Universidade do Minho
Escola de Ciências

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Geoconservation diagnosis as a tool for aspiring geoparks: a case study in Alto Ricaurte region, Boyacá, Colombia

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Geoconservation diagnosis as a tool for aspiring geoparks: a case study in Alto Ricaurte region, Boyacá, Colombia

ABSTRACT

The Alto Ricaurte region, located in north-eastern Colombia, 160 km from the capital, includes the municipalities of Sáchica, Santa Sofía, Sutamarchán and Villa de Leyva. This territory, a cradle of Colombia's archaeological, historical-architectural, cultural, natural and geological heritage, possesses the necessary components to become a UNESCO Global Geopark. In the region, for example, there are examples of appropriation of geoscientific knowledge by local institutions and social actors, geo-education initiatives, geo-products, examples of successful museum management, ecotourism activities, among others. The area is also an exceptional place to study the relationship between geology and society through the approach of geodiversity values, with remarkable cultural, spiritual and economic values. The work methodology included a literature review, the definition of a conceptual and philosophical model to structure the geoconservation strategy, conversations and interviews with social actors and experts, fieldwork, surveys through the use of geoconservation forms, and analysis of the information. After an assessment based on the recognition of the different services provided by geodiversity to society, as well as the value and usefulness of the local knowledge, it was possible to accomplish a diagnosis of the state of conservation of geodiversity, and to propose a geoconservation strategy. The analysis revealed that the main threats to geodiversity in the area are the private character of the land, territorial expansion, quarrying, tourism pressure and lack of awareness. The proposed geoconservation strategy consists of six key steps: 1. Defining the scope and purpose; 2. Understanding geodiversity and geoheritage; 3. Inventory, assessment and selection of sites; 4. Geoconservation diagnosis; 5. Strategic action plan on geoconservation; 6. Application and monitoring of the strategy. It is hoped that this master thesis will contribute to the comprehension of the geodiversity of the Alto Ricaurte, in addition to territorial planning and geoconservation policies and actions in the area, especially in the context of a possible UNESCO Global Geopark application.

Keywords: Colombia, geoconservation, geodiversity, geoparks, paleontological heritage

Diagnóstico de geoconservação como ferramenta para os geoparques aspirantes: um estudo de caso na região de Alto Ricaurte, Boyacá, Colômbia

RESUMO

No nordeste da Colômbia, a 160 km da capital do país, situa-se a região de Alto Ricaurte, incluindo os municípios de Sáchica, Santa Sofia, Sutamarchán e Villa de Leyva. Este território, berço do património arqueológico, histórico-arquitectónico, cultural, natural e geológico da Colômbia, tem todos os ingredientes necessários para se tornar um Geoparque Mundial da UNESCO. Na região, por exemplo, existem exemplos de apropriação do património geocientífico por instituições e actores sociais locais, iniciativas de geoeducação, geoprodutos, exemplos de gestão de museus, ecoturismo, entre outros. Além disso, é um lugar excepcional para estudar a relação entre a geologia e a sociedade através da aproximação dos valores da geodiversidade, sendo notáveis os valores cultural, espiritual e económico. A metodologia de trabalho incluiu revisão bibliográfica, definição de um modelo conceptual e filosófico para estruturar a estratégia de geoconservação, inquéritos, conversas e entrevistas com actores sociais e especialistas, trabalho de campo, utilização de fichas de geoconservação e análise da informação. Após uma avaliação baseada no reconhecimento dos vários serviços de geodiversidade à sociedade, bem como do valor e utilidade do conhecimento local, foi feito um diagnóstico do estado de conservação da geodiversidade na área, e foi proposta uma estratégia de geoconservação. A análise levou à conclusão de que as principais ameaças à geodiversidade da área são a natureza privada do terreno, a expansão territorial, as pedreiras, a pressão turística e a falta de sensibilização. A estratégia de geoconservação proposta compreende seis passos-chave: 1. Definição de âmbito e objectivo; 2. Conhecimento da geodiversidade e o património geológico; 3. Inventário, avaliação e selecção de sítios geológicos; 4. Diagnóstico da geoconservação; 5. Plano de acção estratégico para a geodiversidade; 6. Implementação e acompanhamento da estratégia. Espera-se que esta tese de mestrado contribua para o conhecimento da geodiversidade de Alto Ricaurte, bem como para políticas e acções de planeamento territorial e de geoconservação na área, especialmente no quadro de uma possível candidatura como Geoparque Mundial da UNESCO.

Palavras-chave: Colômbia, geoconservação, geodiversidade, geoparques, património paleontológico

Diagnóstico de geoconservación como herramienta para geoparques aspirantes: estudio de caso en la region del Alto Ricaurte, Boyacá, Colombia

RESUMEN

Al noreste de Colombia, a 160 km de la capital del país, se encuentra la región del Alto Ricaurte, y en ella, los municipios de Sáchica, Santa Sofía, Sutamarchán y Villa de Leyva. Este territorio, cuna del patrimonio arqueológico, histórico-arquitectónico, cultural, natural y geológico de Colombia, posee todos los ingredientes necesarios para convertirse en un Geoparque Mundial de la UNESCO. En la región, por ejemplo, se encuentran ejemplos de apropiación del patrimonio geocientífico por parte de instituciones locales y actores sociales, iniciativas de geo-educación, geo-productos, ejemplos de gestión museológica, ecoturismo, entre otros. Además, es un lugar excepcional para estudiar las relaciones entre geología y sociedad a través del enfoque de los valores del a geodiversidad, siendo notable los valores cultural, espiritual y económico. La metodología de trabajo incluyó revisión literaria, definición de un modelo conceptual y filosófico para estructurar la estrategia de geoconservación, encuestas, conversaciones y entrevistas con actores sociales y expertos, trabajo de campo, uso de fichas de geoconservación y análisis de la información. Tras una evaluación que se basó en el reconocimiento de los diversos servicios de la geodiversidad a la sociedad, así como del valor y utilidad del conocimiento de los locales, se logró un diagnóstico del estado de conservación de la geodiversidad de la zona, así como proponer una estrategia de geoconservación. El análisis permitió concluir que las principales amenazas a la geodiversidad de la zona son el carácter privado de los terrenos, la expansión territorial, las canteras, la presión turística y la falta de concientización. La estrategia de geoconservación propuesta comprende seis pasos fundamentales: 1. Definición del alcance y el propósito; 2. Conocimiento de la geodiversidad y el geopatrimonio; 3. Inventario, evaluación y selección de sitios geológicos; 4. Diagnóstico de la geoconservación; 5. Plan de acción estratégico para la geoconservación; 6. Aplicación y monitoreo de la estrategia. Se espera que esta tesis de maestría contribuya al conocimiento de la geodiversidad del Alto Ricaurte, así como al planeamiento territorial y a las políticas y acciones de geoconservación en la zona, en especial en el marco de una posible candidatura como Geoparque Mundial de la UNESCO.

Palabras clave: Colombia, geoconservación, geodiversidad, geoparques, patrimonio paleontológico

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Chapter 1. Presentation

This first section briefly presents the study area, the objectives of this Master's dissertation, and the methods that were used to achieve these objectives.

1.1. Introduction and background

In the last 20 years, the interest in the study and conservation of geoheritage has shown significant growth in Colombia. Since 2016, the Colombian Geological Survey (SGC) has been working on a methodology for the national inventory, with a pilot plan in the department of Boyacá. This first departmental inventory used a specific method developed conjointly with the Spanish Geological Survey (IGME) and resulted in an inventory of 83 geological sites for an area of 23.189 km^2 (Servicio Geológico Colombiano, 2016a). The SGC has also worked on other research and dissemination initiatives and projects, which can be consulted on its website. Besides the interest in geoheritage and geoconservation stimulated by SGC projects, numerous academic publications and public events (see section 2.3) resulted in several social actors and communities involved in these topics. In the last years, at least five geopark projects have been launched in Colombia.

The Alto Ricaurte region shelters outstanding geological elements subject to diverse and important research mostly related to the Cretaceous paleontological record. In this area, with several museums dedicated to conservation, education and research, the idea of a geopark project has been promoted since 2020, namely by the Zaquenzipa Geopark project. Due to the presence and support of different public and private institutions interested in the promotion of education, geotourism and geoconservation in the region, the journey for a UNESCO recognition of a geopark has started. Although there is some basis for a geoheritage inventory in the region, there is no detailed information about the conservation status of geological sites in Alto Ricaurte. Moreover, there are no general instructions or guidelines for geoconservation in Colombia at any scale. Given the high potential of the area to be a UNESCO Global Geopark (UGGp) (see Chapter 3), it becomes necessary to make advances in a geoconservation diagnosis and to propose some geoconservation strategies for the region. These diagnoses and guidelines will be an important input for an eventual UNESCO application dossier.

This dissertation deepens in threats and conservation issues of geological sites in four municipalities of the Alto Ricaurte region (Sáchica, Villa de Leyva, Sutamarchán and Santa Sofía) and proposes some general geoconservation guidelines for the territory under the approach of a potential geopark project. These guidelines will comprise both general and specific recommendations, with an emphasis on a broad geoconservation strategy to be followed by stakeholders, decision-makers and management bodies within the geopark project.

1.2. Objectives

The main objective of this master dissertation is to propose some geoconservation strategies for the region comprising the municipalities of Villa de Leyva, Sáchica, Sutamarchán and Santa Sofía, envisaging a UNESCO geopark project.

The specific objectives are:

- To identify the main threats to the geodiversity, and geoconservation issues and challenges in the study area;
- To assess the general conservation status of geological sites in the study area;
- To propose a systematic geoconservation strategy and outline a strategic action plan on geoconservation for the study area;
- To make recommendations for the conservation of geological sites, in terms of management, legal protection, physical protection, land-use planning, potential use and promotion;
- To involve the local communities of the Alto Ricaurte region in the diagnosis of the conservation status of the local geodiversity and geological heritage;
- To include local knowledge and the cultural and spiritual values of geodiversity of the Alto Ricaurte region in the geoconservation strategies.

1.3. Methods

The development of this dissertation followed successive stages represented in figure 1 and detailed below.

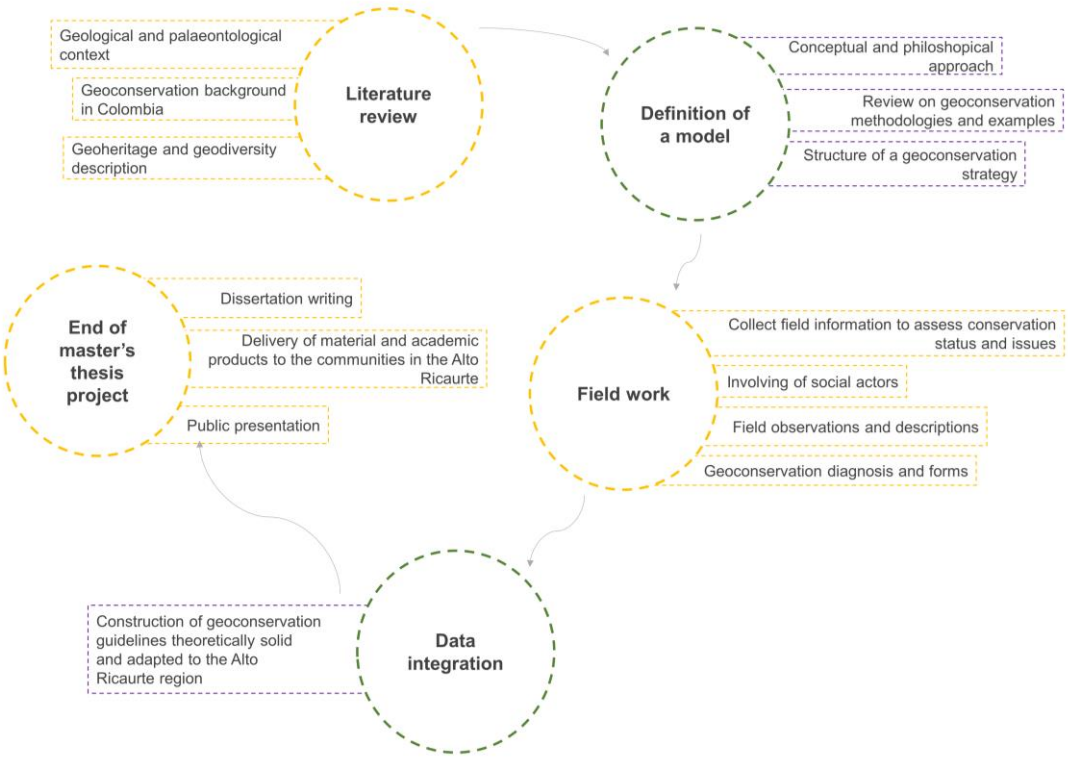


Figure 1. General methodology stages followed in this master dissertation.

The first stage comprised a literature review of the subjects to contemplate in the design of a geoconservation strategy for the study area, namely:

- General literature review on geoconservation methodologies and procedures;
- Geoconservation in UGGp;
- Background and context of geoconservation in geopark projects in Colombia;
- Geological context, geodiversity and geoheritage in the study area;
- General paleontological context and notable paleontological discoveries in the study area;
- Nature conservation problems and potential threats in the territory.

This stage involved the selection of geoconservation basis and strategies to be used as a reference for the construction of geoconservation guidelines for the Alto Ricaurte region. In this respect, the IUCN's Guidelines for geoconservation in protected and conserved areas (Crofts et al., 2020) were used as an important conceptual and philosophical basis for this dissertation. Geoconservation terminology, as well as its definition and importance for nature conservation and society, are clearly explained in this

publication. Moreover, given the UGGp definition, an approach that considers geodiversity as an integral part of nature as supporting biodiversity and providing ecosystem services (Gray, 2011; Van Ree & Van Beukering, 2016; Brilha et al., 2018) is necessary for any methodological design within a geopark project. The key guiding principles for geoconservation in conserved areas management followed during this dissertation are shown in table 1.

Table 1. Key guiding principles for geoconservation in protected areas management (Crofts et al., 2020).

1	The multiple values of geodiversity and geoheritage should be recognised.
2	Effective geoconservation requires a rigorous and systematic approach to all aspects of site identification, assessment, management and monitoring.
3	Management of natural systems should 'work with nature', allowing for natural processes to operate over their full range of variability.
4	Natural systems and processes should be based on sound understanding, and managed in a spatially integrated manner.
5	Geoconservation strategies should include vulnerability and risk assessment.
6	The inevitability of natural change should be recognized.
7	The effects of global climate change should be assessed and acted on as far as achievable.
8	Natural systems should be managed within the limits of their capacity to absorb change.
9	The interaction and interdependency of geodiversity, biodiversity and cultural heritage should be recognised.

The literature revision was also focused on concrete geoconservation methodologies and strategies that have been proposed or applied in other territories. Some of the methodologies analysed include Sharples (2002), Wimbledon et al. (2004), Prosser et al. (2006), Santucci et al. (2009) and Brilha (2016). The geodiversity strategies of Basque Country (Arana & Monge-Ganuzas, 2013) and Andalucia (Junta de Andalucia, 2008) in Spain were particularly useful for the proposed geoconservation guidelines (see Chapter 5). These methodologies encompass diverse practical aspects often ignored or not deepened such as the administrative and institutional framework, land-use planning, the inclusion of geodiversity in environmental administrations, the coordination between institutions, and the need for policies and programmes fostering the conservation of the geodiversity and geoheritage.

After analysing these documents, the geoconservation guidelines were designed on two different levels: a general geoconservation plan and a specific geoconservation strategy to be applied to each geological site (see Chapter 5). The fieldwork allowed:

- To understand the community perception about conservation issues and main threats to local geodiversity and geoheritage;

- To compile information about geodiversity values in the Alto Ricaurte region;

- To collect field information to assess the conservation status of the most relevant geological sites in the study area;

- To involve local communities in the construction of the knowledge about the values, potentials and threats to local geodiversity and geoheritage, including their local knowledge and their cultural and spiritual linkages with geological and landscape elements;

- To evaluate links of the running geopark initiative with the community.

The fieldwork resulted in a rich body of knowledge that was integrated with the definition of a geoconservation model produced in the previous stage, to construct the geoconservation diagnosis (chapter 4) and geoconservation proposals theoretically solid but additionally adapted to the geological, cultural and social conditions in the study area. The data integration resulted in a general diagnosis of geodiversity conservation in the region, a specific diagnosis of the conservation status of the inventoried geological sites, and some proposals for a geoconservation strategy in the region (see Chapter 5).

Chapter 2. State of art about geoconservation in geoparks and other conserved areas

2.1. Introduction

According to UNESCO's website, Global Geoparks are 'single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development' (UNESCO, 2021). Given this definition, geoconservation emerges not only as one of the key strategies within UNESCO Global Geoparks – along with tourism and education – but as a compulsory strategy to achieve the ultimate goal of sustainable development.

As referred by Brilha (2014), the first definitions of geoconservation date back to the early 1990s when in Tasmania, several reports about the inventory of landscapes and sites with "geoconservation significance" were published (Sharples, 1993; Dixon & Duhig, 1996; Dixon & Household, 1996, etc). At that time, geoconservation was defined as "conserving the diversity of earth features and systems ('Geodiversity') and allowing their ongoing processes to continue to function and evolve in a natural fashion" (Sharples, 1993). Almost 30 years after, the definition is more elaborated and geoconservation could be described as "the practice of conserving, enhancing and promoting awareness of those features and underlying processes of geodiversity that have significant scientific, educational, cultural, aesthetic or ecological value" (Crofts and Gordon, 2015; Prosser, 2013 in Gordon et al., 2018).

According to Brilha (2016), the principal steps in the development of an effective geoconservation strategy for an area or a country involve: 1) inventory of geoheritage; 2) assessment of values; 3) conservation; 4) interpretation and promotion where appropriate; 5) monitoring. Recent definitions of geoconservation have underlined its importance for the conservation of the whole of nature (Gray, 2018; Gray, 2019; Gordon, 2019; Crofts et al., 2020). As geodiversity is an integral part of nature, geological heritage is part of the natural heritage of the Earth (IUCN, 2008; IUCN, 2012). Since the elements of geodiversity are part of the natural capital of the Earth and represent the ground on which biodiversity has developed, providing ecosystem and geosystem services (Gray, 2018; Brilha et al., 2018), geoconservation strategies become an essential component of modern holistic nature

conservation, protection and management, and necessary to achieve, for instance, UN Sustainable Development Goals (Gill, 2017). When the important role of the Earth's materials for the development of societies and their activities is recognised, and as a connection of the different spheres on the Earth, geoconservation becomes a must-do (figure 2)

Some general geoconservation strategies and systematic methodologies reviewed in this dissertation are shown in table 2.

