled by landslides and torrential processes.

The large areas of massive Aptian limestone throughout the territory of the aspiring area have undergone intense karstification, giving rise to a great diversity of karst forms both at surface and depth levels [30–32]. There are extensive areas of limestone pavements and a large number of endokarst forms such as shafts, caves, and other underground conduits that reach developments of kilometres in length. The factors that have determined this peculiar underground Gruyére cheese-like "orography" are the type and nature of the materials that form its relief (easily soluble Cretaceous limestone) and the climate (alternation of cold and hot periods, with different amounts of precipitation in the form of rain or snow), mainly during the Quaternary.

2. Materials and Methods

A working group composed of university professors and researchers from different fields reviewed the documentation available for the territory and investigated the features of potential geological interest and other natural and socioeconomic data to assess the geotourism and educational potential of the area.

The bibliographic review included over 150 bibliographic references on geological–geomorphological aspects; the importance of and interest in this sector of the Cantabrian Mountains has led to an abundance of scientific research over the years. This review was followed by additional analyses and fieldwork, resulting in a list of geological features considered potential sites of geological interest (SGIs). This initial list included both SGIs already contained in existing inventories and new ones not previously catalogued in any official inventories. To obtain a sound SGI inventory, the most significant sites were selected through a semiquantitative evaluation based on the work team knowledge and their expert judgement.

For this evaluation, a worksheet was completed for each geosite according to the methodology proposed in [33] for the Basque Coast Geopark; Figure 3 shows an example. The worksheet presents, in a synthetic and alluring manner, the description, assessment, and characterisation of each SGI. The description includes a brief explanatory text on the peculiarities of the SGI, with graphic material, location, and accessibility. The assessment and characterisation part reflects the intrinsic value, the educational and geotouristic potential, and the vulnerability and risk of degradation of the SGI.

To characterise SGI intrinsic value, the working group considered the type of feature (geomorphological, hydrogeological, tectonic/structural, stratigraphic/sedimentological, paleontological, petrological, paleoclimatic, etc.), geodiversity, and previous literature. The assessment was based on the singularity of the SGI within the geological context, its usefulness as reference model of the geology, its relevance, and its state of conservation. The potential for use was assessed by analysing the comprehensibility of the feature, its aesthetic value, spectacularism and beauty of the environment, observation conditions, accessibility services and infrastructure, and association with other cultural, natural, or recreational elements. Finally, different threats were evaluated for the vulnerability assessment. All variables were weighted from 1 to 4, and the final value for each section was computed using the arithmetic mean; the final SGI catalogue was compiled according to these values.

SGI 1: Miera glacier valley

Intrinsic value: **3.75** (**Very high**)
Potential for use: **3.75** (**Very high**)
Vulnerability: **2.0** (**Medium**)

DESCRIPTION OF THE GEOSITE

This glacial valley stands out as one of the best international examples of glacial morphologies and is included in the list of geological sites of interest by IGME with the number SGI-59003. It is also noteworthy because there are glacial remnants at altitudes around 600 meters, among the lowest in the Iberian Peninsula. During the Pleistocene and Holocene, several glaciations occurred in this area, including the Riss and the Wurm. The maximum glacial development occurred between 44,000 and 29,000 years B.P. Within this environment, both depositional features (moraine ridges, dammed lakes, etc.) and erosional features (cirques, snow niches, etc.) can be found. These morphologies are being partially dismantled by slope and torrential processes.

ACCESS

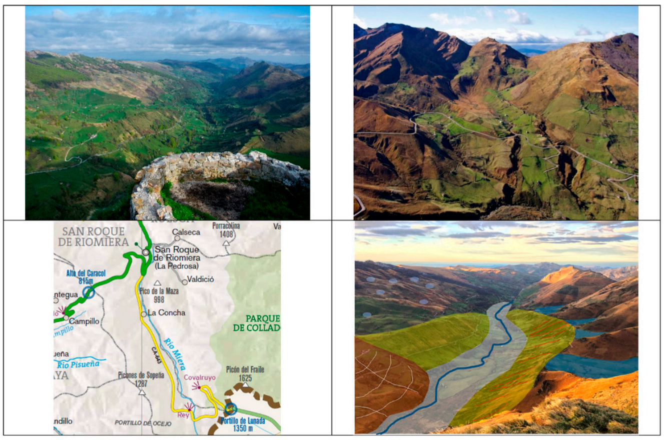
Take the CA-260 road, which starts from the town of Liérganes, and follow the Miera valley. In San Roque de Riomiera, continue towards the Lunada pass through the CA-643.

VIEWPOINT

From the Covalrruyo viewpoint, you can enjoy a spectacular view of the entire ensemble, meaning that from this single point, it is possible to see all the distinctive morphologies of the glacial valley.

COORDINATES UTM//GEOGRAPHICAL

X: 445000; Y: 4780915 // N: 43º 10' W: 3º 40'



SGI 1: Miera glacier valley

INTRINSIC VALUE				
ASSESSMENT	**LOW**	**MEDIUM**	**HIGH**	**VERY HIGH**
Geomorphological				**X**
Hydrogeological				
Tectonic/Structural				
Stratigraphic/Sedimentological				
Paleontological				
Petrological				
Paleoclimatic				**X**
Other				
Geodiversity		Individual	Group	**X**
Bibliometric index: **4**				
Serrano E., González-Trueba JJ., Pellitero R., González-García M., Gómez-Lende M. (2013). Quaternary glacial evolution in the Central Cantabrian Mountains (Northern Spain). Geomorphology 196. 65-82.				

ASSESSMENT	**1 to 4**
Singularity in the geological context	**4**
Useful as a reference model to show processes or regional geology	**4**
Relevance level	**4**
State of conservation	**3**
Average value	**3.75**

POTENTIAL FOR USE (TEACHING/TOURISTIC)	
ASSESSMENT	**1 to 4**
Comprehensibility	**4**
Aesthetic value	**4**
Spectacularity and beauty of the environment	**4**
Observation conditions	**4**
Accessibility to the observation point	**4**
Infrastructure and services	**3**
Association with other cultural or natural elements	**4**
Relation with other elements of recreational nature (beach, trekking, canoeing, boat, mountain bike ...)	**3**
Average value	**3.75**

VULNERABILITY AND RISK DEGRADATION		
ASSESSMENT		**1 to 4**
Intrinsic vulnerability (mainly due to sea level rise)		**3**
Degradation risk: external factors and anthropic causes	Threats to public use (erosion / garbage ...)	**2**
	Current or potential threats from development (infrastructures, buildings ...)	**2**
	Plunder risk	**1**
Average value		**2.0**

Figure 3. Description and assessment form of the Miera Glacier valley geosite.

To evaluate the socioeconomic weaknesses that could justify a need to promote the development of the studied area, the working group analysed the evolution of population data (inhabitants, density, aging rate), available income per capita, and type and evolution of the productive sectors. Possible synergies with other tourist and recreational resources (availability of tourist facilities) were also explored.