Table 2. Example of systematic geoconservation methodologies.

Author	**Elements/Aspects**
Wimbledon et al. (1995)	✓ Defining a subject framework ✓ Identify potential sites within each sub-division of each framework ✓ Select "best" sites by developing and applying existing criteria ✓ documenting each locality selected for conservation ✓ producing, publishing and disseminating the results
Sharples (2002)	✓ Legal and Administrative Instruments and Procedures ✓ Awareness of Issues ✓ Identification of Significant Sites and Processes ✓ Development and Implementation of Management Prescriptions ✓ Monitoring and Indicators
Brilha (2005, 2016)	✓ Inventory ✓ Quantitative assessment ✓ Conservation ✓ Interpretation and promotion ✓ Monitoring of sites
Crofts et al. (2020)	✓ Defining the purpose and operational scale ✓ Making an inventory ✓ Determining site assessment criteria ✓ Examples of geoheritage inventories and assessments ✓ Incorporating geoheritage into national, regional and local action plans ✓ Protection mechanisms ✓ Types of governance ✓ Expertise requirements ✓ International approaches

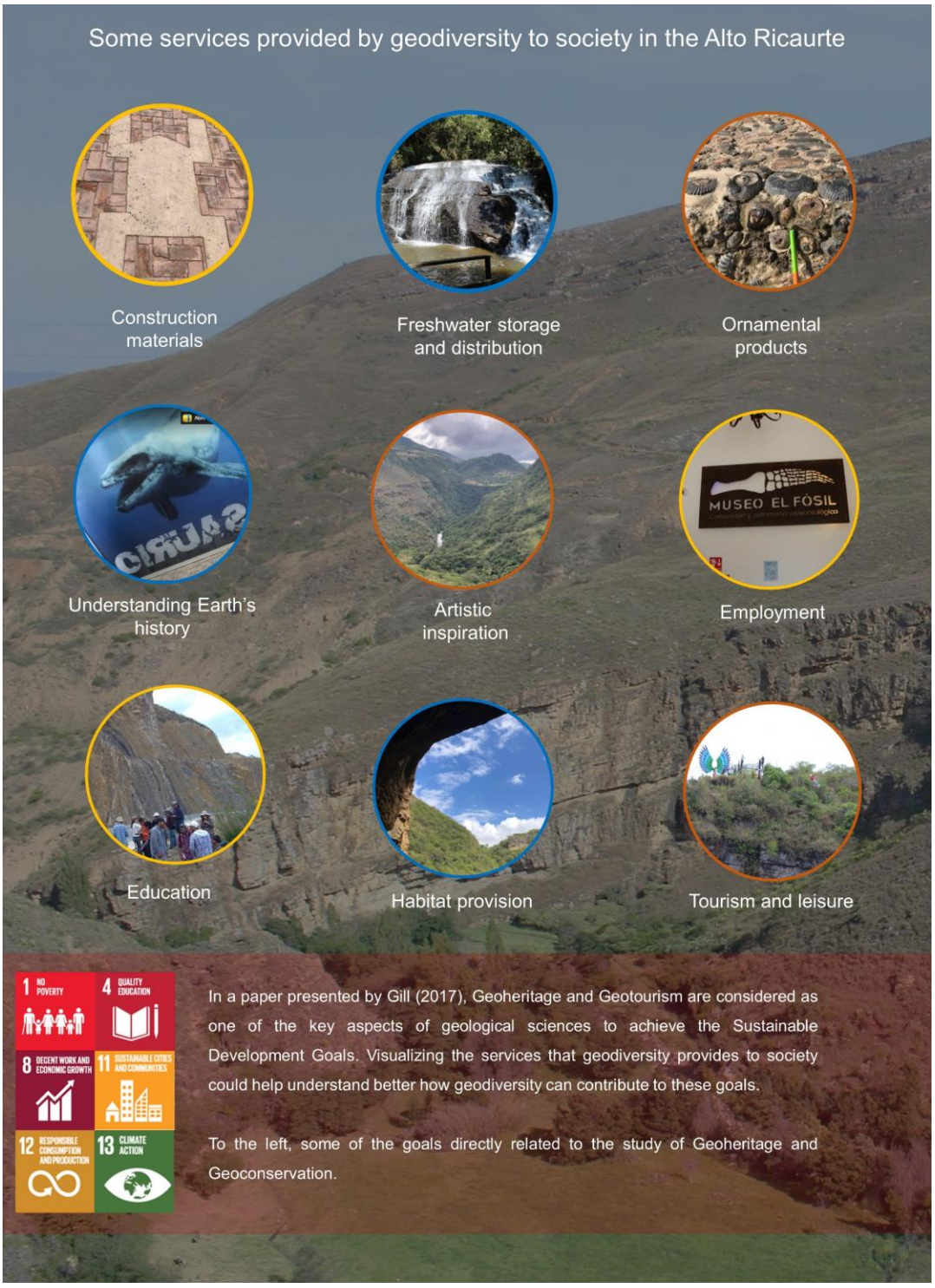


Figure 2. Geodiversity and society. Some services provided by geodiversity in the Alto Ricaurte region. After Gray (2011) and Gill (2017).

2.2. Geoconservation in UNESCO Global Geoparks

Geoconservation is necessarily one of the most urgent tasks to develop within any territory aiming to become a UNESCO Global Geopark. The *Self-Evaluation Checklist for aspiring UNESCO Global Geoparks (aUGGp)* provided by the UNESCO, includes 8 questions related to geoconservation:

- Do you have a aUGGp geological sites database and inventory?
- Do you have a map of the geological sites of your aUGGp?
- Do you have a geological map of your aUGGp?
- Do your most important aUGGp geological sites benefit from a conservation status?
- Do you announce the regulations to prevent misuse and damage?
- Do you provide regular maintenance and cleaning of these sites?
- If you have specific protected fragile geological/geomorphological sites, do you develop protective measures against erosion?
- Is your aUGGp involved in Cultural and Natural conservation?

These questions may serve as a guide to setting conservation goals to meet these requirements and start developing a geoconservation strategy. In the application dossier, four aspects must be detailed regarding geoconservation in the proposed geopark: current potential pressure, current status in terms of protection, data on the management and maintenance of the sites, and a list of non-geological sites.

Several documents and scientific publication were reviewed in the interest of listing the most popular geoconservation actions and strategies that UGGp are implementing around the world. The selection of geoparks was made according to the availability of the information (table 3). From this revision, it can be noticed that the most popular actions for geoconservation include physical protection, interpretation sources, education or socialization, and monitoring schemes.

The Geopark Toolkit (https://www.geoparktoolkit.org/) a website developed to offer advice and support to aspiring and existing geoparks under the auspices of the European Union Interreg-funded Atlantic Geoparks Project (2017-2020), includes a section dedicated to geoconservation.

Table 3. Summary of geoconservation strategies in some UNESCO Global Geoparks

UGG name	Country	Geoconservation strategies	Source
Hong Kong	China	▪ Construction of paths ▪ Signpost and notices ▪ Fencing or structures to avoid physical damage ▪ Imposing of fines ▪ Education ▪ Upgrading existing facilities ▪ Repairing identified damages ▪ Training courses and seminars ▪ Monitoring schemes	Ng et al. (2010)
Lesvos Island	Greece	▪ Regular maintenance (fencing, cleaning) ▪ Custodial services ▪ Protective installations ▪ Treatment of vulnerable geosites ▪ Annual conservation and protective measures ▪ Installation of shelters and stone walls ▪ Interpretation panels ▪ Monitoring system based on the creation of a sophisticated geosite database	Zouros (2010)
Estrela	Portugal	▪ Implementation of Integrated Management Areas (IMA) ▪ For each IMA, a Management Plan that will include, among others, detailed maps, characterization of geosites, existing routes, elements of cultural interest, tourist infrastructure, monitoring of susceptible areas, strategic plans	Gomes et al. (2018)
Napo Sumaco *aspiring	Ecuador	▪ Exploration and characterization of caves ▪ Socialization with local communities ▪ Identification of caves suitable for geotourism activities	Sánchez Cortés et al. (2018)
Las Loras	Spain	▪ Statutory protection ▪ Geosites monitoring ▪ Interpretation resources ▪ Scientific activities	Canesin et al. (2020)
Molina & Alto Tajo	Spain	▪ Statutory protection ▪ Geosites monitoring ▪ Interpretation resources ▪ Sites in the Global Geosites Program	Canesin et al. (2020)
Azores	Portugal	▪ Geosite Monitoring ▪ Management through protected areas figures ▪ Involving territorial planning instruments ▪ Interpretation material ▪ Educational programs on geoconservation ▪ Training courses	Lima et al. (2018)

According to this tool, geoconservation priorities may vary according to the nature of the geopark, and they can be:

- Site conservation
- Develop a geoconservation agenda and relevance of geoconservation to society
- Interpretation, outreach and policies

Also, some geo-management actions can help the geopark to meet its geoconservation goals. Some typical actions include:

- Auditing / Inventory of sites and collections
- Engaging with national designating bodies
- Conservation proposals for sites
- Managing access and visitor expectations
- Identifying interpretation opportunities

2.3. Geoconservation in Colombia

Alike the rest of the world, geological features and resources have been side-lined from the history of nature conservation in Colombia. Considering the magnificent biodiversity of the country, ranked as the first biodiversity country per kilometre squared in the world (World Wildlife Fund, 2017), it is understandable that most nature conservation laws and actions address biodiversity and neglect the "not living" part of nature, geodiversity.

More than 200 years ago, Alexander von Humboldt had noted, in its famous *Naturgemälde*, that the outstanding biodiversity of the Andean region was connected with the rocks, active volcanoes and geological processes in the area, and that nature was a complex network of which the human being is part (figure 3) (Wulf, 2015). Modern studious of geodiversity have also concluded that geodiversity is the basis of biodiversity, and that is impossible to protect biodiversity without considering the rocks, soils and landforms in which these lifeforms have developed, and argue for a more integrated approach (Reverte *et al.*, 2000; Alahuhta *et al.*, 2020; Crofts, 2019). In a territory with such biodiversity, geodiversity and geoconservation issues become relevant. Furthermore, Colombia, by its high biodiversity, possesses one of the highest geodiversity in the world (Vargas, 2018), with a wide range

of minerals and mining resources, rocks of diverse origin and composition, active geological processes such as volcanism, karst, glacial and others (Servicio Geológico Colombiano, 2018).

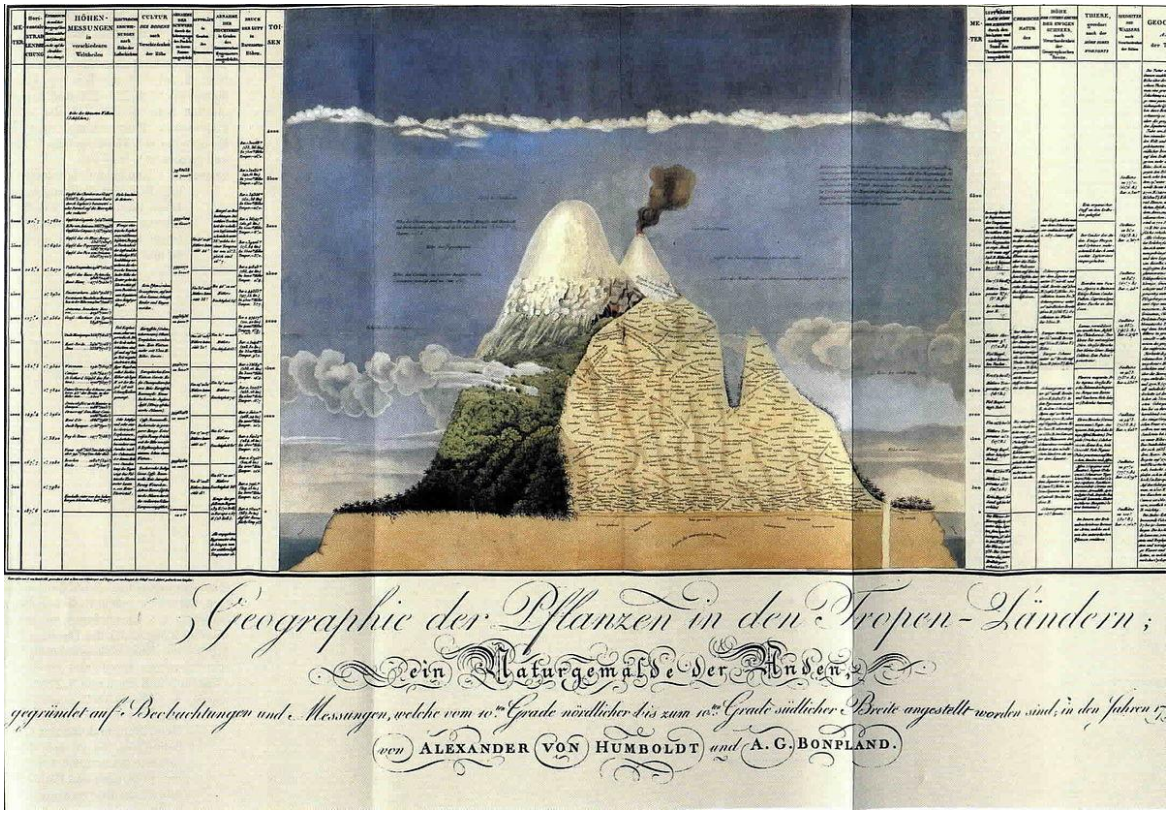


Figure 3. *Naturgemälde* (meaning "nature-painting") by Alexander von Humboldt. This magnificent illustration shows part of the complexity of the interactions between natural systems. The drawing includes the name of plant species distribution according to altitude, as well as humidity, gravity, and blueness of the sky variation in the vertical columns. His ventures through the Andes, including Colombia, inspired his holistic vision of nature. Humboldt's philosophy can be used to better conceptualise the relationship between the modern concepts of geodiversity and biodiversity. Source image: Wikipedia, https://es.wikipedia.org/wiki/Archivo:Humboldt1805-chimborazo.jpg

According to Jaramillo-Zapata et al. (2016), geological heritage studies began in the 80s, and these decades of work and research are embodied in dozens of articles, book chapters, and national and international events and papers. Vargas (2018) traces the beginning of the history of geoconservation in Colombia at the end of the 20th century, when Margaret Medo, a geologist from the Colombian Geological Survey, proposed the geoheritage concept, as well as the basis for accomplishing the first inventory. During the 21st century, several studies on geological heritage, geotourism and geodiversity were published as scientific publications. These studies have created a basis for the state of art about geoheritage in the country, being regional inventories and some geoheritage use proposals the main topics.

As Quintero-Marin et al. (2022) point out, museums have also contributed to the conservation and awareness of geoheritage in the country through research, education and dissemination. Finally, several conferences and academic events about geoheritage have taken place in Colombia in the last decades (table 4). It is important to highlight, for instance, the training on geological heritage offered by the Grupo de Investigación en Geología Ambiental (GEA) from the National University of Colombia in Medellín, as well as the inauguration of the I Symposium of Geoheritage and Geoconservation during the XVIII Colombian Geological Congress in 2021. An important outcome of this event was the launching of the Colombian Geoconservation Network (Red Colombiana de Geoconservación). This launching was preceded by the first national meeting on geological heritage, held in the Cañón del Rio Claro Nature Reserve in February 2020.

Table 4. Record of geoheritage and geodiversity-related events in recent years in Colombia.

Name of the event	Year	Place
Curso Internacional de Aprovechamiento y Conservación del Patrimonio Geológico y Minero en la Facultad de Minas	2004	Medellín
I Curso de Patrimonio Geológico	2012	Medellín
II Curso de Patrimonio Geológico: Reconocer para actuar y proteger	2014	Medellín
III Curso de Patrimonio Geológico: Geoparques y Divulgación	2016	Medellín
IV Curso de Patrimonio Geológico: Conservación y Estrategias de Gestión	2018	Medellín
Día Latinoamericano del Geoturismo – 2da versión	2019	Armero, Tolima
II Taller Regional – Geoparques Mundiales de la UNESCO para América Latina y el Caribe	2019	Manizales
I Encuentro Colombiano de Patrimonio Geológico	2020	Reserva Natural Cañón del Río Claro, Antioquia
Cuarentena con Geociencias: La semana de los Geoparques Mundiales de la UNESCO	2020	Online
I Fiesta del Geoparque – Proyecto Zaquenzipa	2020	Online
Seminario virtual 'Promoviendo Geoparques de la UNESCO en Colombia'	2021	Online
I Simposio de Patrimonio Geológico y Geoconservación – XVIII Congreso Colombiano de Geología	2021	Online
II Fiesta del Geoparque – Proyecto Zaquenzipa	2021	Alto Ricaurte, Boyacá
II Seminario sobre Patrimonio Paleontológico, Geológico y Antropológico del Macizo de Floresta Boyacá - Colombia	2022	Online

During the event, it was agreed that network meetings would be held every 2 years at the national geoheritage meetings. At approximately the same time, in 2020, a geoheritage network was created by the civil society with activities posted on platforms such as Facebook or YouTube. For a more detailed review of the background of geoheritage and studies done in the country, see Jaramillo-Zapata et al. (2016), Vergara (2018) and Quintero-Marín et al. (2022).

2.3.1. Decree No. 1353 of 2018

Decree No. 1353 published in 2018 was preceded by decrees No. 4131 (2011) and No. 2703 (2013), in which the identification, assessment, and protection of the geological and paleontological heritage of the country are assigned to the Colombian Geological Survey (SGC). Signed in 2018 by the Ministers of Culture, Environment, and Mines and Energy, Decree No. 1353 contains the official dispositions related to 'the integral management of the geological and paleontological heritage of the Nation'. Some of the contents that make this document so significant are:

- To provide the official definitions of geological heritage, geotope, geosite, inventory, zone of geological protection, etc., for the Colombian territory.
- To integrate the geological and paleontological heritage of the Nation.
- To establish the Colombian Geological Survey as the entity responsible for the methodology to declare the geological and paleontological heritage, as well as the guidelines for protection, conservation and infrastructure.
- To name the entities related to the protection and management of geoheritage protection zones, such as the Colombian Geological Survey, the Colombian Institute of Anthropology and History (ICANH) and the regional environmental authorities.
- To introduce the National Geological and Palaeontological Inventory, including ex situ elements.

This decree also includes other dispositions regarding the possession, finding, mobilisation, exhibition and export of geological elements, and represents a major advance in the identification and protection of in situ and ex situ geological heritage in Colombia. For instance, the methodology to be followed for the national inventory considers 15 geological domains covering the total area of the country. For the moment, the national inventory includes 57 sites, all of them located in the Boyacá Department in the

Eastern Cordillera (https://www2.sgc.gov.co/patrimonio/Paginas/Inventario-nacional-de-patrimonio-.aspx). Another important advance was the definition of the first zone of geological protection in the country, as defined by the decree (see section 3.6).

Despite the importance of this decree for the progress of geoconservation in the country, there are still some gaps regarding the statutory protection of geological sites, the methodologies for local and regional inventories, and a general geoconservation strategy for the country.

2.4. Geopark projects in Colombia

In May 2022, there are four active geopark projects in Colombia, and they will be briefly described below.

The Cañón del Chicamocha geopark project, located in Santander, Eastern Cordillera, takes its name from the Chicamocha canyon. This geomorphological feature, according to the management team, is the second biggest canyon on Earth, after the Colorado canyon in the USA. Besides this main element, the area counts with well-preserved sedimentary sequences, the second most important seismic nest in the world, paleontological heritage, flora, fauna and architectonical heritage associated with the geographical and geological context of the area (Ríos-Reyes et al., 2020).

The Chambú-La Cocha geopark project, located in Nariño Department, southwestern Colombia, aims to enhance the regional identity of the communities through the awareness and conservation of its geological, mining, cultural and natural heritage. As relevant geological features, the project names the Cerro Gualcalá ("The Finger of God"), the "Nudo de Los Pastos", the place where the Andes are bifurcated into the three Colombian cordilleras, active in volcanoes, and associated biodiversity and cultural heritage.

The Nevado del Ruiz geopark project, in Central Cordillera, is supported by the regional government and to date is perhaps the most advanced geopark project in the country, with an area of 4397 km^2 distributed by 20 municipalities. In this geopark project, the relationship between the catastrophic event of November 13th, 1985 – the second biggest disaster with volcanic origin in the 20th century –, the active volcanism and geological risk management seem to be the most relevant geological features. In addition, the Ruiz-Tolima volcanic complex is also an important place for monitoring glacial

retreatment and climate change. The geopark polygon embraces part of a region that already is a UNESCO World Heritage region, the Coffee Cultural Landscape.

Finally, the Zaquenzipa geopark project, located in the Alto Ricaurte region in Boyacá, Eastern Andes, was initially conceived by IKA Group, a private consort that has been working on its development and dissemination since 2020. The exceptional fossil record from the Lower Cretaceous, including some of the best-preserved examples of pliosaurs and plesiosaurs in the world (Noè & Gómez-Pérez, 2018) give an international scientific relevance to the territory. In addition, there is an important background on the local communities' empowerment and appropriation of their geodiversity and geoheritage. The network of museums in the region is composed of nine museums, of which at least four have exhibitions related to local geology and palaeontology. Moreover, the local paleontological heritage has inspired diverse artistic, economic and social projects and entrepreneurship in the region. A detailed description of this territory is presented in Chapter 3.

Chapter 3. Geodiversity and geoheritage in the study area

As mentioned in the Methods section, the first step for defining a geoconservation model and making practical proposals is to know the geodiversity and geoheritage in the study area. Therefore, some questions addressed in this chapter are: What do we know about the geodiversity in the region of study? What are its values, and the most representative sites according to the values? How can we classify this geodiversity to easily describe it? What are the cultural and spiritual relations between geodiversity and the local communities? Addressing these issues will provide a general overview of the natural geodiversity of the area, which in turn represents an important background to continue with the future steps, such as the selection of sites, the geoconservation diagnosis, and the geoconservation proposals.

It is also important to identify the sites that better represent this geodiversity and that may be considered a geological heritage of the region. To this end, an inventory of geological sites was done, as well as a quantitative assessment of the sites selected as a complementary tool. As it is going to be discussed, several ex situ and in situ elements of the geodiversity in the Alto Ricaurte region possess international relevance, as well as important cultural links with the locals. Therefore, there is a potential world-class geological heritage in the region of study that urges to be managed and conserved by specific actions based on a systematic geoconservation strategy.

3.1. Historical background

The municipalities of Sáchica, Villa de Leyva, Sutamarchán and Santa Sofía are located in the Zaquenzipa valley at 2100 – 2400 m.a.s.l, in the Boyacá department in north-eastern Colombia, 165 km from the capital of the country. The culture and traditions of the locals are a blend of the traditions of the Spaniards who first invaded the region and the *Muisca* or *Chibcha* indigenous heritage. Several histories, myths and legends are inherited from the Muisca Amerindian people and culture. This agrarian and ceramic society populated the Alto Ricaurte probably more than 1000 years before the arrival of the Spanish travellers (Ministerio de Cultura, 2015). Due to these early human settlements, the land has gone through a long history of agriculture, live stocking and changes in the use of soils and materials (Casas et al., 2017). Some of the most famous vestiges of this culture are the astronomical observatory, nowadays an archaeological park in Villa de Leyva, and the rock art site of

Sáchica. Other archaeological sites such as 'El infiernito' are believed to be pre-Muisca (Silva-Celis, 1983). Thereby, the area possesses a high cultural and scientific interest from archaeology and historical perspectives.

The architectonic heritage of Alto Ricaurte is also widely acknowledged, including mills constructed after the Spanish invasion and religious sanctuaries from the 17th century and before, such as the Santo Ecce-Homo monastery. In Villa de Leyva, a town originally built by Spaniards, the main square and historical centre are subject to a big number of visitors due to its traditional colonial architecture (figure 4). The main square of Sáchica reveals an important part of the local religious history and the indoctrination by priests, by the presence of the church and the Stone of Punishment (Piedra del Castigo).

Figure 4. Colonial architecture in the main square of Villa de Leyva, constructed during the XVI century.

According to Casas et al. (2017), the Alto Ricaurte region went through big changes during colonial times. Some of the traditional products of the region such as corn, potato, green pea and bean have been replaced in the valleys by cereals and forage legumes. Nowadays, agricultural activities have intensified, representing a threat to the native ecosystems and landscape. According to these authors, in the last 20 years, there has been a switch to tourism and mining of coal and limestone. These activities have produced changes that represent a threat not only to living nature but also to geodiversity and geoheritage (see section 4.2).

In brief, the territory in question is a cradle of cultural heritage with national relevance in Colombia. Part of this heritage is intrinsically associated with the geodiversity and geoheritage in the region (see section 3.5). The exceptionality of the Alto Ricaurte region resulted in an attempt for the region to be

included in the UNESCO World Heritage List (Ministerio de Cultura, 2015). Even if this candidature was rejected, the region is on the indicative list of UNESCO and has enormous potential for a UNESCO Global Geopark recognition, based on the scientific, educational and touristic activities around the geological heritage of international value (see section 3.6).

3.2. Location and geographical setting

The study area is characterized by its highland landscape, its dry and temperate climate and its constant flux of tourists due to its cultural and natural heritage. The main access to Alto Ricaurte is through the Tunja-Villa de Leyva road, along 38 km of paved road from Tunja, although it can also be reached through the Medellín-Puerto Berrío-Barbosa-Moniquirá-Santa Sofía or the Bogotá-Tocancipá-Puente Boyacá-Samacá-Sáchica roads (figure 5).

The scope of this dissertation is limited to the municipalities of Sáchica, Santa Sofía, Sutamarchán and Villa de Leyva in the Alto Ricaurte region. This represents an area of around 372 km^2 and 33,000 inhabitants (table 5). Nevertheless, due to the homogeneity of the region, the methodology and results of this project should be regarded as an example to implement geoconservation actions in other municipalities of the region. From the geographical point of view, the municipalities are settled in the Altiplano Cundiboyacense (high plain) in the Colombian Eastern Cordillera. In Villa de Leyva, for instance, the temperatures vary between 10°C and 24°C with an average of 16,5°C (IDEAM, 2014). According to its elevation, vegetation and climate conditions, the region can be divided into three main ecosystems: the *paramo*, the high Andean dry enclave and the Andean and high Andean forests (Casas et al., 2017).

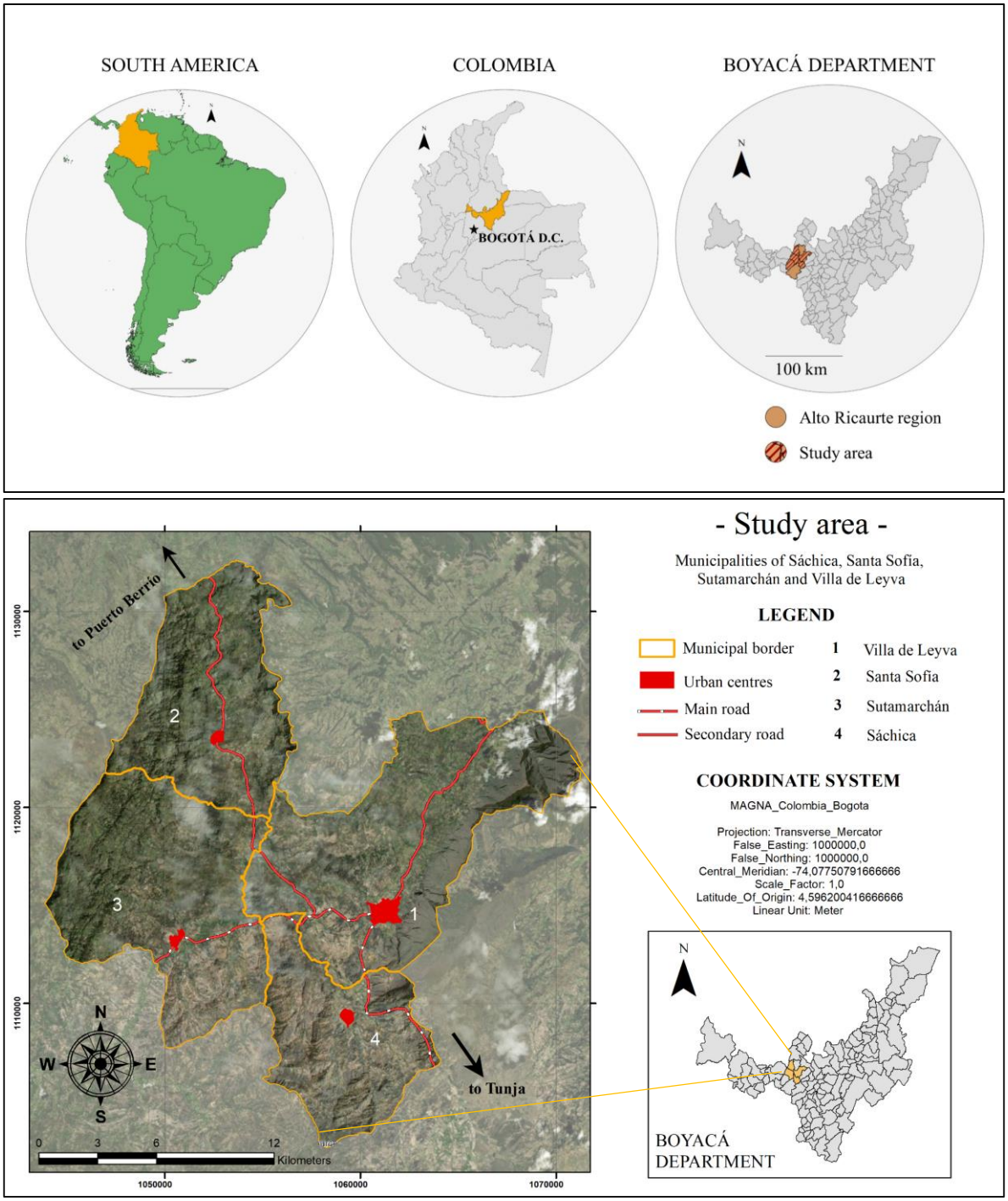


Figure 5. Location of the study area in Alto Ricaurte region, Boyacá, Colombia.

Table 5. Municipalities, populations and size of municipalities in the study area.

Municipality	**Area (km²)**	**Population (DANE, 2018)**
Sáchica	64,18	5667
Santa Sofía	76,73	2552
Sutamarchán	109,34	6228
Villa de Leyva	122,23	18606
TOTAL	372,48	33053

Some of the wet mountains surrounding the Zaquenzipa valley are the *paramos* of Rabanal, Merchán, Iguaqué (see figure 6) and Chaute and El Peligro *serrania*. In these high-mountain sectors, there are some ecosystems of high importance due to the environmental services they provide, such as biodiversity, water supply and climate regulation.

Figure 6. Páramo de Iguaqué as seen from La Periquera.

The landscape of the study area is characterized by dry mountains, mounds and *serranias* shaped in sedimentary materials with an important structural influence (figure 7). This mountainous landscape is cut by some alluvial valleys associated with the main rivers such as the Leiva, Samacá, Monquirá, Sáchica, Sutamarchán and Cane, which have shaped the irregular Zaquenzipa Valley. Northwest, around the municipality of Santa Sofia, a karstic landscape shaped in limestone from the Rosablanca Formation can be appreciated.

Figure 7. A: Semi-arid landscape in La Roa sector, Sutamarchán B: Structural influence in the landscape seen from La Roa to SW.

3.3. Protected areas and sites protected by law

The most important protected area located in the study area is the Iguaqué Flora and Fauna Sanctuary. It is a National Park (corresponding to the IUCN II Category) with important rainforest, *paramo* and Andean forest, as well as fauna and a historical-cultural context associated with the Muisca culture in the territory. This park was created in 1977 and covers 69.23 km^2 (figure 8). There are no civil society reserves in the area.

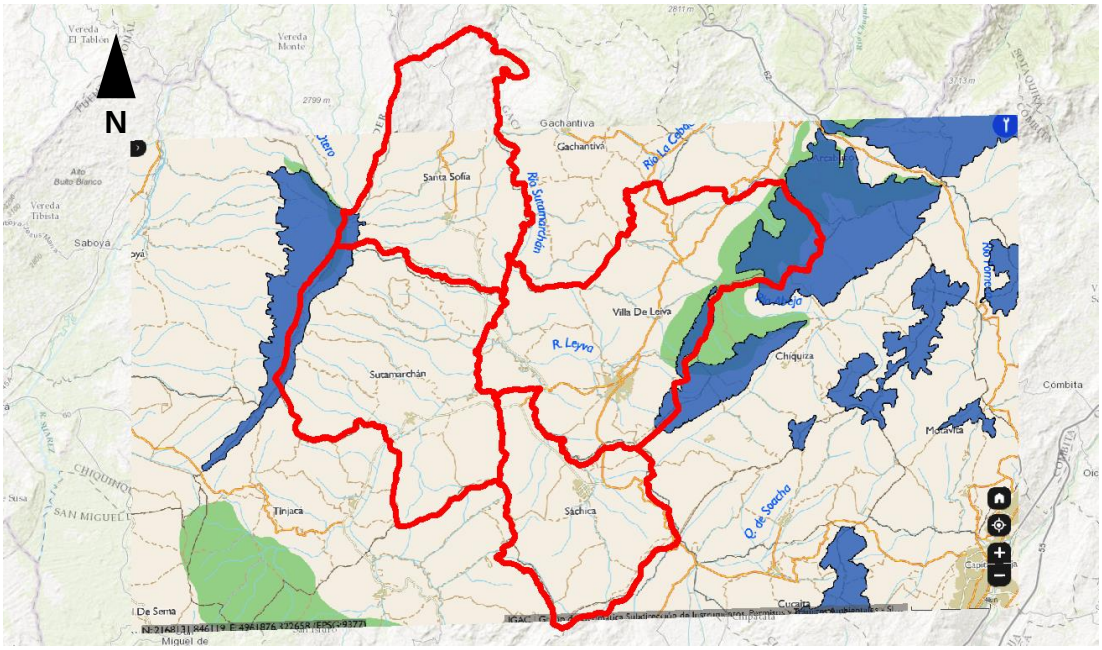


Figure 8. Georeferenced image of moorland (*paramo*) complexes (in blue) in the study area (red polygon). To the west, Merchán paramo (Santa Sofía, Sutamarchán). To the east, Iguaqué Flora and Fauna Sanctuary (Villa de Leyva). Modified from Colombia en Mapas.

The only protected area due to archaeological reasons in the El Infiernito Archaeological Park (figure 50), though there are several archaeological discovery sites along the four municipalities.