Simultaneously, a digital cartographic inventory was prepared; this included the geological, natural, and cultural heritage selected to promote the project according to the criteria proposed for this type of study [34], namely potential for geotourism use, intrinsic or scientific value, type of interest, presence of other complementary values, and existence of conservation designations.

3. Results

The territory analysed has an important geological, biological, and cultural heritage. The main existing elements are presented in order to offer resources related to geotourism and geoeducation that is suitable for all audiences and constitutes an excellent opportunity to promote the socioeconomic development of this area.

3.1. Geosites

The final SGI catalogue includes over 66 sites of geological–geomorphological interest (Table 1; Figure 4). Eight of them are of international importance, five of national, fifteen of regional, and thirty-eight of local importance, and they are included within the following Spanish geological framework of international importance [35]:

- Carbonate and evaporite karst systems in the Iberian Peninsula and Balearic Islands.
- oasts of the Iberian Peninsula.

- The Pb–Zn and Fe mineralization of the Urgonian (Aptian–Albian, 125–100 Ma) in the Basque–Cantabrian Basin.

Table 1. List of sites of geological interest (SGI) of international (code: 1–8) and national (code: 9–38) importance included in the geopark proposal. Geological interest (Ge: Geomorphologic; Pa: Paleoclimatic; St: Structural; Hy: Hydrogeological; Se: Sedimentological; Pe: Petrological; Pal: Paleontological; Str: Stratigraphic; Me: Metallogenic; Cul: Cultural); main use (Sc: Scientific; Ed: Educational; Geot: Geotourism); general description of the geosite.

SGI No	Geosite	Geological Interest	Main Use	Description
1	Valle glaciar del Miera	Ge/Pa	Sc/Ed/Geot	Spectacular example of glacier morphologies
2	Mineralizaciones de Fe en paleokarst de Peña Cabarga	Me	Sc	Global Geosite UR005: Fe deposits as oxides originating from the oxidation of the Aptian dolomites
3	Polje de Matienzo	Hy/Ge	Sc/Ed/Geot	One of the largest poljes in Spain and Europe
4	Sistema hidrogeológico y lapiaces del Mortillano	St/Hy	Sc/Ed/Geot	More than 140 km of underground conduits, cavities, torques, and exokarst
5	Diapiro de Liendo	Ge/St/Pe	Sc/Ed/Geot	A diapiric intrusion that brings Triassic materials into contact with Cretaceous materials
6	Dunas de Sonabia	Ge/Se	Sc/Ed/Geot	The inactive climbing dunes rise the slope of the Candina Mount forming an orthogonal framework
7	Estuario del Asón	Ge/St/Se/Pa	Sc/Ed/Geot	An example of a Cantabrian estuary, lithological and tectonic control related to the sea movements occurred during the Neogene; natural park
8	Cueva de Covalanas	Ge/Cul	Sc/Ed/Geot	Prehistoric site, with paintings from around 20,000 BP, declared World Heritage in 2008
9	Bosque fósil de Trengandín	Se/Pa/Ge/Pal	Sc/Ed	Intertidal fossil forest with peats and abundant tree trunks dated around 3000–4000 years BP
10	Deslizamiento de Ajanedo	St/Ge	Sc/Ed/Geot	An unstable area with a large complex landslide, rock avalanches, and rock-falls
22	Sistema Cueto Coventosa	Hy/Ge	Sc/Ed/Geot	One of the largest and most explored hydrological systems, considered as a sanctuary for the practice of caving
23	Sistema hidrogeológico de Cueva del Valle	Hy/Ge	Sc/Ed/Geot	Karstic development of more than 60 km where the Silencio river rises
38	Depresión de Liendo	Ge/St/Se/Pa	Sc/Ed/Geot	A large depression dating back more than 30,000 years BP, close to the coast, whose origin is being investigated

These SGIs show, among other things: (a) glacial morphologies: glacier circus, ancient glacier lakes, and moraine deposits, which appear at lower altitudes in the Iberian Peninsula; (b) karstic processes: large cavities and pits, underground lakes and rivers, wells, or exokarstic forms (this area represents an exceptional Cretaceous limestone cave system, one of the largest known in the world); (c) coastal-type forms and wind modelling processes: aeolian forms, beach-dune systems, cliffs, estuaries, etc.; (d) fluvial processes and forms: meanders, river captures, or terrace deposits; and (e) paleontological sites represented by the presence of a fossil forest in the coastal area, dating from about 3000 to 4000 years BP.

These elements are of great interest for the study of the climate during the Holocene and to determine the position of the ancient coastline [36].