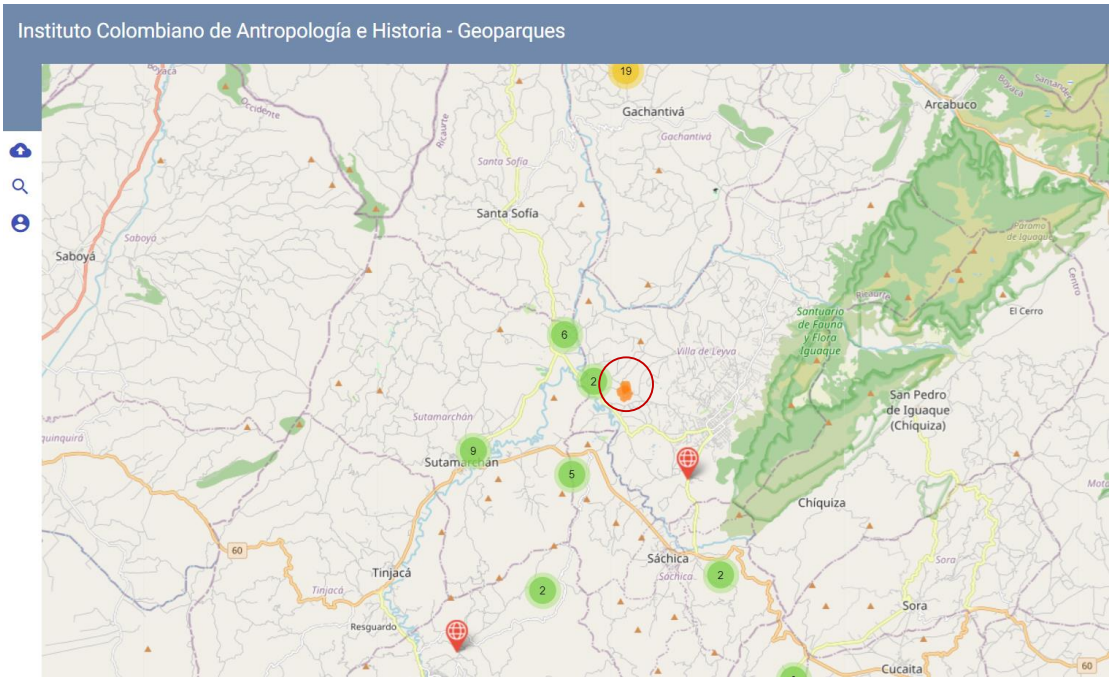


Figure 9. Orange area: El Infiernito archaeological park, the only protected polygon by the Colombian Institute of Anthropology and History (ICANH) in the study area. Green and red points: Archaeological find sites. Source image: ICANH, https://geoparques.icanh.gov.co/#/

3.4. Geological setting of Alto Ricaurte region

The geological history of the Alto Ricaurte region goes back to the Jurassic-Cretaceous transition, when the oldest exposed rocks in the region were deposited: The Arcabuco Formation. Most of the geological materials in Alto Ricaurte were formed during the marine transgression that took place in the Cretaceous and cropping out nowadays in the Eastern Cordillera (figure 10). Finally, some Quaternary deposits and formations are overlaying the Mesozoic sediments, such as the travertine deposit of Villa de Leyva, soils, and some slope deposits. A geomorphological map covering a large part of the study polygon, prepared by the author, can be found in Appendix 4.

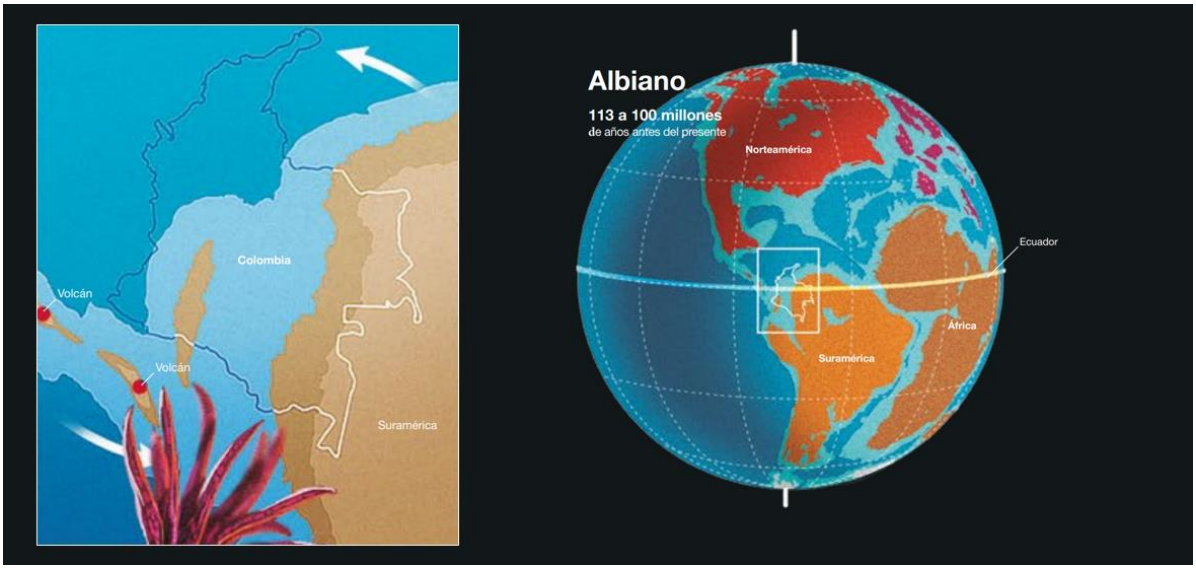


Figure 10. Colombia during the Cretaceous marine transgression. Modified from Jaramillo and Oviedo (2017).

The totality of the rocks outcropping in the region corresponds to sedimentary rocks, with great exposures of strata, tectonic structures such as folds and fractures, sedimentary structures and fossils. These rock outcrops have been studied for more than 75 years and constitute one of the best records of the Lower Cretaceous in the whole world (Etayo-Serna et al., 2015; Noè & Gómez-Pérez, 2018; Pérez-Méndez, 2019).

The classification of the rocks outcropping in the area varies according to the author and the criteria used. It is possible to find seven different rock formations (table 6), with extensive and well-exposed outcrops, for instance in the Tunja-Sáchica road, where a full sequence from the Valangian to the upper Albian can be studied – more than 40 million years in 5 km (Ministerio de Cultura, 2015). Since the

first paleontological descriptions of marine reptiles, ammonoids, bivalves and other invertebrates in the region (Botero, 1945; Bürgl, 1954; Etayo-Serna, 1968), an important number of compelling fossil findings have been reported. These findings include new species, holotypes, and gigantic marine reptiles with an exceptional degree of conservation (see section 3.4.2).

Table 6. Classification of the main lithological formations in the study area.

Formations		**Main lithology**	**Age**
Etayo-Serna, 1968; Renzoni et al. 1998	**Fuquen & Osorno, 2005**		
Arcabuco Formation	Arcabuco Formation	Quartzy sandstones intercalated with red claystone	Jurassic (Scheibe, 1938) Lower Cretaceous (Etayo-Serna, 1968)
Rosablanca Formation	Rosablanca Formation	Dark grey micritic limestones	Upper Valanginian (Etayo-Serna, 1968)
Ritoque Formation	Ritoque Formation	Grey micaceous siltstones with intercalations of calcareous claystone	Lower Hauterivian (Etayo-Serna, 1968)
Paja Formation	Paja Formation	Divided into three members: - Lower Black Lutites - Variegated Claystones - Claystones with Hollow Nodules	Barremian to Aptian (Etayo-Serna, 1968)
Inferior San Gil Formation	Tablazo Formation	Calcareous mudstones and limestones	Superior Aptian to Inferior Albian (Fuquen & Osorno, 2005) Superior Aptian to Albian (Etayo-Serna, 1968)
Superior San Gil Formation	Simití Formation	Lutites, grey shales, calcareous sandstones	Superior Aptian to Superior Albian (Etayo-Serna, 1968)
Churuvita Formation	Churuvita Formation	Sandstones with intercalations of claystone and siltstone; fossiliferous limestone and shale; sandstone and calcareous siltstone.	Cenomanian (Etayo-Serna, 1968) Superior Albian to Cenomanian (Terraza, 2004)

3.5. Geodiversity in the Alto Ricaurte region

The study area hosts sedimentary rocks ranging from the Upper Jurassic to the Upper Cretaceous and the Quaternary, a paleontological record from the Lower Cretaceous, records of tectonic deformation

associated with the uplift of the Andes in late Cenozoic, hydrological features, erosion features and badlands, fluvial landforms and karst features (figure 11).

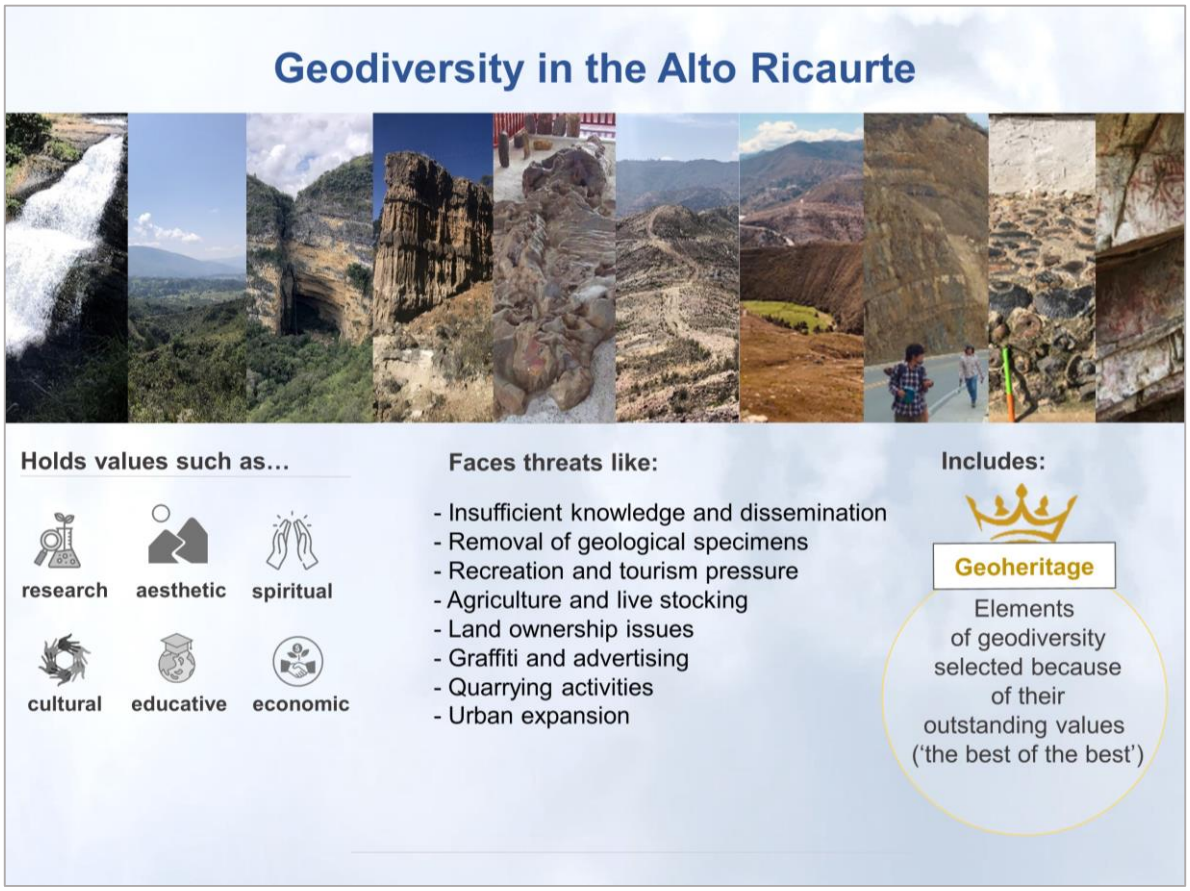


Figure 11. Geodiversity in the Alto Ricaurte region. When defining the geodiversity of Alto Ricaurte it is important to consider its different values and its potential threats, as well as the geological heritage which are those geological sites selected because of their special interest or value.

The geodiversity of the study area is presented based on a division in thematic areas which provides a practical categorisation of geodiversity useful for designing guides, itineraries and interpretation materials in the context of a geopark, and does not represent a technical categorisation of the geodiversity in the region nor the description of geological frameworks. The thematic areas defined in this study and associated colours are the following:

- Mesozoic sedimentary formations
- Palaeontological record
- Hydrological features and associated landforms
- Tectonic structures
- Karst landforms
- Erosion landforms and processes

3.5.1 Mesozoic sedimentary formations

Includes mainly the exceptional outcrops from the Cretaceous Period and to a lesser extent the Jurassic rocks of the Arcabuco Formation. The stratigraphic and paleontological record of the Lower Cretaceous and its marine habitats within these lithological units has been largely studied and is one of the most complete and accessible in the world (Etayo-Serna et al., 2015; Noè & Gómez-Pérez, 2018; Pérez-Méndez, 2019). The bare sedimentary sequences due to dry weather conditions are convenient for stratigraphic studies (figure 12).

Figure 12. Rock expositions in the Sáchica-Samacá road. Several rock formations have been described in this complete and easily accessible road section.

On the other hand, the rocks deposited in an anastomosed sandy river system (Galvis & Rubiano, 1985) of Arcabuco Fm. are the oldest geological materials in the region. Its age has been assigned to the Jurassic (Scheibe, 1938) and Lower Cretaceous (Etayo-Serna, 1968). Despite their low fossil content, these rocks present a feature of exceptional interest: the ichnites or dinosaur footprints described by Moreno-Sánchez et al. (2011) on the eastern flank of the Arcabuco anticline, 5 km southeast of the municipality of Villa de Leyva within the jurisdiction of the Iguaqué Fauna and Flora Sanctuary (figure 13). According to these authors, the fossil tracks were generated by theropods, sauropods and ornithopods. Traces also include plantar prints of unidentified dinosaurs. During the interviews done during the fieldwork, local geologists suggested the occurrence of other dinosaur

footprints located on the flanks of the Arcabuco anticline which opens the possibility of more significant paleontological findings contributing to the regional geological heritage.

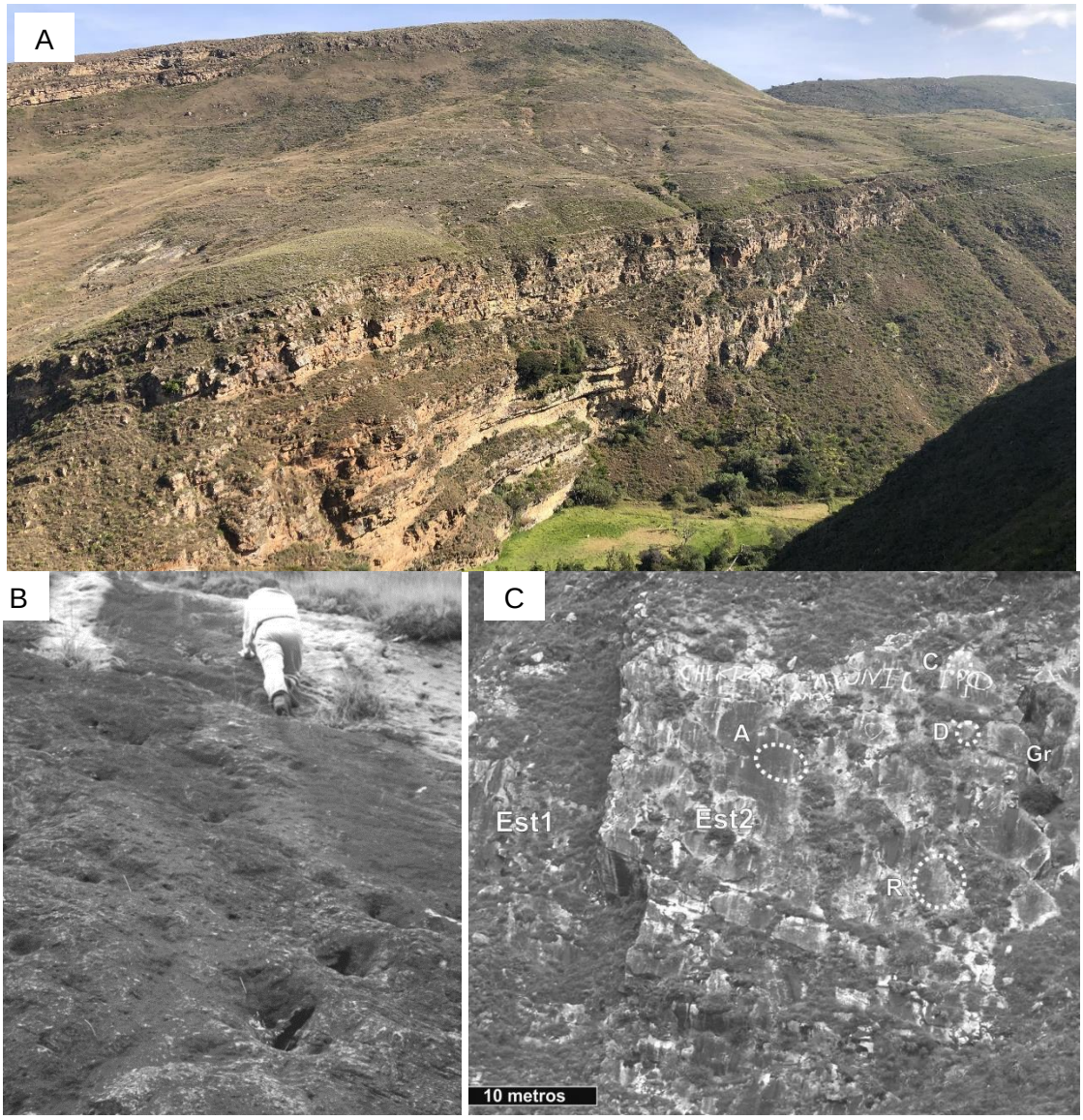


Figure 13. A: Rocks from Arcabuco formation in the Arcabuco anticline. B, C: Dinosaur footprints on the same flank of the anticline (Moreno et al., 2011).

3.5.2. Paleontological record

Cretaceous time is famous for its maximum sea levels in the history of Earth (Miller et al., 2005). The current Eastern Cordillera of Colombian Andes preserves exceptional records of marine lifeforms that inhabited the shallow seas that once extended into the nowadays Colombian territory. Paja Formation keeps one of the best pieces of evidence of the Lower Cretaceous on Earth (Etayo-Serna et al., 2015;

Noè & Gómez-Pérez, 2018). The exceptional fossil fauna includes virtually complete and articulated marine reptiles such as plesiosaurs, ichthyosaurs, marine turtles, crabs (Luque et al., 2020), diverse fishes, numerous pelagic ammonites and bivalves (Noè & Gómez-Pérez, 2018). A summary of the paleontological diversity of Alto Ricaurte is presented in table 7. According to Noè & Gómez-Pérez (2021), due to the abundance, variety, and exceptional preservation of Plesiosauria, the Paja Formation is the most important Lower Cretaceous plesiosaur assemblage in the world and, consequently, is considered a *Lagerstätte*.