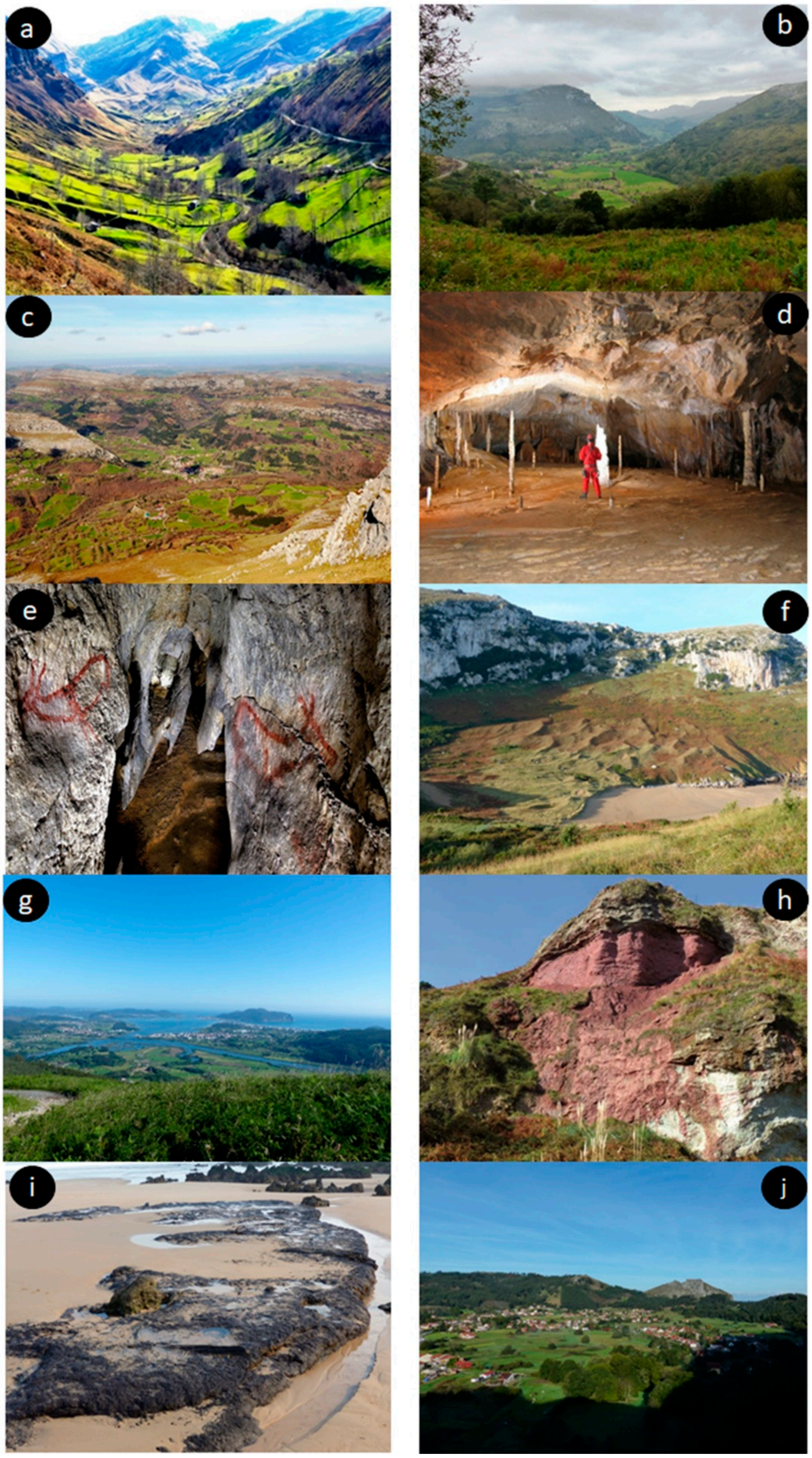


Figure 4. Examples of geosites in the aspiring UNESCO Global Geopark (aUGGp) *Valles de Cantabria*: (**a**) Miera glacier valley (SGI 1); (**b**) Matienzo polje (SGI 3); (**c**) Mortillano hydrogeological system (SGI 4); (**d**) Cueto Coventosa hydrogeological system (SGI 22); (**e**) Covalanas cave World Heritage Site (SGI 8); (**f**) Sonabia climbing dunes (SGI 6); (**g**) Asón estuary (SGI 7); (**h**) Liendo diapir (SGI 5); (**i**) fossil forest in Trengandín beach (SGI 9); (**j**) Liendo depression (SGI 38).

The international and national relevance of the geosites has been proposed because of the existence of bibliographic references and research projects. The sites include: Miera glacier valley [17,27,35,37–44]; iron mineralisation in Peña Cabarga Paleokarst (included in the Global Geosites Project); the Matienzo polje [32,45–47]; the Mortillano hydrogeological system [18,22,48–52]; the Liendo diapir [31,32]; the Sonabia dunes [26,32,42,53,54]; the Asón estuary [24,55–64], and the Covalanas cave, a *UNESCO World Heritage Site* since 2008 [64–66].

A new site of geological Interest called Marismas de Santoña has been recently added to the Spanish Inventory of Geological Sites of Interest (IELIG for its Spanish acronym); this includes the estuary of the Asón River (code CV063) [67].

Among the proposed geosites, glacial and karst morphogenetic systems are the most relevant, due to their originality, size, and state of conservation. The glacial system is composed of five large units or systems, all of them located on the southern edge of the aspiring territory. One of the most representative examples at the international level is the Miera glacier valley (Figures 3 and 5). The glacial forms and deposits present different states of conservation and development; the coexisting forms (cirques, valleys, moraines) were built in different glacial phases, mainly attributed to the MIS2 and MIS3 episodes [29]. The maximum glacial development in this area occurred between 44,000- and 29,000-years BP [28]. Glacial remains appear at elevations around 600 m above sea level, representing the lowest in the Iberian Peninsula. A wide range of slope processes (landslides, rockfalls, mudflows, etc.) act on both glacial deposits and rocky outcrops, dismantling glacial morphologies or acting on the exposed reliefs.

Figure 5. View of the Miera glacier valley from the Covalruyo viewpoint. The valley extends from the village of La Concha (573 m) to its headwaters at Portillo de Lunada (1350 m) and the foothills of Castro Valnera (1718 m) and presents a typical glacial valley shape (a defined U shape), representing one of the best examples of glacial morphology at international level.

The large extension and thickness of massive Aptian limestones (which account for approximately half of the territory) have been affected by intense karstification, resulting in a great diversity of karstic forms, both on the surface and underground. This territory therefore presents extensive karren areas and a large number of endokarstic forms: chasms, caves, and other underground conduits that reach kilometric lengths. Of the 82 largest caves in Spain, 15 are located within this area. The Porracolina System or Alto Tejuelo with 173 km of development (Figure 6) and the Mortillano System with 145 km of development, constitute the 1st and 2nd largest systems in Spain, the 3rd and 6th in Europe, and the 12th and 15th in the world, respectively [68]. The Cueva del Valle System, with 60 km of development, occupies the 4th place in Spain and the 55th in the world. The second largest pit in the world and largest in Spain is also present in this territory: the Gran Pozo MTDE, with a 435 m long vertical drop. This is the fourth largest in volume in the world and the largest in Europe [69]. Some of these caves have been used as shelters, at least for the last 45,000 years, and important Palaeolithic cave art has been found in them, such as the parietal art findings in the Covalanas cave that are around 20,000 years old [70].

Figure 6. Underground karst formations present on the territory of the aUGGp (photo courtesy of J. García-Collado).

It is also worth noting the presence of several poljes in this territory, among which the polje of Matienzo stands out as one of the largest in Spain and Europe, along with others that are less developed. It was formed over the past 2.6 million years, which means that the caves of the region could contain a record of the climate and environmental changes throughout the Quaternary [47]. The intense dissolution of the limestone has produced important deposits of terra rossa in this polje, resulting in excellent agricultural production areas. The 26.4 km^2 Matienzo depression includes 200 km of explored passage.

Of the specified number of geosites selected in the study, almost 70% show high relevance to serve as references for geological heritage in a geopark proposal. A total of 45 of them have obtained a high or very high rating due to their intrinsic value (scientific) and potential for use (educational and geotouristic). Obviously, the highest-rated ones correspond to sites of national and international importance (Table 2).

Table 2. Assessment (minimum value: 1; maximum value: 4) of sites of geological interest (SGIs) presented in Table 1.