In addition to the vast Cretaceous paleontological record, there are some reports of Quaternary fossils in a travertine deposit in Villa de Leyva, such as mastodon bones, *armadillos*, and the first register of the Smilodon tiger in Colombia (Galvis & Valencia, 2009). After interviews done during the fieldwork, it was possible to verify that other mastodon bones have been found in the surroundings of Sáchica. In the future, there might be further findings on Quaternary animals that should be included in this thematic area.

Table 7. Paleontological diversity of the Alto Ricaurte region (including non-Cretaceous fauna).

Category	Sub-category	Taxa	References	Location
Terrestrial organisms	Dinosaurs	*Padillasaurus leivaensis* (sauropod)	Carballido et al. (2015)	El Roble, Villa de Leyva (Carballido et al., 2015)
		Theropods, sauropods, and ornithopods	Moreno et al. (2011)	Iguaqué Fauna and Flora Sanctuary
	Mastodont	*Gomphotheriidae*	Hubach (1952)	Travertine quarry, Villa de Leyva
Great marine reptiles	Plesiosaurus (long neck)	**Callawayasaurus colombiensis*	Welles (1962) Goñi & Gasparini (1983) Carpenter (1999) Jerez–Jaimes & Narváez–Parra (2001)	Loma La Catalina and surroundings Loma La Cabrera (Noè & Gómez-Pérez, 2021)

			Páramo–Fonseca (2015) Gómez–Pérez & Noè (2017)	
	Pliosaurus (short neck)	**Monquirasaurus boyacensis*	Acosta et al. (1979) Hampe (1992)	Monquira, Villa de Leyva
		**Stenorhynchosaurus munozi*	Páramo–Fonseca et al. (2016)	Loma La Cabrera (Páramo–Fonseca et al., 2016)
		**Acostasaurus pavachoquensis*	Gómez–Pérez & Noè, (2017)	Santo Ecche Homo convent surroundings (Noè & Gómez-Pérez, 2021)
Other marine reptiles	Marine turtles	** Desmatochelys padillai*	Cadena & Parham (2015)	Loma La Asomada Loma La Catalina Loma La Cabrera (Noè & Gómez-Pérez, 2021)
		*Leyvachelys cipadi	Cadena (2015)	Loma La Catalina (Noè & Gómez-Pérez, 2021)
	Ichthyosaurs	**Muiscasaurus Catheti*	Maxwell et al. (2016) Páramo-Fonseca et al. (2021)	Arrayán, Sáchica (Noè & Gómez-Pérez, 2021) Loma La Catalina (Páramo-Fonseca et al., 2021)
		Platypterygius Sachicarum o **Kyhytysuka sachicarum*	Páramo–Fonseca, (1997) Cortes et al. (2021)	Loma Pedro Luis, Villa de Leyva (Noè & Gómez-Pérez, 2021)
Others	Fishes	Vinctifer	Schultze & Stöhr (1996)	Loma Blanca, Sáchica Noè & Gómez-Pérez, 2021)

	Ammonites	*Acanthohoplites,* *Acrioceras,* *Ancyloceras,* *Australiceras,* *Cheloniceras,* *Colchidites* *Colombiceras,* *Crioceratites,* *Epicheloniceras,* *Dufrenoyia,* *Gargasiceras* *Hamulina,* *Karsteniceras,* *Heinzia,* *Heteroceras,* *Neodeshayesites* *Nicklesia,* *Olcostephanus,* *Paracrioceras,* *Parasaynoceras,* *Pedioceras,* *Phylloceras,* *Prochelonicera*s, Pulchelliidae, *Pseudoaustraliceras* *Pseudohaploceras,* *Riedelites,* *Spitidiscus,* *Valdedorsella* *Zurcherella,* Others...	Etayo–Serna (1964, 1979, 1981) Patarroyo (2000) Patarroyo (2009)	-
	Crabs	**Bellcarcinus aptiensis* *Planocarcinus olssoni*	Luque et al. (2020)	-
	Bivalves Gastropods, echinoderms,	-	Etayo-Serna (1968) Etayo–Serna (1968) Patarroyo (2009)	-

	Decapod Crustaceans	-	Bermúdez et al. (2013)	San Gil Group
	Plants	Ferns (Polypodiopsida) Seed plants Cycads (Cycadophyta), Conifers (Pinophyta) Abundant fossil wood	Etayo–Serna (1968) Etayo–Serna et al. (2015) Van Waveren et al. (2002) Huertas (1967, 1970) Moreno–Sánchez et al. (2007)	-
	Insects	Aeschnidiidae	Gómez–Cruz et al. (2011)	-
	Microfauna	Benthic foraminifera: *Epistomina caracolla*	Patarroyo (2009) Patarroyo–Camargo et al. (2009)	-

*New species

Figure 14. Some of the fossil diversity in the study area. A, B: Ammonoids; C: Bivalves; D: *Monquirasaurus boyacencis*; E, J: Ictiosaur skulls; F: Pliosauroid; G: Plant trace fossils. H: Plesiosaur *Callawayasaurus colombiensis;* Photo: https://stringfixer.com/pt/Callawayasaurus_colombiensis#wiki I: Turtle *Desmatochelys padillai*; Cadena (2015) K: Mastodont molars. Photos H, E, K: http://lapaleontologiaencolombia.blogspot.com/

The abundance of fossils in the Alto Ricaurte is so remarkable that along 5 km there are at least three museums dedicated to the study and conservation of these geodiversity elements. The diversity of fossils is therefore found both in situ as well as ex situ in local private collections and museums, either in the municipalities or in other parts of the country.

A complete revision of the paleontological heritage in Alto Ricaurte region is presented by Páramo-Fonseca (2015), regarding big marine reptiles, Noè & Gómez-Pérez (2021) for Paja Formation, and Cadena (2014) for fossil turtles.

3.5.3. Hydrological features and associated landforms

The water system in the area is part of the Sáchica-Leyva sub-basin of the Suárez river basin, which is part of the larger Magdalena river basin (Casas et al., 2017). The surface water network in the municipality is constituted of rivers, streams, wetlands, waterfalls and springs.

Figure 15. Hydrological elements. A: La Periquera waterfalls. B: Moniquira river canyon viewed from El Hayal. C: Hidden valley (Valle Escondido); Photo: LuisFer Cadavid (Wikiloc), https://www.wikiloc.com/mountain-biking-trails/villa-de-leyva-valle-escondido-11869181/photo-7263203. D: Sutamarchán Blue Wells (Pozos Azules de Sutamarchán).

Most of the streams that are part of this system are intermittent. Its main tributaries are the Leyva river which rises in Morro Negro to the south of the Iguaqué massif and empties into the Sáchica river, which forms at the mouth of the Chíquiza stream, and the Monquirá river. The interaction of this fluvial system with rocks, soils and geological structures with weathering and erosion processes results in landforms such as valleys, terraces, waterfalls, abandoned meanders, etc. (figure 15). The value of these sites lies in their touristic potential and the spiritual value that they have within the Muisca cosmogony (see section 3.5.2, Spiritual value of geodiversity).

3.5.4. Tectonic structures

The well-exposed Cretaceous sedimentary sequences show evidence of tectonic deformation such as folds and faults (figure 16). These tectonic structures are the result of the intense activity of the Andean orogeny in Colombia (20 – 2,5 Ma), one of the most important tectonic events in the northern part of the South American continent that raised the Andes to 5 kilometres above sea level. The block Chiquinquirá-Arcabuco, in which most of the study area is located, is characterized by anticlinal and synclinal tight folds within the Arcabuco Anticlinorium, locally disturbed by normal and strike-slip faults (Rodríguez-Parra & Solano, 2000). Some of the structural features mentioned in the literature are the Tunja anticline, Ráquira anticline, Ráquira syncline and the Arcabuco anticline.

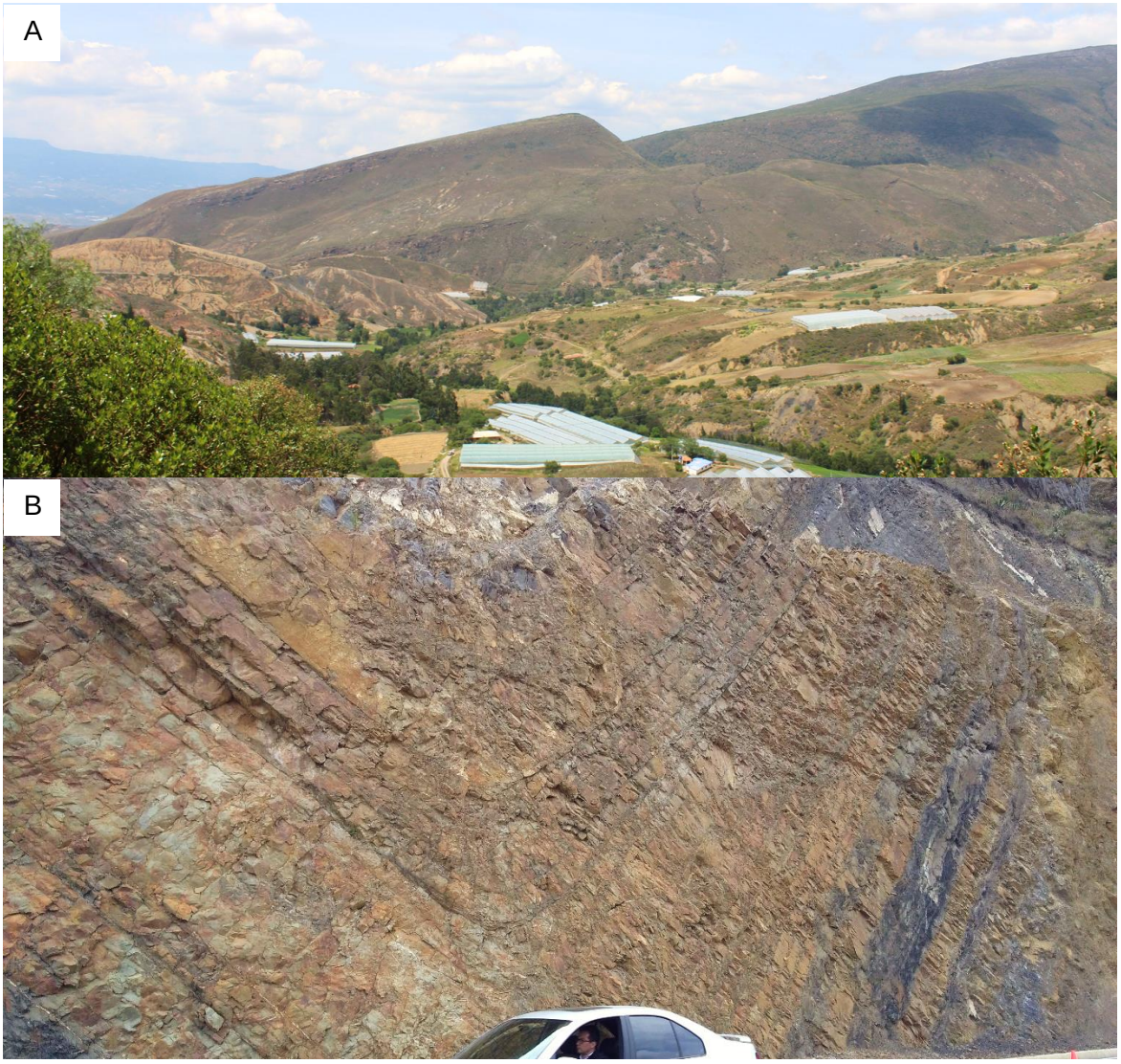


Figure 16. A: Panoramic view of the Arcabuco Anticline. B: Metric-scale folds in the Sáchica-Samacá road.

There is not enough research to confirm the scientific importance of these features but they certainly have educational value because these sites are already used by university geoscience professors and students from all over the country.

3.5.5. Karst landforms

The action of water on limestone rocks from the Rosablanca Formation has shaped escarpments, caves and speleothems such as stalactites, stalagmites and columns that constitute a karstic landscape in the northeastern part of Santa Sofía municipality (figure 17). Four of these cavities have been identified and studied in more detail (Asociación Espeleológica Colombiana, 2005). Even if the

karstic area is not vast and only limited to this sector of the study area, it is frequently used for touristic and extreme sports activities.

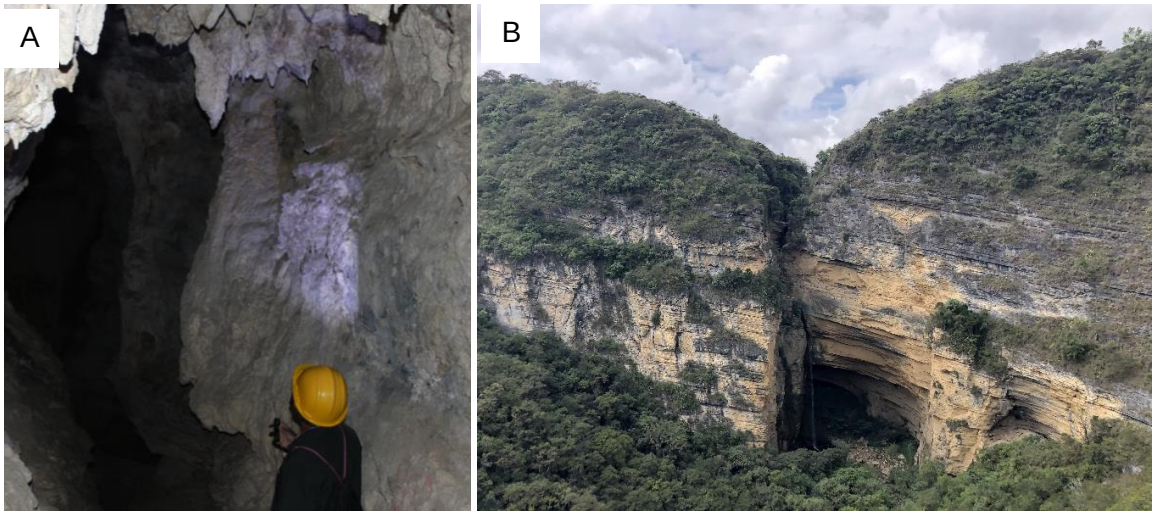


Figure 17. Karstic features. A: Speleothems in La Fábrica cave. B: Overview of El Hayal cave and waterfall.

The importance of karstic elements in the region lies not only in their tourism significance but also in their scientific potential. For instance, in one of the caves a new brachiopod species, *Hadrosia gracilis*, was discovered (Schemm-Gregory et al., 2011).

3.5.6. Erosion landforms and processes

Some processes are wearing away and lowering the elevated or positive landforms of the local landscape, by the action of physical agents such as water, wind, ice, etc., which are often called denudation processes (Smithson et al., 2002). As it is characteristic in a tropical arid region, erosion processes often dominate over weathering ones. The dry and eroded landscape in some areas of Alto Ricaurte has resulted in “badlands” (Botero, 1945). Some examples of erosion landscapes are also observed, such as the ones ascending Morro Negro in the municipality of Villa de Leyva, or the Quebrada Arriba gullies in Sáchica (figure 18). Erosion and denudation processes can be affected by several factors, including human activity, and are a reminder of an active and dynamic Earth in which almost all landscapes are formed by these degrading processes. Despite elements with scientific value not yet being found for this thematic area, there is a current touristic interest and potential educational use for geological elements within this thematic area.

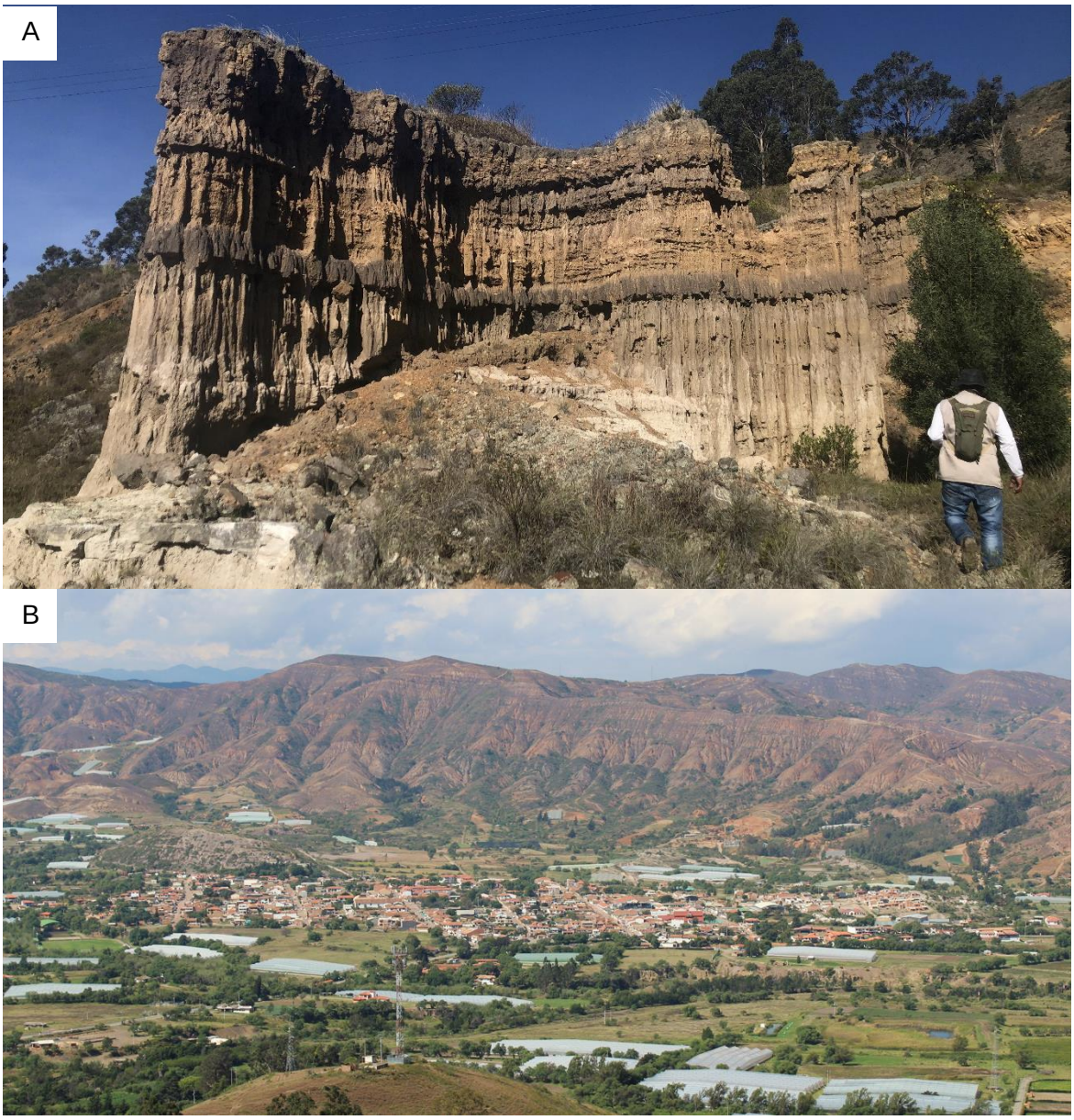


Figure 18. A: Erosion landform in the Quebrada Arriba gullies site. B: Semi-arid landscape around Sáchica.