SGI No	Geosite	Intrinsic Value	Potential for Use	Vulnerability and Risk Degradation
1	Valle glaciar del Miera	3.75	3.75	2.00
2	Mineralizaciones de Fe en paleokarst de Peña Cabarga	3.50	3.40	1.80
3	Polje de Matienzo	3.75	3.12	1.00
4	Sistema hidrogeológico y lapiaces del Mortillano	3.50	2.87	1.00
5	Diapiro de Liendo	3.50	2.62	2.00
6	Dunas de Sonabia	3.75	3.75	1.50
7	Estuario del Asón	3.50	3.75	2.50
8	Cueva de Covalanas	3.25	3.62	2.75
9	Bosque fósil de Trengandín	3.75	3.75	3.00
10	Deslizamiento de Ajanedo	3.25	3.10	1.00
22	Sistema Cueto Coventosa	3.50	2.87	1.00
23	Sistema hidrogeológico de Cueva del Valle	2.75	3.62	1.75
38	Depresión de Liendo	3.00	3.12	2.25

However, some of them are, at the same time, those that present the greatest risk of degradation, such as the fossil forest of Trengandín (SGI 9), the Covalanas cave (SGI 8), or the Asón estuary (SGI 7). The vulnerability of these geosites responds to different realities. In the first case, it is due to its fragility in the face of natural processes, such as coastal erosion and in the context of rising sea levels; the carrying capacity of visitors is important in the second case, whereas the human pressure due to the diversity and intensity of uses is important in the surroundings of the Asón estuary.

3.2. Biological and Cultural Heritage

Conservation of geological features is closely linked to the safeguarding of biotic elements; the combination of these two elements represents an integral aspect of overall environmental conservation. A total of 39% of the proposed territory is located in protected natural areas: 13 SGIs are located in the Marshes of the Santoña, Victoria, and Joyel Natural Park, 37 are either within a Special Conservation Area, a Special Protection Area for Birds (Natura 2000 Network), or Wetlands of International Importance on the Ramsar Agreement (Ramsar Convention), and 33 are located within one of the Important Bird Areas and Biodiversity (IBA) (Figure 7).

Some of the best examples of the interrelationship established between geological and biological conditions are as follows. A colony of tawny vultures, considered the only one in Europe on sea cliffs, is present on the eastern coast of this territory. The coastal limestone massifs host the best-preserved Cantabrian oak groves (*Quercus ilex*) in northern Spain, a species that bore witness to the environmental conditions of the Paleogene–Neogene, when the climate was warmer and drier. The Santoña Marshes are included in the Ramsar Convention and owe their relevance to their ornithological interest, as these are considered "the most important coastal wetland in the north of the Iberian Peninsula for waterfowl" due to the high number of species and individuals. The role of these coastal wetlands is especially important for a large number of waterbirds on their migration routes, as they are one of the few resting and wintering stations available for seasonal movements between northern Europe and northern Africa.

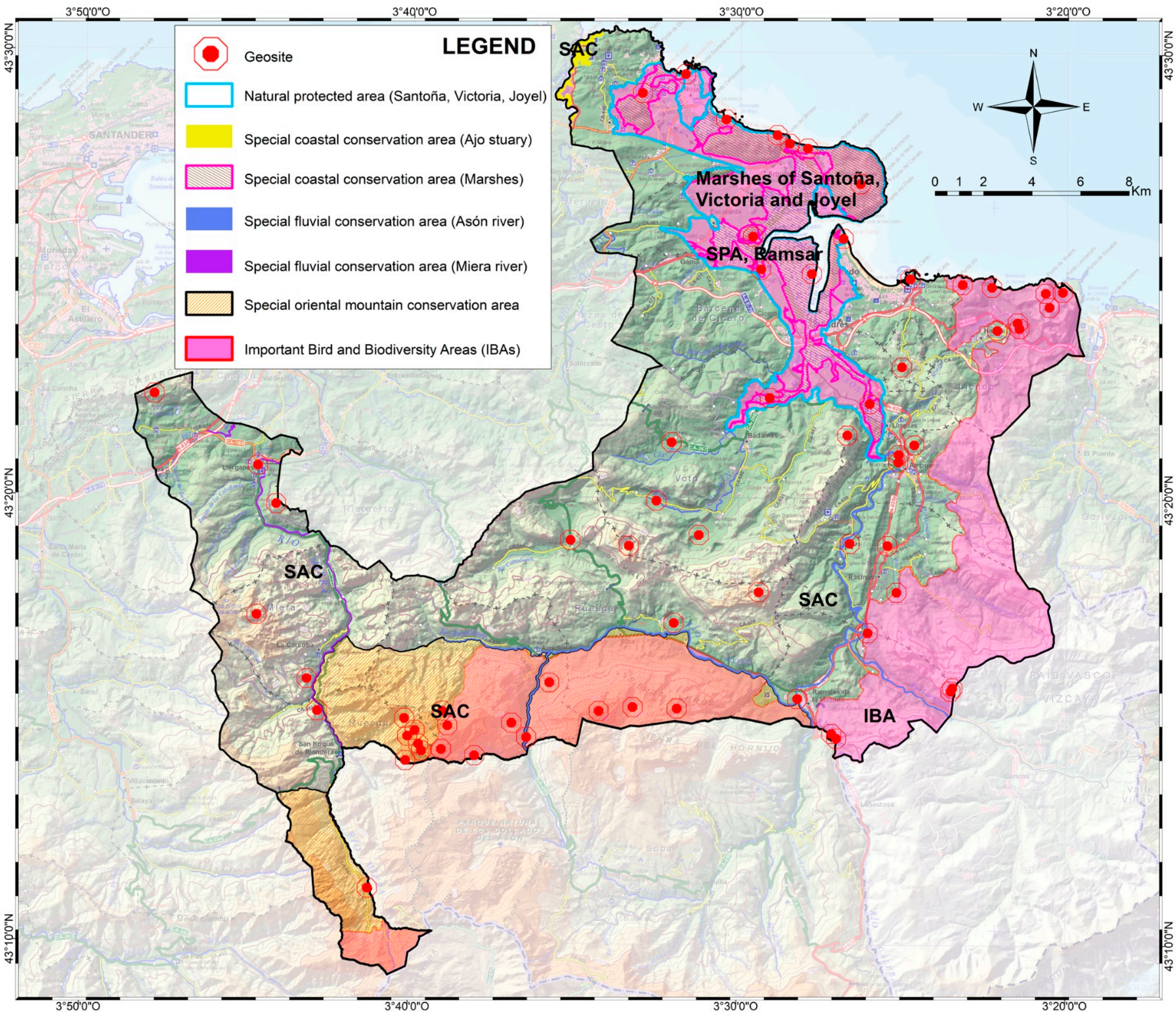
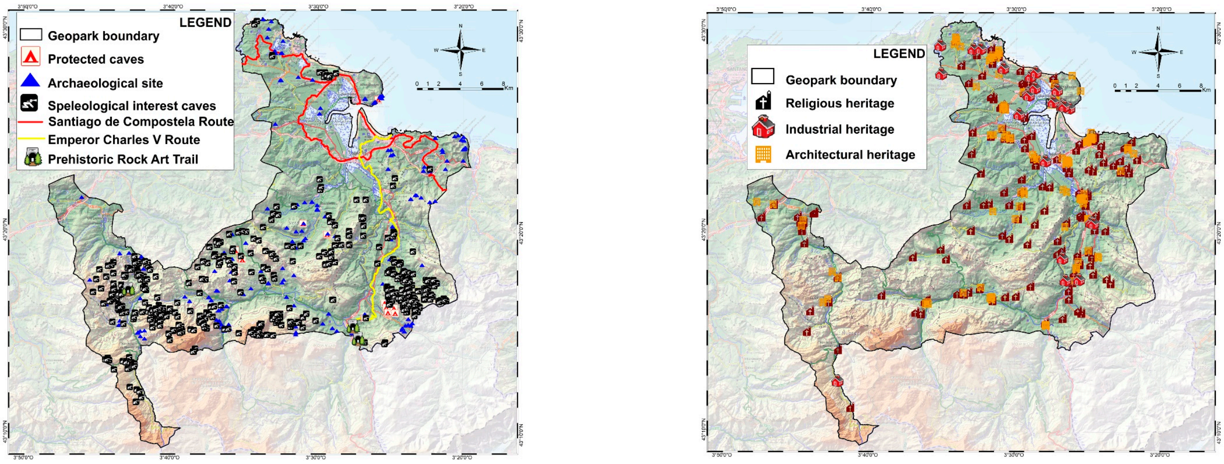


Figure 7. Protected areas within the aUGGp *Valles de Cantabria*.

A large number of historical, cultural, and industrial elements, including an important civil and religious architectural heritage, complements the natural heritage in the future geopark. Archaeological areas, many of them with the remains of ancient human settlements from the Palaeolithic to recent times [37,65], show the human occupation in many of the existing caves or shelters (Figure 8a). In this territory, there is a UNESCO-designated site, the Covalanas Cave, declared a World Heritage Site in 2008 due to the presence of cave paintings. The occupation of the territory by the first humans took place in prehistoric times, at least since the Lower Palaeolithic, up to the present day, when the first manifestations of paintings in caves and shelters appeared. The Covalanas and El Mirón caves constitute an extraordinary archive of information from the past, given that the prehistorians represent more than 40,000 years of human occupation, from the last Neanderthals to the beginning of the Bronze Age [37,71]. It is also worth noting the existence of megalithic constructions (Ilsos or Yelsos) that indicate a human presence in the area during the Neolithic period, which should be highlighted and geoconserved for the use and enjoyment of inhabitants and visitors. In addition, there are 73 Assets of Cultural Interest (BIC) declared by the Government of Cantabria and 10 Assets of Local Interest (BIL), among which are churches, chapels, towers, palaces, mills, etc., (Figure 8b).



(**a**) (**b**)

Figure 8. Inventory of cultural heritage: (**a**) underground explored caves, archaeological sites, protected caves, and Cultural Routes of the Council of Europe; (**b**) religious, architectural, and industrial heritage sites.

3.3. Socioeconomic Context

The studied area, as a whole, shows a stagnation of the population throughout the present century that will be maintained in the next decade, according to the projections of the Cantabrian Institute of Statistics. The population in this area also show relatively low income (about EUR 13,990 average per capita; Table 3 and Figure 9a), especially in rural areas, in comparison with that of the total population of Cantabria (EUR 15,919) and of Spain (EUR 15,817).

The population of the territory analysed is also characterised by an uneven distribution in which the most inner municipalities lose inhabitants at the expense of those located closer to the coast. The population density and ageing rate are both clear indicators of this process, revealing an evident spatial pattern (Figure 9b,c).

This behaviour corresponds to the economic expectations of the inhabitants, who move towards areas with greater diversity of economic sectors, more employment opportunities, and better communications. In rural environments, which make up most of the territory, livestock farming still plays a major role, although the farming of cattle, especially dairy cattle, is in recession (Figure 9d).

Therefore, the municipalities in the studied area present different social and economic characteristics. Combining the indicators used above, more than 50% of the territory has been classified as "Rural Area of Cantabria at Risk of Depopulation" [72] because this meets some of the following criteria: less than 2000 inhabitants, population density less than 12.5 inhabitants/km^2, or ageing rate greater than 30% (Table 3).

As a result, the final picture shows great inequalities in a territory that requires development initiatives and alternative attractive incentives, especially for the population of the most depressed areas.

The goal of the proposal for the Valles de Cantabria candidacy as a geopark is to ensure a sustainable and spatially balanced development that involves the local community and considers their interests and needs. The declaration of this area as a geopark could result in an enhancement of its cultural, historical, and natural potential, which could attract both visitors and residents. This could generate tourism-related jobs and strengthen local identity. In this sense, cooperation and participation initiatives have been created by different organisations to enhance the socioeconomic development of the territory through promotion and conservation actions. The necessary commitments have been made to develop coordination and joint management with the Government of Cantabria, the rural development groups, the Cantabrian Network for Rural Development (RCDR), the Eastern

Coastal Action Group (GAC), and the associations and town councils, that is, all the bodies and institutions present in the territory.