3.6. Geodiversity values

Different geodiversity values can be considered as a reason to protect, conserve, and manage geodiversity because they enhance our understanding of its importance. Gray (2004) proposes the following values for geodiversity: intrinsic, aesthetic, cultural, economic, functional, research, and educational. The "sense of place" value related to the identity is here observed as a part of the cultural value and refers to the degree to which a human community regards a geodiversity feature as integral

to the 'identity' of their place (Sharples, 2002). The geodiversity values of the Alto Ricaurte region were described taking into account these categories and grouped as:

- Intrinsic value
- Cultural, spiritual and aesthetic values
- Economic value
- Research and educational value
- Ecological value

3.6.1. Intrinsic value

According to Gray (2004), intrinsic value refers to the ethical belief that geodiversity elements are of value simply for what they are, independently of the economic, utilitarian or extractive value that we give to it as a society. This reason is congruent with society's responsibility to conserve nature (Crofts et al., 2020), and it represents a non-anthropocentric perspective. In Alto Ricaurte, the intrinsic value refers to the natural worth of geodiversity elements such as the Jurassic and Cretaceous rock sections, the abundance of fossils, minerals, and other geological features and processes described above and that constitute part of the natural capital of the region.

3.6.2. Cultural, spiritual and aesthetic values

The characteristic desert landscape of some areas in Alto Ricaurte is one of the features constituting its scenic value. This arid and yellowish landscape is related to the occurrence of certain geological materials and the climate and geographical context of the region, influenced by its position in the Eastern Colombian Andes. As an eye-catching landscape, constantly portrayed and typically considered attractive, its aesthetic value becomes a potential reason to protect the geodiversity in the area. It is important to mention that Colombia is a green country and this type of landscape is not common to most of the country's population. Therefore, this distinctive arid landscape can be an element of identity in the region, for example in the official municipal coat of arms of Sáchica (figure 21).

On the other hand, the territory has a history of occupation of more than 2800 years, in which human communities have constantly interacted with the environment, including the geodiversity elements. Pre-Hispanic communities used rocks to make axes and tools and left archaeological remains and pictograms in several rock shelters and outcrops of different lithology.

The local Bachué tale is about the creation of the mother of the Muisca indigenous culture, who was born in the lagoon of Iguaqué (Laguna de Iguaqué) and then descended to the valley where Villa de Leyva is located and created humanity (Fray Pedro Simón). Therefore, all landforms in the study area are part of this story. Because of this tale, the water element in Muisca mythology is very important, and archaeologists suspect that there is a relation between the most frequent rock art motifs such as serpents and frogs, and the water element (figure 19).

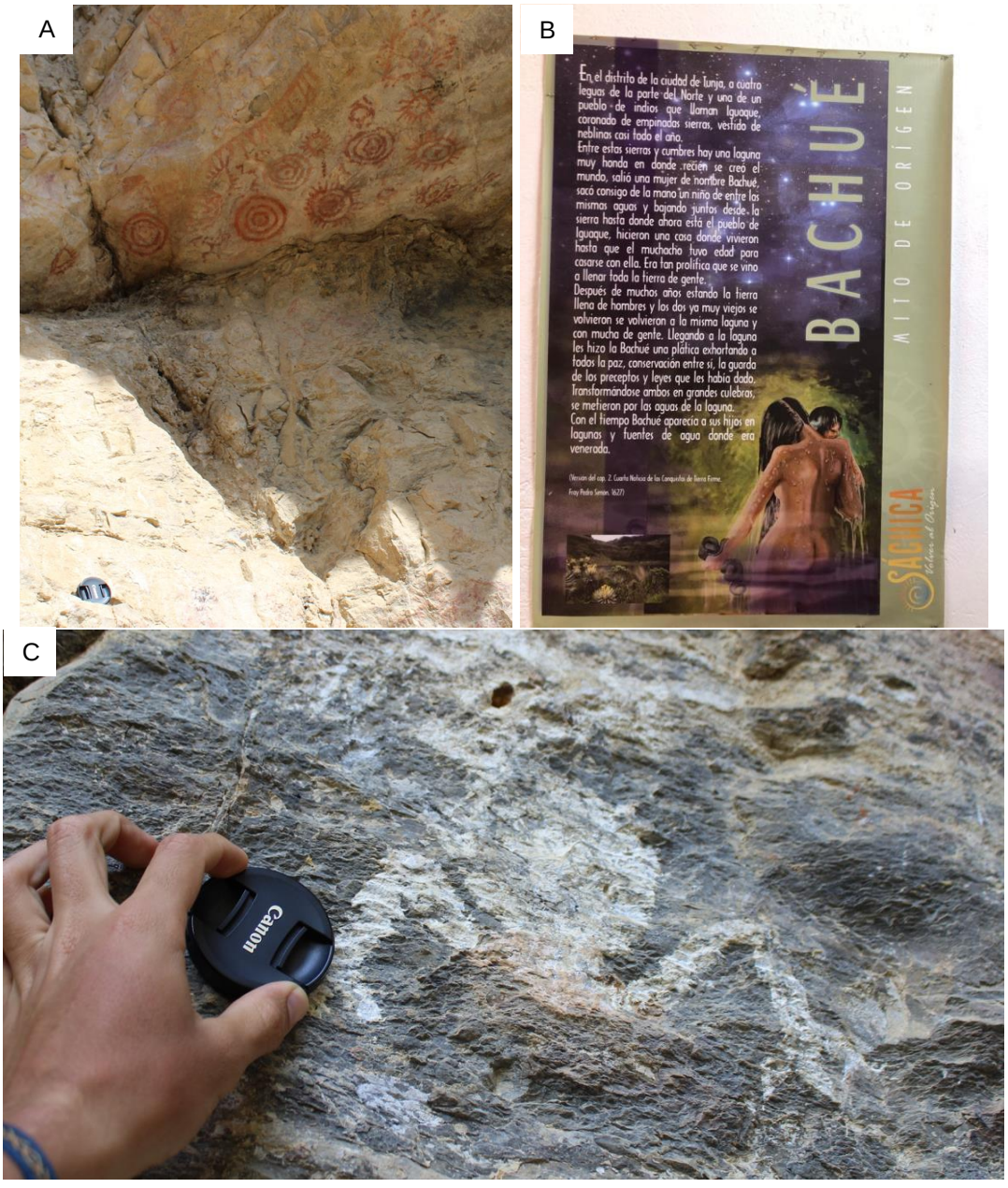


Figure 19. A: Pictograms in the "valley of the pictograms" site, Sáchica. B: Poster on the legend of Bachué in the archaeological museum of Sáchica. C: Pictogram interpreted as a frog in the Cueva El Hayal site.

Along with Iguaqué, the triad of archaeological heritage includes the rock art site of Sáchica and "El Infiernito" ancient astronomical observatory (figure 20) (Rojas-Durán, 2019).

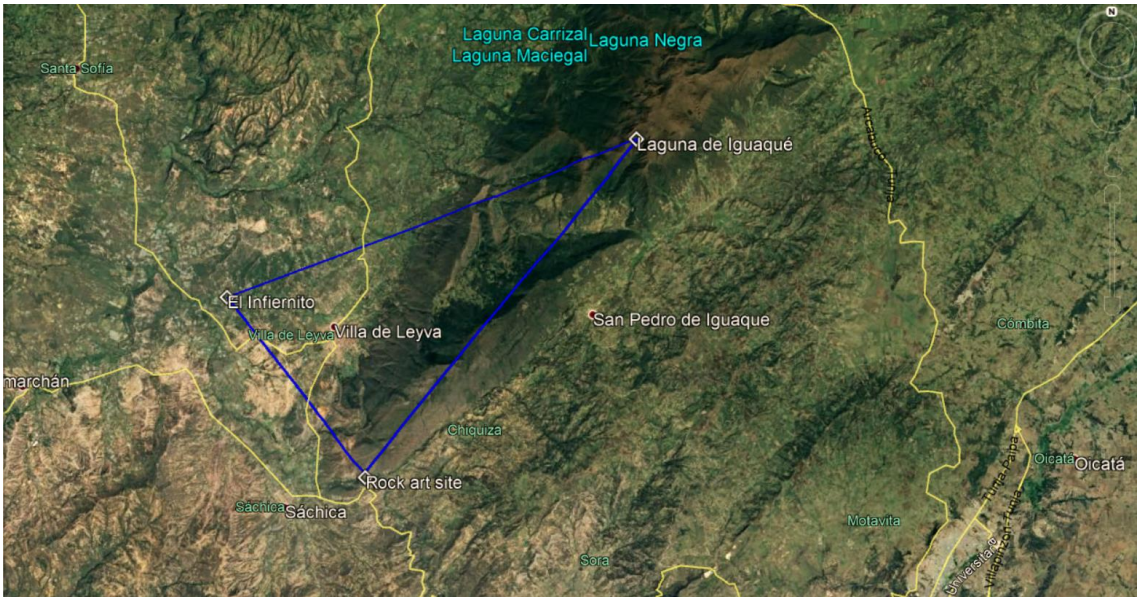


Figure 20. The triad of cultural-archaeological heritage, based on Rojas-Durán (2019)

This archaeological site, consisting of 30 phallus-shaped megaliths, records another important spiritual value since this set of rocks was a ceremonial site of the Muisca indigenous culture. Caves in the area (locally called "cucas") were also subject to witchcraft offerings (Javier Durán, verbal communication) in which mountains and rivers were venerated, but these sorts of rituals were later demonized by Spanish colonizers. These heritage vestiges highlight the importance of the Saquencipá valley for the Muisca culture and its relationship with ancestral rituals and myths. The territory itself as a landscape and a sacred place was visited, respected and appreciated by all the Muiscas since Bachué went down to the valley and populated humanity. In this sense, the region becomes the original valley of the human being, Muisca culture and society (Rojas-Durán, 2019)

A

I

¡Oh! Tierra de raíces milenarias
refugio de estrellas y cometas,
desde el cielo infinito de Iguaque
protegida por Bachue.

II

Suelo de un mar antiguo
tapizado de amonitas.
Casa de la cultura Muisca,
mi amada Villa bonita.

CORO

Villa campesina,
taller de artesanos,
sueño de poetas,
remanso de paz,
manantial de luz,
Monumento Nacional,
Villa de Leyva.

B

Figure 21. A: Anthem of Villa de Leyva, alluding to the geological history and fossils in the area. B: Coat of arms of Sáchica, including an onion, the main church, and the mountainous landscape as background.

The inhabitants of Villa de Leyva have also cultural links with Cretaceous fossils (figure 22). As these fossils are abundant, frequently peasants find fossils in the fields and paths while doing their work. In 1977, a peasant discovered some giant bones that resulted to be the most complete record of a *Kronosaurus* in the world. After this magnificent discovery, the community appropriated the fossil and built a museum that is managed by the local Community Board. This fossil constitutes a cultural reference and it is part of the identity of the territory and a source of work and progress for the region due to the tourism activities generated by the museum (Salgado-Jauregui, 2018).

Figure 22. A: Cultural relationship between the peasants, the economic activities, the fossils and the soils; Photo: Casas et al. (2007). B and C: The use of fossils in the façades and floors of Villa de Leyva.

3.6.3. Economic Value

The diversity of geological materials has been exploited over the centuries and has provided societies with the huge range of materials they have needed to progress to their modern sophistication (Gray, 2004). The value of some geological materials such as gold, diamonds and oil is obvious for most of the world population and has been addressed in several cultures in ancient myths and folktales. As Gray (2004) points out, several fossils and skeletons in the world are valued at hundreds of thousands of euros. In Alto Ricaurte, some geological materials such as gypsum, mudstones, limestone, travertine

and marbles have been exploited as construction materials. On the other hand, fossils themselves can have a high economic value and be commercialized, although this is considered as an illegal activity according to Colombian law. In the study area, fossils of ammonites, fishes and bivalves have been informally commercialized for several decades and offered as decoration or accessories to tourists. Even if this problem has decreased over time through the raising of awareness of the local population, it still poses a threat to the geoheritage of the region (see section 4.2.5). Fossils have also been indirectly exploited through replicas in different materials such as plastic and chocolate (figure 23). Hence, geodiversity elements have been exploited in non-extractive ways such as tourism, for example in the dedicated public and private geological and paleontological museums and recently through geotourism.

Figure 23. A: Ammonite-shaped chocolate from the Chocolate Museum (https://museodelchocolate.com.co/), Villa de Leyva. B: Fossil replicas sold by locals.

3.6.4. Research and educational value

Geodiversity is a scientific and educational resource that contributes to the knowledge of the Earth's evolution (Crofts et al., 2020). Even if there is further research to do, the sedimentary sequences occurring in the four municipalities have been studied under topics of sedimentology, structural geology, geochemistry, stratigraphy, palaeontology, and micropaleontology, among others. These studies add up to dozens of scientific publications and reports regarding local geodiversity. The abundant fossil record justifies numerous field trips made by university geology students from all over the country (figure 24). The importance of the stratigraphic and fossiliferous record of the region makes it one of the most important places on the planet for understanding the marine life in the Early

Cretaceous (Noè & Gómez-Pérez, 2018). The implementation of geoconservation in this area is important to guarantee the access of future generations of students to research and education in this exceptional geological setting, which has been used for decades as an educational scenery for practising and learning stratigraphy, sedimentary petrology and palaeontology.

Figure 24. University students observing sedimentary rock formations in the Tunja-Sáchica road.

3.6.5. Ecological value

This value recognises how geodiversity is important in maintaining natural systems and ecological processes, recalling that by definition 'ecosystems' are understood as comprising both biotic and abiotic components which interact and are interdependent (Sharples, 2002). Geodiversity contributes to ecosystems not only by being part of important geomorphic and soil processes linked with life development but also by providing habitat (figure 25) and in general as being the substrate in which ecological diversity is settled.

Figure 25. Caves are a good example of one of geodiversity's geosystem services: provision of habitat.

3.7. Geoheritage in the study area

Due to its wide variety of uses and services to society, it is impossible to protect all geodiversity elements. In Alto Ricaurte, these elements hold different values (scientific, cultural, ecological) which are also related to the use that communities and locals make of this part of nature. Thus, it is important to identify and delimitate the most important geodiversity elements that are worth protection and conservation for society. These elements constitute the geological heritage of the region. Ideally, the geological heritage would be represented by a network of geological sites, as well as ex situ geological heritage.

The definition of geological heritage adopted in this dissertation is provided by Crofts et al. (2020): "it comprises those elements and features of the Earth's geodiversity, either singly or in combination, that are considered to have significant value for intrinsic, scientific, educational, cultural, spiritual, aesthetic, ecological or ecosystem reasons and therefore deserve conservation. Geoheritage constitutes a legacy from the past to be maintained in the present and passed on for the benefit of future generations". The preference for this definition is because it includes many values of geodiversity, without privileging

the scientific; because it emphasises the relationship to ecosystems; and because it reminds us of the basic notion of heritage as something to be passed on to future generations.

In Colombia, Decree No. 1353 of 2018 defines geological heritage as: "...A set of geological sites that have their heritage values with scientific, cultural and/or educational characteristics, and which allow us to learn about, study and interpret: the origin and evolution of the Earth, the processes that have shaped it, the climates and landscapes of the past and present, the origin and evolution of life...". The difference between the preferred definition and the official definition for Colombia found in this decree is that the last one insists on the scientific nature of geological heritage as a set of elements that help us to understand the evolution of Earth and life. In the academic community, there are different approaches to defining, identifying and assessing geological heritage. Brilha (2016) also emphasises the scientific value as geological heritage is formed by a network of geosites, which are sites of greatest scientific relevance. Thus, sites with no scientific relevance but with other values are not part of the geological heritage and are called geodiversity sites. However, for Brilha, both types of sites deserve protection, and the only difference is in the way they are named (geosites or geodiversity sites). For Carcavilla et al. (2008), inventories of geological heritage are a selection of the most significant geological features of a region, according to different criteria such as intrinsic value, representativeness, rarity, etc. On the other hand, geodiversity seeks to analyse the variability and number of geological elements of a region, regardless of their value.

For the author, the definition of geoheritage must consider all the values of geodiversity, as proposed by Crofts et al. (2020) and other academics in the past, as there are numerous geological sites that, despite not having a proven scientific interest, have a majestic scenery of deep cultural and spiritual links with the local communities. In those cases, (geo)scientists should admit they are not the only human authorities to provide criteria on which sites are worth (or not) to be protected and inherited for future generations. In Latin America, this approach takes special importance as 8% of the total population is indigenous (Banco Mundial, 2015); there are high indexes of rurality, and local myths, legends and tales everywhere; and is a region with high cultural, biological and geological diversity.

From a scientific perspective, the geoheritage importance in Alto Ricaurte is mainly related to the Cretaceous sequences and their fossil content. Using the prevalent criteria for assessing the scientific value of geosites such as representativeness, integrity, rarity and scientific knowledge, some

geoheritage sites in the study area can be referred to. A good example of representativeness and rarity, for instance, lies in the exceptional fossil record of the Paja Formation, which includes several new species and holotypes. According to the Colombian palaeontologist María Paramo from the National University of Colombia, the largest Pliosaur in the world is located at Sáchica (Páramo-Fonseca et al., 2018; https://www.semana.com/vida-moderna/articulo/en-sachica-boyaca-se-encuentra-el-pliosaurio-mas-grande-del-mundo/565032/). This fossil is a good example of ex situ geoheritage with high representativeness and rarity (figure 26).