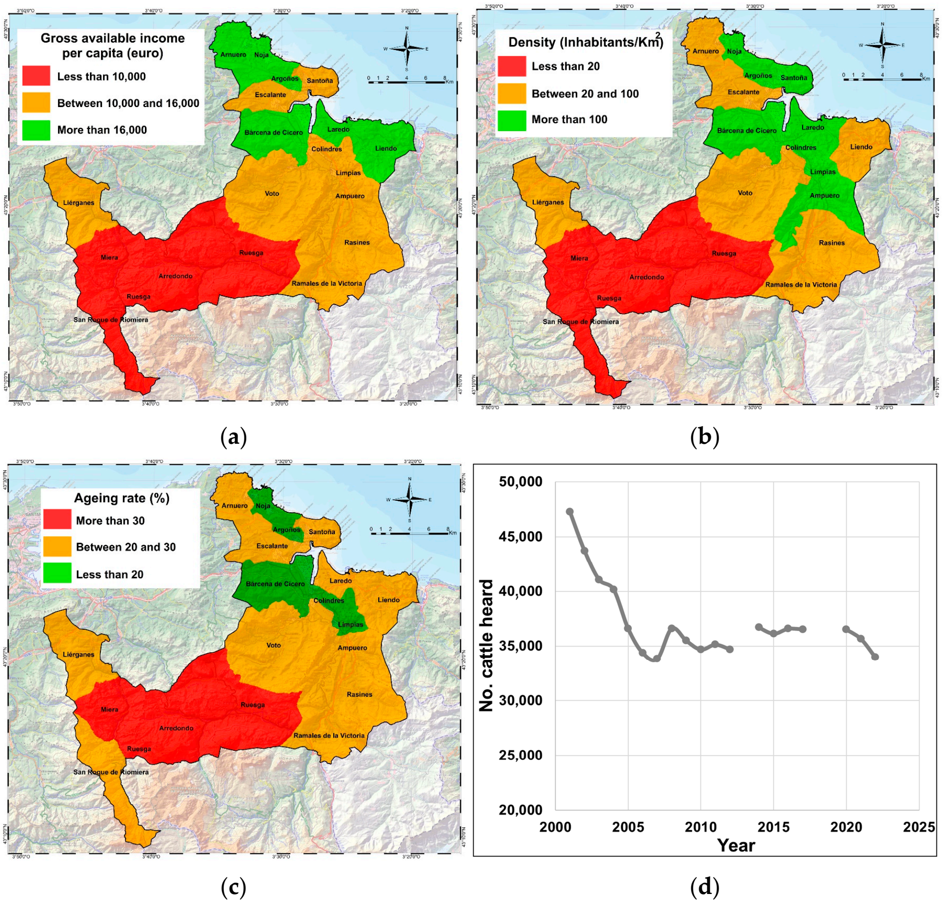


Figure 9. Socioeconomic indicators in 2020: (**a**) income per capita; (**b**) population density; (**c**) ageing rate; and (**d**) evolution of livestock herd during the twenty-first century.

The already existing infrastructure, oriented to sports, historical, and nature activities, could be used and/or adapted to incorporate the diffusion of geological aspects, at both an educational and a touristic level, with relatively little effort and cost. Currently, around 30 active tourism companies offer tourism activities that are always in touch with nature and understanding the geology of the surroundings while respecting it. Bird watching, canyoning, canoe descents, diving, hiking, horseback riding between forests and beaches, kayaking, mountain bike routes, mountain trails and races, orienteering circuits, photographic routes, sea excursions, speleology, surfing, paddle surfing and big sup, via ferrata, and climbing, are some of the activities implemented in the territory that could be related to the dissemination of geological heritage (Figure 10). For example, this territory is internationally known for its varied and rich underground heritage, which has attracted interest from speleologists from different countries since the mid-twentieth century. The Coventosa hydrogeological system is one of the most relevant karstic systems among those most visited by speleologists, not only from Spain but also from other countries, especially UK and France. To promote the value of speleological activities, new itineraries have been proposed within the candidacy, focusing on the most representative karst elements and including visits to underground caves or climbing activities adapted for people with disabilities. From a historical point of view, three routes present in this territory have been recognised as the "Cultural Route of the Council of Europe": the Santiago de Compostela Pilgrim Route, the European Routes of Emperor Carlos V, and the Route of the Prehistoric Rock Art.

Any of these routes can easily be transformed into interpretive trails and viewpoints that address geological, biological, and cultural themes with an integrated approach (Figure 11).

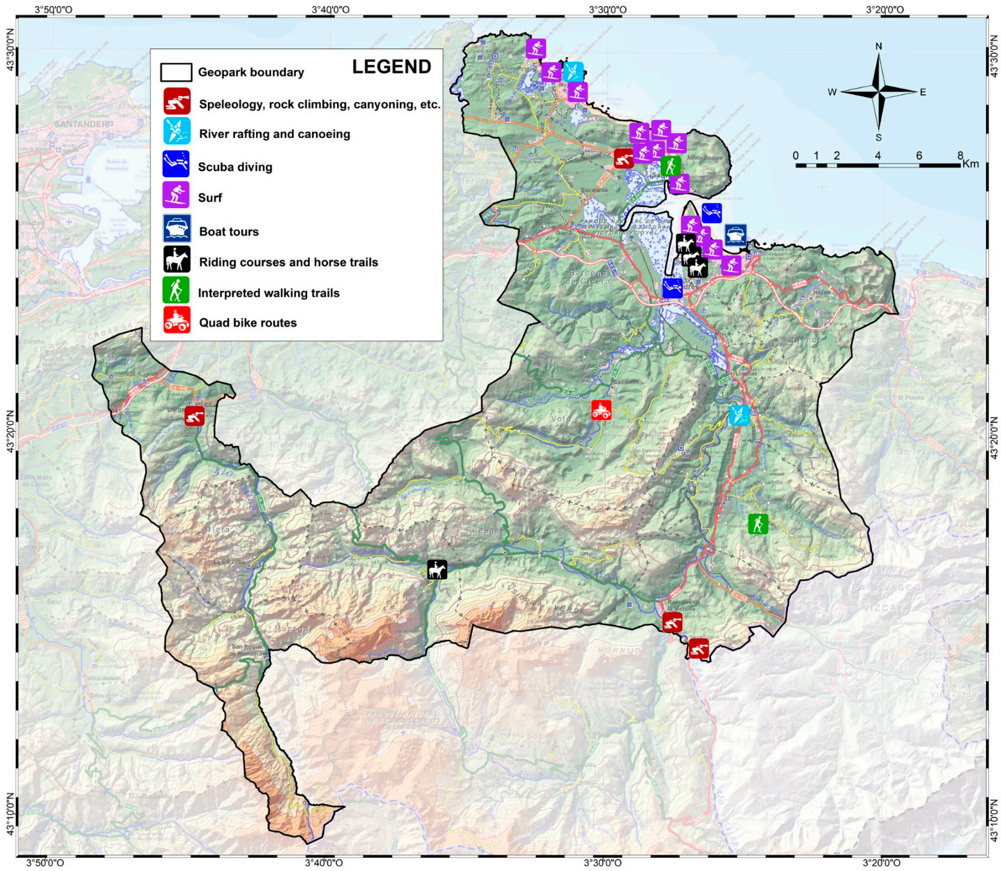


Figure 10. Distribution of active tourism companies linked to geotourism in the aUGGp.

The area has a network of 12 Tourist Information Offices that provide information on the resources of the territory (Figure 12), as well as on the different activities carried out in the area. They also offer general information about existing services and facilities for tourism (accommodation, hospitality, communications, landmarks, viewpoints, etc.). For instance, in collaboration with public administrations, guided visits to farms, workshops related to rural activities, routes traversing various geosites offered by specialised guides, etc., are organised.

Finally, since the primary activity has and has had an important weight in the economy of the area, there is a high number of local producers (more than 40) from the primary sector who depend on agriculture or organic farming, livestock, or fishing. Thus, there is a high quality of agricultural and fishing products and a well-established agro-food industry. Different food products are produced in the territory, such as cheeses, yoghurts, jams, typical sweets wine, vegetables, semi-preserved fish, etc., with quality marks awarded by the Government of Cantabria (D.O., I.G.P., Controlled Quality, Mountain Products, and Certified Organic Agriculture). A database including the local companies or local producers has been compiled (Figure 13). The development of the area based on geotourism and the development of local products could be integrated through the *Geofood* initiative, which has been successful in other geoparks.

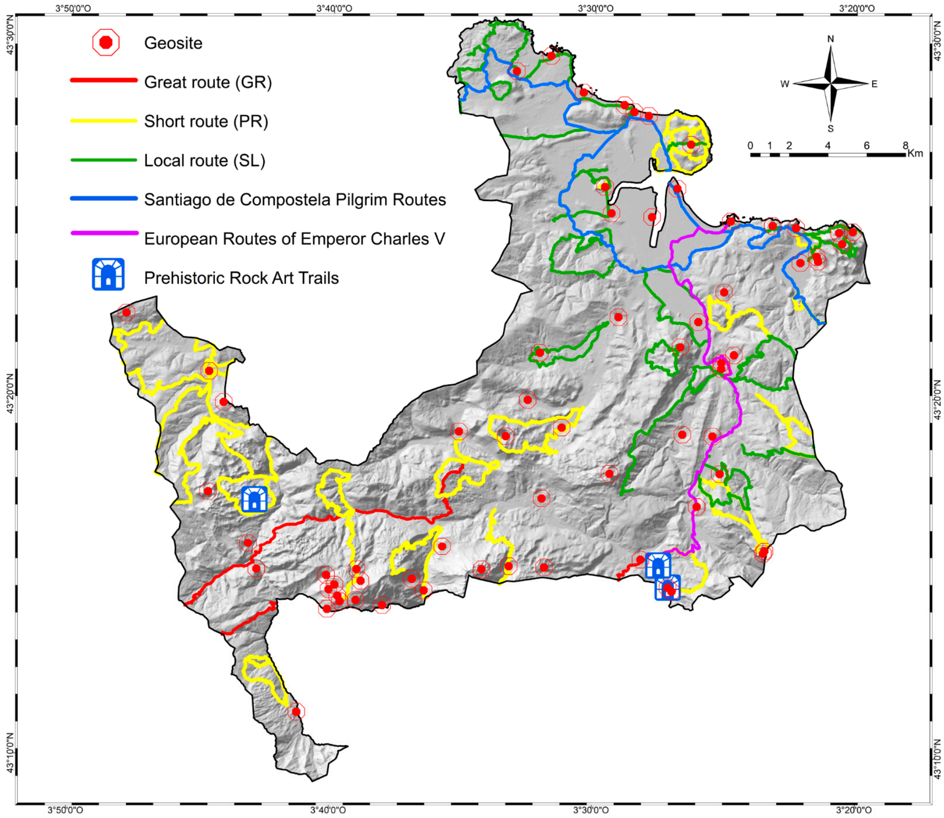


Figure 11. Different routes or trails that cross or go around some of the geosites; some are geointerpreted.

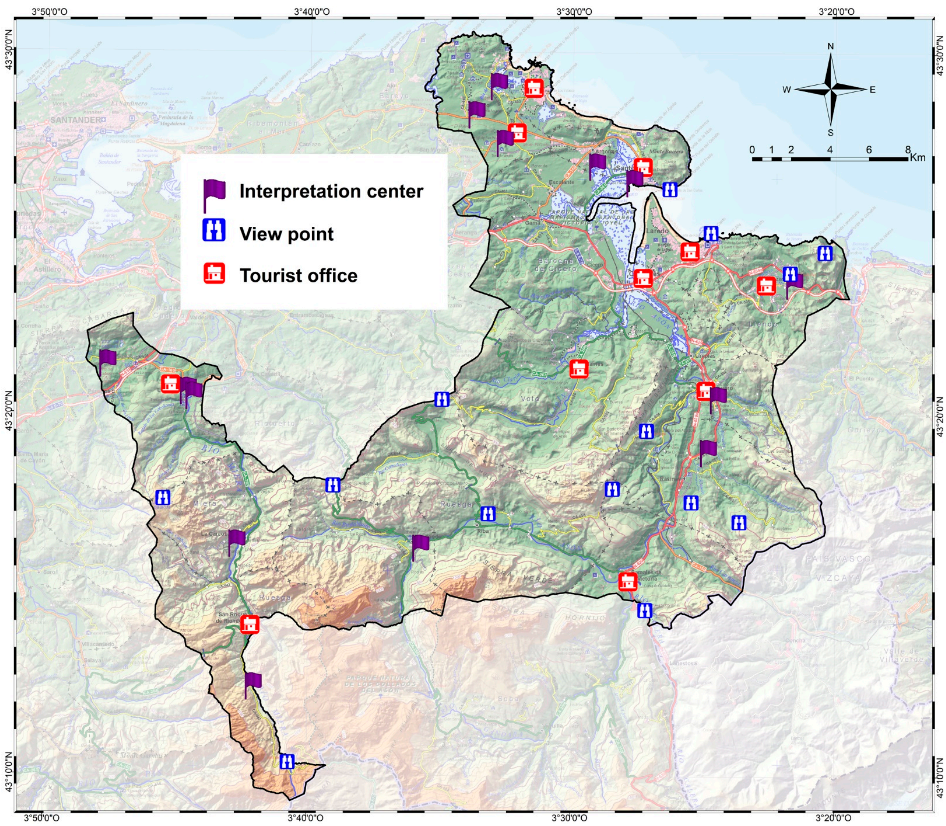


Figure 12. Facilities and infrastructure present in the aUGGp.

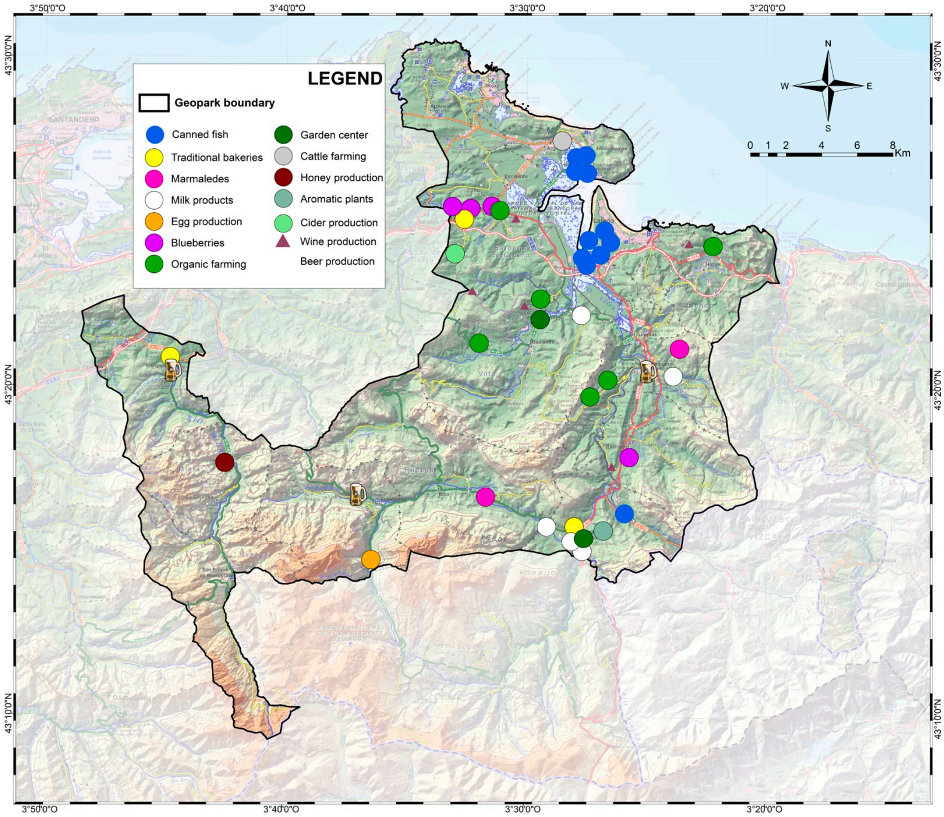


Figure 13. Local producers working in the aUGGp.