Figure 26. Skeleton of *Sachicasaurus vitae*. This specimen is considered the biggest Pliosaur in the world.

Recently, the Colombian Geological Survey is working on the inscription of the *geotope "*Lagerstätte of marine reptiles from the Barremian - Aptian of the south of the province of Ricaurte Alto, Boyacá*" in the National Geological and Palaeontological Inventory (INGEP), with a primary palaeontological interest and secondary with stratigraphic and palaeoecological interest. This polygon covers around 42 km^2 and includes the municipalities of Villa de Leyva, Sáchica and Sutamarchán. Geologically, it is framed by the Variegated Claystones (Arcillolitas Abigarradas) member of the Paja Formation (Servicio Geológico Colombiano, 2021).

A preliminary inventory and assessment of geological sites in the municipalities of Sáchica, Santa Sofía, Sutamarchán and Villa de Leyva is presented next. These sections will show that the most valuable geological sites in the region are found not only in fossils of high scientific value but also in karst features or rock outcrop sites with great scenery and other values.

It is important to recall that the objective of this master's dissertation is to present a diagnosis of geoconservation issues and to elaborate on geoconservation recommendations for the region. In this sense, section 3.7 introduces an inventory and assessment of geological sites in the study area, to give

* A geotope, according to Decree 1353 of 2018, is defined as "a clearly delimited spatial segment or portion of the geosphere, defined by reason of the geological or palaeontological heritage values existing in its constituent element (...)"

a context for the proposed geoconservation strategy. Even if there are some preliminary inventories in the region, it is important to emphasize the urgent need for a systematic inventory and assessment of geological sites in the territory, to better achieve the next steps of a management strategy such as conservation, promotion and diffusion.

3.8. Inventory of geological sites

According to Lima et al. (2010), a geoheritage inventory should answer to four main points: the object, the value, the scope and the utility. In this case, geological sites (object), with scientific, touristic, cultural or educational relevance (value), in the municipalities of Sáchica, Sant Sofía, Sutamarchán and Villa de Leyva (scope), to include in a preliminary inventory of geological sites for a geopark project (utility) were selected. Following the classification by Sharples (2002), this could be considered as a reconnaissance inventory – a 'first step' identifying significant features based on the experience of who is doing the inventory, literature reviews and consultation with experts.

The expression "geological sites" is used through this document to refer to geodiversity elements both in situ or ex situ (rocks, minerals, fossils, landforms, soils, etc.,) with a potential scientific, touristic, educational or cultural interest, whose values and heritage status must be assessed. The list of geological sites will contain the network of geodiversity elements that constitute the geological heritage of the region but also other sites and elements with cultural, touristic or educational value that are not necessarily considered as geological heritage. The term "geological sites" is also used by UNESCO in official documents regarding Geoparks such as the *Application dossier for UNESCO Global Geoparks* and the *Self-Evaluation Checklist for aspiring UNESCO Global Geoparks (aUGGp)*.

The inventory of geological sites was constructed based on several sources of information. Firstly, past inventories of geological sites were reviewed, mostly:

- The inventory of geological sites of the Boyacá Department done by the Colombian Geological Survey in 2016 (Servicio Geológico Colombiano, 2016a)
- The inventory of geological sites included in the project "Ruta Anillo de los Dinosaurios" (INGEOMINAS, 2011)

- The lists of natural and geological sites in the application of the Alto Ricaurte region as a World Heritage Site (Ministerio de Cultura, 2018).

These lists were analysed and complemented after fieldwork done in February 2022 and online and in-person interviews with experienced geologists, social actors, and locals. Finally, the inventory of geological sites for the municipalities of Santa Sofía, Sutamarchán, Sáchica and Villa de Leyva resulted in 19 sites (figure 27, table 8).

Table 8. Inventory of geological sites in the municipalities of Santa Sofía, Sáchica, Sutamarchán and Villa de Leyva.

Code	Name	Description	Main interest(s)	Thematic area	Municipality	Coordinates
GZP01	Cueva La Fábrica ***(La Fábrica cave)***	A cave of karstic-fluvial origin, with active formations of stalactites and stalagmites, moulded in rocks of the Rosablanca Formation.	Touristic	Karst landforms	Santa Sofía	5.705762, -73.577303
GZP02	Paso del Ángel ***(The Angel's ridge)***	Narrow and steep sharp geoform separating two sub-parallel watercourses, formed by the erosion of shales and mudstones of the Rosablanca Formation, with notable aesthetic interest and ongoing touristic activities.	Touristic	Erosion landforms and processes	Santa Sofía	5.750367, -73.581879
GZP03	Hoyo La Romera ***(La Romera hole)***	Collapse doline developed in limestones of the Rosablanca Formation with stalactites, stalagmites and columns inside. It is an inactive karst site and has ongoing tourist activities	Touristic	Karst landforms	Santa Sofía	5.729726, -73.580838
GZP04	Pozos Azules de Sutamarchán ***(Sutamarchán Blue Wells)***	Deep wells formed by lateral and bottom erosion in the riverbed. Dark claystone of the Paja Formation outcrop. It is a site frequented by tourists.	Touristic	Hydrological features and associated landforms	Sutamarchán	5.597264, -73.621448
GZP05	Cascada y Cueva El Hayal ***(El Hayal waterfall and cave)***	Cave and waterfall developed within a large yellowish-coloured escarpment (limestones of the Rosablanca Formation). The waterfall is about 30 m. The site has mainly aesthetic and geomorphological interested, and associated archaeological elements.	Touristic, Educational, Cultural	Karst landforms	Santa Sofía	5.736804, -73.57822
GZP06	Pliosaurio de Sáchica ***(Sáchica Pliosaur)***	A small exhibition centre housing the petrified remains of the *Sachicasaurus vitae* (new species), considered the biggest Pliosaur in the world.	Scientific, Touristic, Educational	Palaeontological record	Sáchica	5.566722, -73.534138

GZP07	Sección tipo Formación Ritoque ***(Ritoque Formation key locality)***	Site where the Ritoque Formation was defined by the geologist Fernando Etayo in 1968.	Scientific	Mesozoic sedimentary sequences	Sáchica	5.605428, -73.519066
GZP08	Museo El Fósil ***(El Fósil Museum)***	Petrified skeleton of *Monquirasaurus boyacensis*, new genus and species (Noè & Gómez-Pérez, 2021). It is exceptionally well preserved in situ and is virtually complete. It is also a world-class example of community-based management of international geological heritage.	Scientific, Touristic, Educational, Cultural	Palaeontological record	Villa de Leyva	5.637177, -73.558817
GZP09	Loma La Yesera ***(La Yesera Hill)***	Hill part of the *Lagerstätte* of the Paja Formation. It has a high scientific knowledge in terms of theses and publications, due to its stratigraphic and palaeontological interest. The site is known for the abundance and abundance and diversity of easily observable and extractable fossils.	Scientific	Palaeontological record	Villa de Leyva	5.605166, -73.535906
GZP10	Loma La Cabrera ***(La Cabrera Hill)***	Fossil site of great international importance for its unique fauna of Lower Cretaceous marine reptiles in rocks of the Paja Formation, part of the *Lagerstätte.*	Scientific	Palaeontological record	Villa de Leyva	5.650787, -73.562364
GZP11	Cascada La Periquera ***(La Periquera Waterfall)***	A series of waterfalls developed over siltstones of the Ritoque Formation, with special geomorphological interest and current eco-touristic activities.	Touristic	Hydrological features and associated landforms	Villa de Leyva	5.716998, -73.521337
GZP12	Excavación Pliosaurio ***(Pliosaur Excavation)***	The Pliosaur *Sachicasaurus vitae* (new genus and species) was found here. The site is of scientific importance as it contains the stratigraphic and palaeontological context of this world-class discovery.	Scientific	Palaeontological record	Sáchica	5.571643, -73.530972

GZP13	Sección referencia Formación Paja ***(Key site of the Paja Formation)***	This outcrop is a reference site of the Paja Formation.	Scientific	Mesozoic sedimentary sequences	Sáchica	5.588615, -73.518138
GZP14	Sección de referencia Grupo San Gil ***(Key site of the San Gil Group)***	Type section of the Upper San Gil Formation (limestone, claystone and sandstone). It contains remains of bivalves and carbonaceous material.	Scientific	Mesozoic sedimentary sequences	Sáchica	5.577418, -73.511062
GZP15	Yacimiento de travertinos ***(Travertine deposit)***	Travertine accumulation currently quarried. There are some reports of Quaternary fauna: mastodons, armadillos and canine teeth of the sabre-toothed tiger. Access to the site is restricted, and there is currently a mining title in place.	Scientific	Palaeontological record	Villa de Leyva	5.619533, -73.530715
GZP16	Secuencia Formación Arcabuco ***(Arcabuco Formation Sequence)***	Rocky outcrop on escarpments, exposing the only Jurassic rock formation in the area. The site is associated with rock art and has great scenery and touristic potential.	Touristic, Cultural, Educational	Mesozoic sedimentary sequences	Sáchica	5.591794, -73.520372
GZP17	Cascada termal de Sáchica ***(Sáchica hot spring waterfall)***	An anthropogenic site where thermal spring waters upwelling a few meters away have been forced to fall. It is of major tourist interest.	Touristic	Hydrological features and associated landforms	Sáchica	5.588295, -73.529553

GZP18	Cárcavas de Ritoque ***(Ritoque Gullies)***	Area with strong erosive processes and gullies up to 2 metres deep. Great scenery and also a viewpoint.	Touristic, Educational	Erosion landforms and processes	Villa de Leyva	5.602068, -73.522000
GZP19	Cárcavas de Quebrada Arriba ***(Quebrada Arriba Gullies)***	Area with strong erosive processes and eye-catching landforms.	Touristic, Educational	Erosion landforms and processes	Sáchica	5.542558, -73.522308

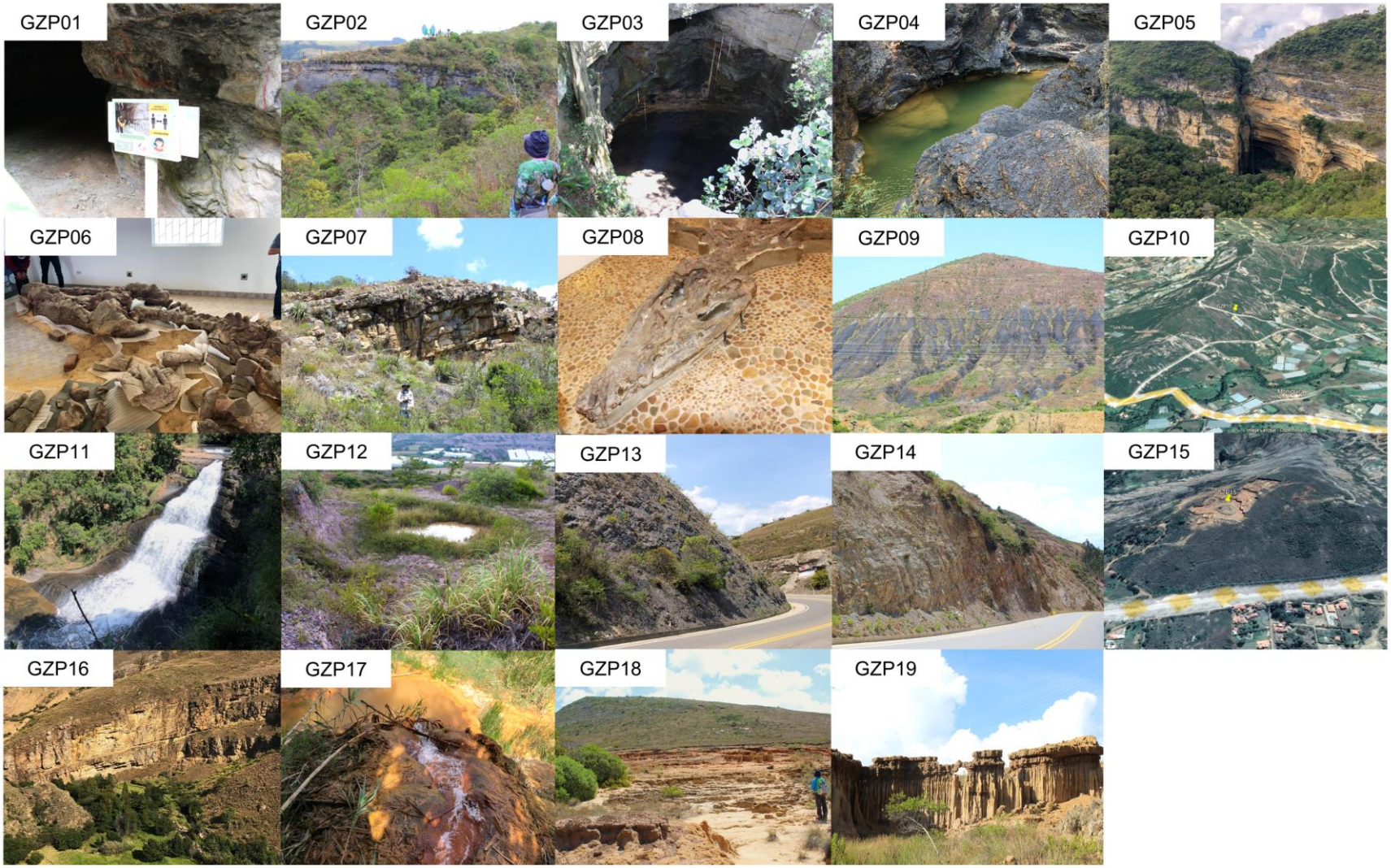


Figure 27. Geological sites included in the inventory.

3.8.1. Assessment of sites

There are different qualitatively and quantitatively methods to assess a set of geological elements and make a selection of sites according to the purpose. In this case study, the bibliographic revision and community surveys done in the first methodological step gave some clues about which are the sites with evident scientific relevance, cultural significance and touristic or educational potential. Since the number of geological sites in the inventory is low (19), a selection of sites and management priorities could be established with this primary information. Nevertheless, since the inventory can extend in the future including other municipalities in Alto Ricaurte, and to test the quantitative method developed for this case study, a quantitative assessment was conducted.

According to Brilha (2016), a quantitative assessment aims to decrease the subjectivity associated with any site evaluation procedure and to define priorities for site management. This analysis results in a list of sites sorted by their values, which allows us to make comparisons between the sites and to take decisions. The results obtained by any quantitative assessment do not always represent the real values and potential of sites so they should be critically analysed (Brilha, 2016) and used along with other considerations to establish priorities for the management of sites.

For this case study, the assessment was made considering the scientific value, potential for tourism use, potential for educational use and risk of degradation (table 9). The methodology of assessment used (Appendix 2) was led by the author with the help of the Grupo de Investigación en Geología Ambiental (GEA) from the National University of Colombia in Medellín. This method was based on Brilha (2016) and the official national methodology proposed in 2016 by the Colombian Geological Survey (Servicio Geológico Colombiano, 2016b).

Table 9. Criteria used for the quantitative assessment and respective weights

Scientific Value	Potential of Educational Use	Potential of Touristic Use (PTU)
Representativeness (30), Scientific knowledge (15), Conservation status (10), Rarity (20), Geological diversity (10), Use limitations (15)	Potential for educational activities (25), Geological diversity (10), Association with other values of cultural or natural heritage (20), Conservation status (20), Use limitations (25)	Potential for recreational activities (25), Landscape quality (15), Association with other values of cultural or natural heritage (15), Conservation status (10), Proximity to recreational areas (10), Use limitations (25)
Risk of degradation		
Deterioration of geological elements (35) Proximity to areas/activities with potential to cause degradation (20) Legal protection (20) Accessibility (15) Density of population (10)		

Thus, the values and potentials of geological sites were calculated as:

Scientific Value (SV) = [(R*30) + (CC*15) + (EC*10) + (R*20) + (DG*10) +(LU*15)] / 40

Potential of Educational Use (PEU) = [(PD*25) + (DG*10) + (ANC*20) + (EC*20) + (LU*25)] / 40

Potential of Touristic Use (PTU) = [(PR*25) + (CVP*15) + (ANC*15) + (EC*10) + (PAR*10) + (LU*25)] / 40

Ranges used for SV, PEU, and PTU are:

≤ 3,2 Low value 3,3 to 6,6 Medium value ≥ 6,7 High value

And the risk of degradation (RD) according to Brilha (2016) is calculated as:

Risk of degradation (RD) = [(PDEG*35) + (PAER*20) + (PL*20) + (A*15) + (DP*10)] / 40

With the following classification ranges used:

0 a 4,9 → Low 5,0 a 7,4 → Moderate 7,5 → High

The scientific value, potential of use and risk of degradation for the 16 sites presented in this study are shown in table 10.

3.8.2. Management classes

Considering the observations done during the field work, the results of the quantitative assessment and the background knowledge of the sites, these were classified into management classes that are related to the proposed use for each site. In this study, the multi-labelled classification proposed by Vergara et al. (2021) was used as a basis. This classification includes the following parameters: geotourism, education, science, and conservation. Classification of the sites in the inventory is exposed below.

Conservation or Restauration (C): Sites with top priority for implementing geoconservation measures, due to their high risk of degradation, either from natural or anthropogenic threats. These measures precede any other use, to ensure the long-term conservation of the site.

Science (S): Refers to sites with relevance for the science at a national or international scale that have been used for research and the continuity for its research use should be guaranteed. These sites need guidelines regarding their responsible scientific use and a strict protocol for scientific activities that require a physical intervention on the site.

Education (E): Besides their didactic potential, these sites meet the accessibility, safety and logistics conditions for their use through educational activities related to Earth sciences. These sites need a handbook of the concepts that can be discussed in them.

Geotourism (G): Sites within this class have either previous touristic activities occurring or a high potential for developing touristic activities, and meet essential criteria such as the possibility for leisure or recreation, easy access and general safety conditions.

Table 10. Scientific Value (SV), Potential of Educational Use (PEU), Potential of Touristic Use (PTU) and Risk of Degradation (RD) for the geological sites in the study area.