Table 3. Municipality data: demographic and socioeconomic characteristics and the risk of depopulation 2020. Data obtained from [73].

Municipality	Area (Km^2)	Inhabitants	Density (Inh/Km^2)	Gross Available Income per Capita (EUR)	Risk of Depopulation
Ampuero	32.3	4319	133.72	14,095	No
Argoños	5.5	1788	325.09	17,434	Yes
Arnuero	24.6	2106	85.61	17,742	No
Arredondo	46.8	452	9.66	9791	Yes
Bárcena de Cicero	36.6	4319	118.01	16,789	No
Colindres	5.9	8598	1457.29	14,683	No
Escalante	19.1	781	40.89	15,422	Yes
Laredo	15.7	11,023	702.1	16,315	No
Liendo	25.9	1196	46.18	18,082	Yes
Liérganes	36.7	2407	65.69	14,576	No
Limpias	10.1	1928	190.89	15,451	Yes
Miera	33.8	381	11.27	6898	Yes
Noja	9.2	2588	281.3	20,534	No
Ramales de la Victoria	34.9	2877	82.44	14,444	No
Rasines	42.9	955	22.26	11,717	Yes
Ruesga	87.9	836	9.51	8927	Yes
San Roque de Riomiera	35.7	345	9.66	5327	Yes
Santoña	11.5	11,019	958.17	13,612	No
Voto	77.7	2686	34.57	13,986	No
Global Geopark	592.8	60,604	102.23	13,991	
Cantabria region	5321.0	582,559	109.48	15,919	

The conservation and dissemination of the geological heritage offers the opportunity to maintain and generate new employment niches that are necessary to fix the population in rural areas while preserving local traditions and villages. The aim is to maximise its potential in order to achieve a more balanced distribution of attractive activities throughout the territory and, therefore, a more equilibrated distribution of population and income.

4. Discussion

This territory has its own signs of identity and an extraordinary natural, cultural, and intangible heritage of great value. The area displays examples of depositional and erosional landforms caused by glacial, karstic, hillslope, fluvial, and coastal processes developed during the Quaternary from materials of the Basque–Cantabrian Basin. Moreover, its geological heritage includes other elements of interest from its geodiversity, such as stratigraphical, structural, mineralogical, or hydrogeological features. Lithostructural control is evident in the configuration of the area, but epirogenic and eustatic fluctuations are also involved. The importance and interest of this sector of the Cantabrian Mountain Range have prompted numerous research works and the area has been studied by different authors over the years [28,48,49,74–77].

The significance and quantity of geosites presented in Tables 1 and 2 (20% of the total inventory) categorised as of international (8) and national (5) interest, would, according to the authors, justify in itself the declaration of this territory as a geopark. The intrinsic value and the potential for use of these geosites account for 60% of the highest scores, indicating their importance based on the evaluation carried out.

In addition, most of them also have a low risk of degradation, which facilitates their use for geotourism and geoeducation. On the other hand, the declaration of the area as a geopark could indeed promote its geoconservation, as it would facilitate the implementation of measures such as restricting access and/or regulating uses.

The environments, processes, and geomorphological landforms are well distributed from the head of the valley to the coastline, showing strong contrasts between the sea and mountains and between the more rural inland and the coastal areas. In addition to the variety of geomorphological elements, the quality and state of conservation of the most outstanding features are also of note. Some of these areas are among the largest and best preserved in Europe because, although somewhat modified by human activities, they essentially retain their nature.

Due to its characteristics, mainly those of a geomorphological nature, this territory could be considered as complementary to those existing in other neighbouring communities, such as the Basque Coast Geopark (Guipuzkoa, Basque Country) and the Las Loras Geopark (Burgos and Palencia, Castile–Leon). These geoparks have collaborated steadily throughout the years and shared experiences that could be applied to the aUGGp presented herein.

Geological features are closely linked to biotic elements whose combination is part of overall environmental conservation. In fact, some of the geosites are located in areas designated for biodiversity protection. The entire territory forms a scenic landscape with a clear geological–geomorphological basis. The limestone massifs serve as genuine topographic landmarks that are scattered and prominent in an environment characterised by lower relief. These act as excellent viewpoints, providing 360° panoramic views of the surrounding areas.

The geosites not only contribute to enhancing the area but also play a crucial role as drivers of socioeconomic development, strengthening the prospects for declaring this area as a geopark. The proposed geopark offers a wide range of diverse landscapes and geosites, providing the territory with significant potential and numerous possibilities for the development of activities related to geotourism and geoeducation that have not been fully explored to date. Also worthy of note are the accessibility and optimal observation conditions of the geosites, which facilitate their management and enhancement, as well as those of the entire territory.

This territory serves as an excellent field laboratory, which facilitates the understanding of the functioning (and its modelling) that affects the Earth system. Due to the good conservation state of the geosites, they are easily identifiable and understandable, even for non-specialists, rendering them suitable for both geoeducational and geotourism activities. An infrastructure is already in place regarding the didactic and recreational use of the natural environment, and this could be used for the promotion of geological resources. In this sense, all materials generated in the proposal preparation could be useful for this purpose.

Obtaining UNESCO status would also encourage the development of a greater number of scientific research projects (some are already underway), which would undoubtedly contribute to a greater knowledge of this territory. By doing so, it would be possible to reconcile the comprehensive knowledge of the geological heritage and its dissemination and enhancement with its conservation in the short, medium, and long terms.

Finally, becoming part of the UNESCO Global Network of Geoparks represents a great opportunity for this area given its severe issues of depopulation and territorial inequalities. An adequate management of these resources could create new job opportunities and contribute to the economic relaunching and community revitalisation of the rural areas. The implementation of actions related to the declaration of a UGGp could constitute a tool for sustainable development in this area. This would contribute to population retention and cohesion in the territory, as well as to the establishment of synergies between urban and rural areas.

In short, geoconservation and socioeconomic development can establish a mutually profitable (win–win) relationship. The preservation of geological resources and their promotion, through sustainable uses, not only contribute to safeguarding geodiversity but also generate opportunities for local economic development.

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