Code	Name	Managem. classes	R	CC	EC	RA	DG	LU	PAD	ANC	PR	CVP	PAR	SV	PEU	PTU	PDEG	PAER	PL	A	DP	RD
GZP01	Cueva La Fábrica (La Fábrica cave)	C, S, E, G	2	1	2	1	1	4	2	4	4	2	4	4,625	7,000	8,750	2	1	3	2	4	5,5
GZP02	Paso del Ángel (The Angel's ridge)	G	0	0	1	2	0	1	0	0	4	4	4	1,625	1,125	5,875	4	1	3	2	4	7,25
GZP03	Hoyo La Romera (La Romera hole)	G	2	1	4	1	0	2	2	4	4	2	4	4,125	6,500	8,000	1	1	3	2	4	4,625
GZP04	Pozos Azules de Sutamarchán (Sutamarchán Blue Wells)	G	0	0	2	1	2	2	1	1	4	4	4	2,250	3,875	7,125	2	1	1	1	4	4,125
GZP05	Cascada y Cueva El Hayal (El Hayal waterfall and cave)	C, S, G	4	0	4	2	1	2	2	4	4	4	4	6,000	6,750	8,750	2	1	3	2	4	5,5
GZP06	Pliosaurio de Sáchica (Sáchica Pliosaur)	C, S, E, G	4	4	4	4	0	2	4	4	2	0	2	8,250	7,750	5,500	1	1	4	2	3	4,875
GZP07	Sección tipo formación Ritoque (Ritoque Formation key locality)	S	4	2	2	2	0	1	0	2	0	0	4	5,625	2,625	2,875	1	1	2	1	3	3,5
GZP08	Museo El Fósil (El Fósil Museum)	C, S, E, G	4	4	4	4	1	4	4	4	4	0	4	9,250	9,250	8,500	1	1	1	4	3	4,125
GZP09	Loma La Yesera (La Yesera Hill)	C, S, E	2	4	2	1	1	2	2	2	1	4	2	5,000	4,750	5,125	3	1	3	4	3	6,875
GZP10	Loma La Cabrera (La Cabrera Hill)	C, S, E	1	4	1	1	1	2	1	1	0	0	2	4,000	3,125	2,375	3	2	3	4	3	7,375
GZP11	Cascada La Periquera (La Periquera Waterfall)	C, G	2	1	4	2	1	2	0	4	4	4	4	4,875	5,500	8,750	1	1	3	2	3	4,375

GZP12	Excavación Pliosaurio (Pliosaur Excavation)	C, S	4	4	1	4	2	0	2	1	2	0	2	7,250	2,750	2,375	4	2	4	2	4	8,25
GZP13	Sección referencia Formación Paja (Key site of the Paja Formation)	S, E	2	2	2	2	1	2	1	2	0	0	2	4,750	4,125	3,000	3	1	1	4	4	6,125
GZP14	Sección de referencia Grupo San Gil (Key site of the San Gil Group)	S, E	4	1	2	2	1	2	1	1	0	0	2	5,875	3,625	2,625	3	1	1	4	4	6,125
GZP15	Yacimiento de Travertinos (Travertine deposit)	E, S	1	1	1	2	1	0	0	2	0	0	2	2,625	1,750	1,500	4	4	3	4	3	9,25
GZP16	Secuencia Formación Arcabuco (Arcabuco Formation Sequence)	E, G	4	1	2	1	1	4	2	4	4	4	4	6,125	7,000	9,500	2	4	3	1	4	6,625
GZP17	Cascada termal de Sáchica (Sachica hot spring waterfall)	G	4	1	0	1	0	1	2	2	4	2	4	4,250	2,875	5,625	4	4	1	1	4	7,375
GZP18	Cárcavas de Ritoque (Ritoque Gullies)	E, G	2	1	2	1	2	4	2	2	4	4	4	4,875	6,250	8,750	2	2	1	1	4	4,625
GZP19	Cárcavas de Quebrada Arriba (Quebrada Arriba Gullies)	E, G	2	0	2	1	1	2	2	1	2	4	2	3,500	4,250	5,375	3	1	1	2	4	5,375
AVERAGES														4,993	4,782	5,809						5,888

3.8.3. Analysis of the inventory

As noted by Vergara et al. (2019), the inventory of geological sites results in a vast amount of information that can be analysed to identify trends and patterns useful for making decisions on future steps in the management and conservation measures in the geological sites. The aspects analysed in this section include sorting by thematic areas, geographical distribution, scientific value, and educational and touristic potential.

3.8.3.1. Results of the quantitative assessment (SV, PTU, PEU)

As mentioned above, it is possible that the results of quantitative assessment do not accurately represent the real value of the geological sites. In this case, the assessment method that was applied had not been tested previously, and therefore this study serves as a useful pilot scheme to calibrate and make adjustments to the method.

Overall, the results obtained from the assessment are reasonable and in line with what was expected. However, some inaccuracies can be seen in some numerical results of the assessment. For example, some sites with an obvious and unique scientific interest have obtained low scores. It is the case of Loma La Yesera (GZP09), Loma La Cabrera (GZP10), and the type sections of some rock formations. This is partly because the criteria used are quite comparative, and for example, the value of these sites lies in the fossil remains that have been discovered there, but which have also been found at various localities in the area, which makes them less rare. Thus, the scores for criteria such as Rarity and Representativeness turn to lower values. In addition, Conservation Status (EC) and Use Limitations (LU) may also lower the scientific value, even if in reality these variables are more related to their potential for scientific use than to the scientific value itself. In general, the LU variable in this methodology decreases the value for most of the sites. In this sense, although the method assesses "potentials", the potential of some sites is overshadowed by the current conditions of the site. For example, the Pliosaurio de Sáchica (GZP06) site has an evident high educational and touristic potential, but since it is located in a place different to its original site, with restricted access, and far from recreational areas or sites with a special cultural or spiritual value, its touristic potential (PTU) was calculated as low.

The top-ranked sites considering the average of SV, PTU, and PEU are shown in table 11. This information could help to justify, from a technical perspective, which sites should be prioritised in terms of management measures, for example in the case of a geopark project, as they are the geological "stars" of the region according to their potential for touristic, educational, and scientific use.

Table 11. Top-ranked sites according to the quantitative assessment

Site	Average (SV, PTU, PEU)	Photos
Museo El Fósil (GZP08)	9,00	
Secuencia Formación Arcabuco (GZP16)	7,54	
Cascada y Cueva El Hayal (GZP05)	7,16	
Pliosaurio de Sáchica (GZP06)	7,16	
Cueva La Fábrica (GZP01)	6,79	

Nevertheless, they do not necessarily represent the geological heritage in the study area, since for this methodological proposal, geological heritage cannot be defined only by scientific or quantitative means, but through an interdisciplinary discussion considering technical criteria of earth science but also the other values of geodiversity already mentioned, and which for example were not quantitatively assessed.

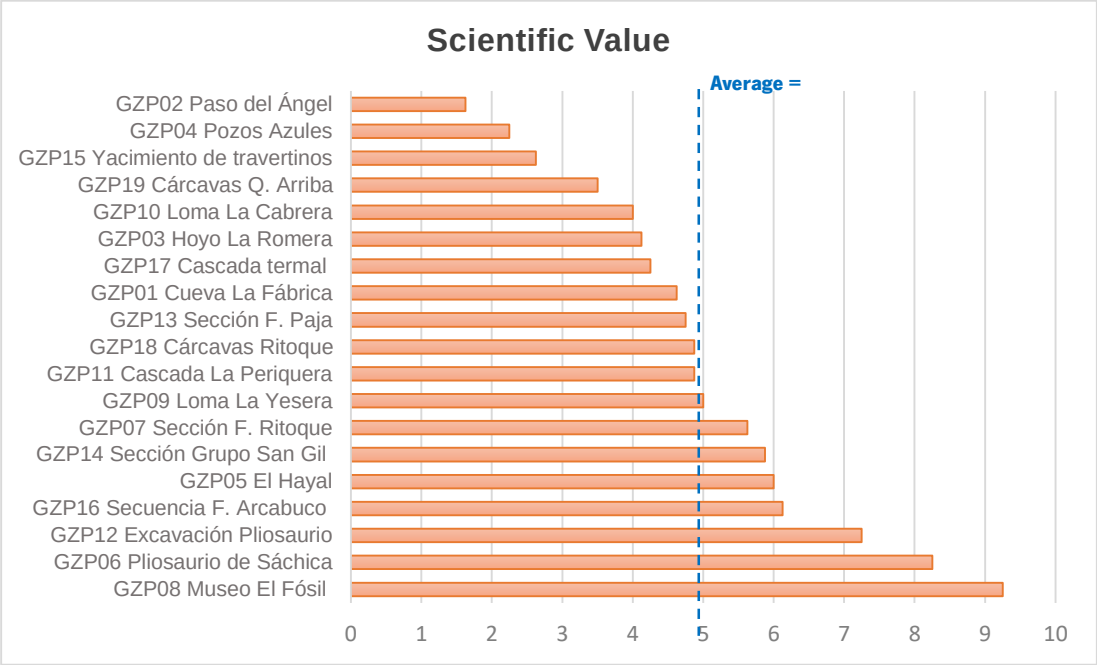


Figure 28. Sorting of sites according to SV.

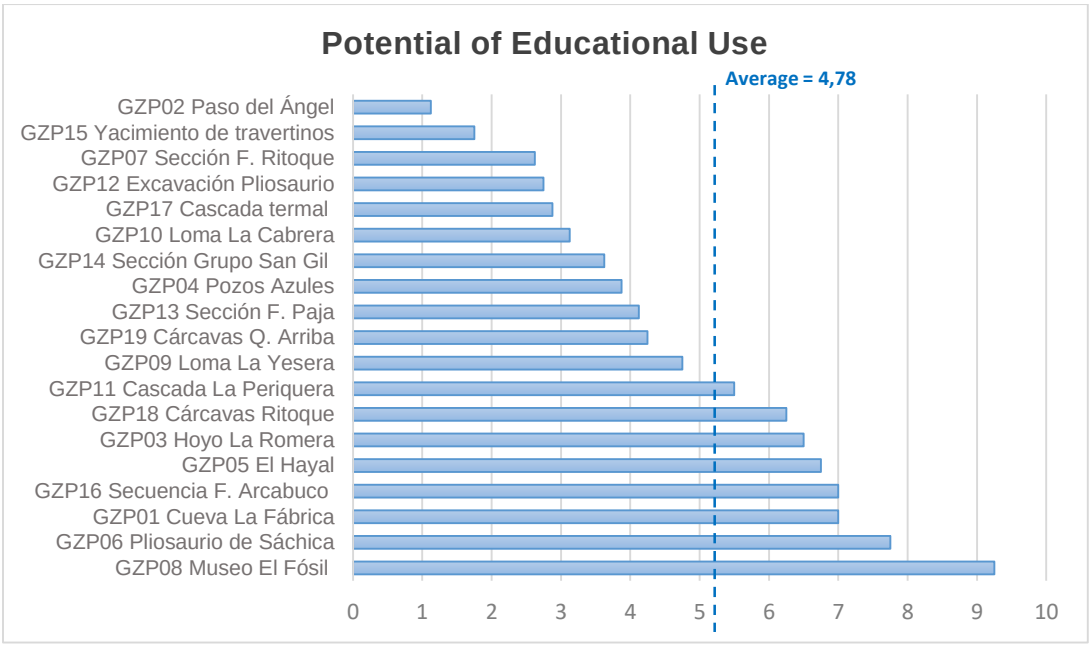


Figure 29. Sorting of sites according to PEU.

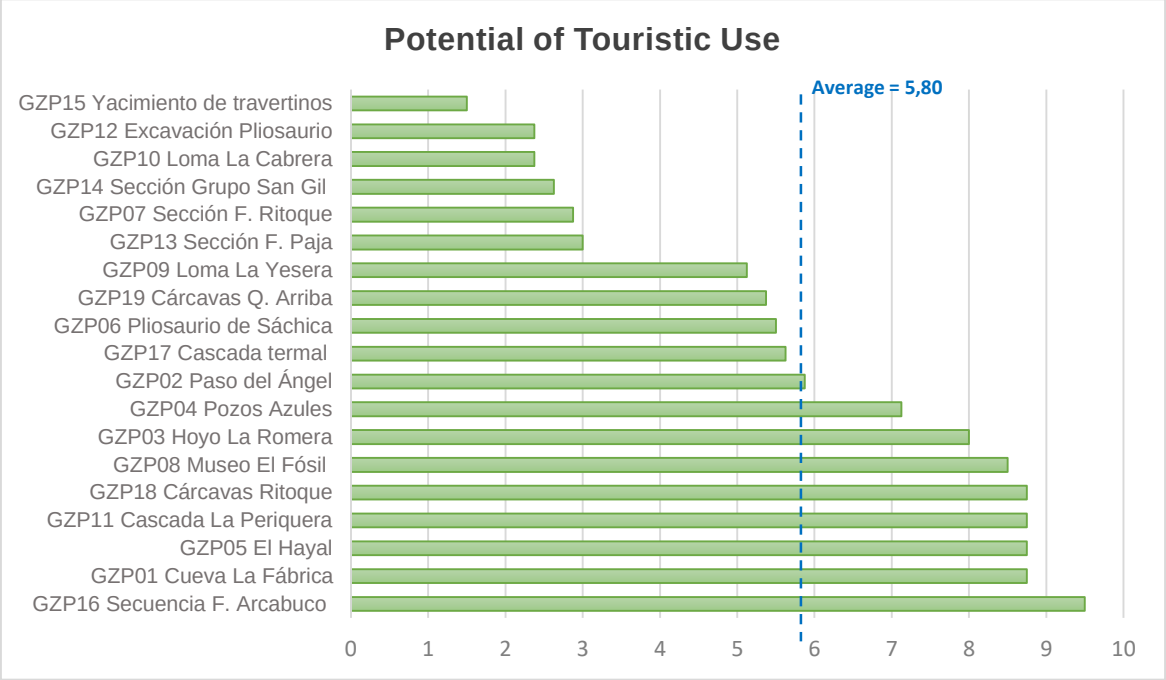
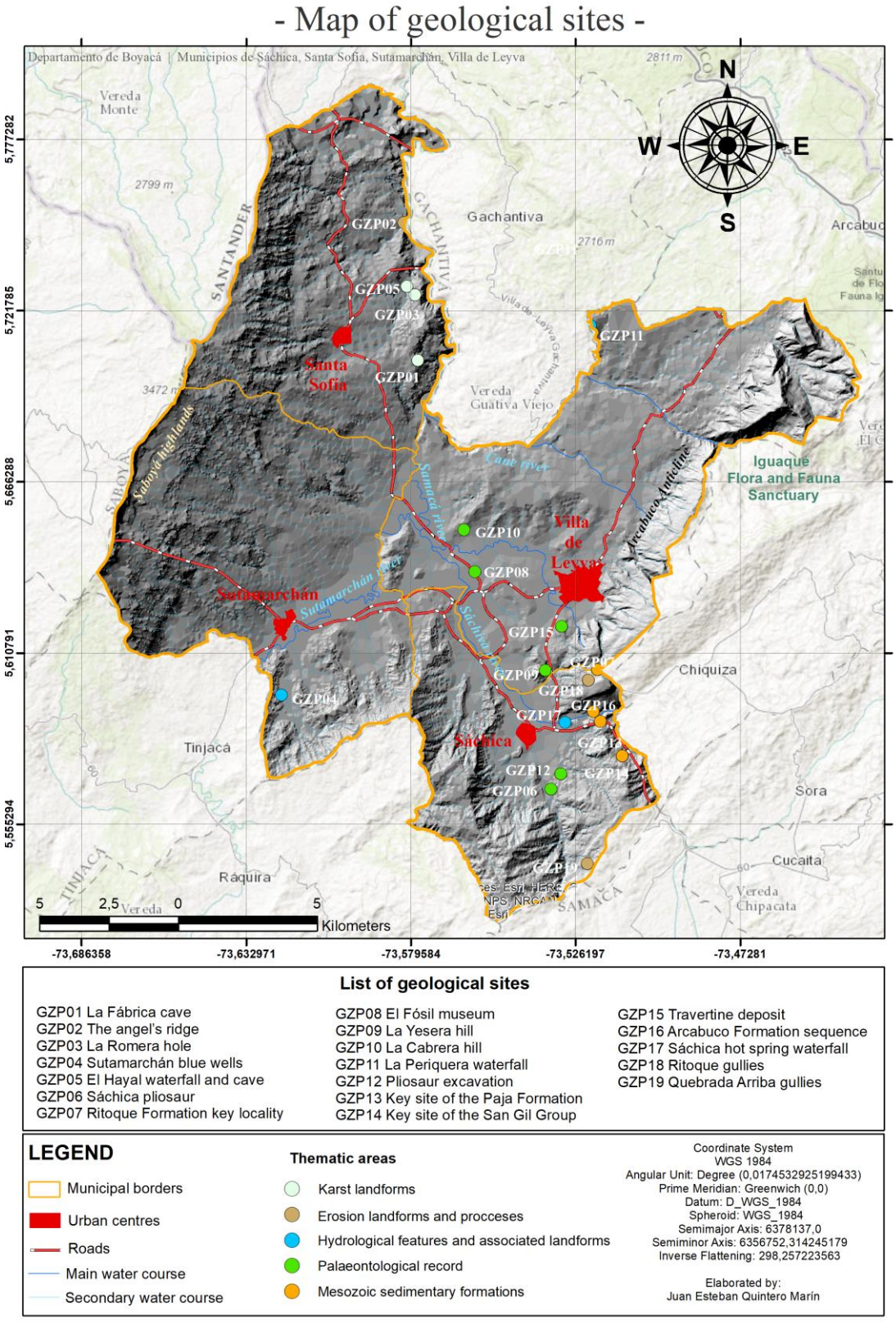


Figure 30. Sorting of sites according to PTU.

3.8.3.2. Geographical distribution

There is a critical accumulation of geological sites located between Sáchica and Villa de Leyva, around Morro Negro, with five geological sites in less than 2,5 km^2. Regarding accessibility, 9 of the geological sites (47%) are located less than 200 m from a paved or unpaved road. Political-administrative distribution is fairly uneven since almost half of the sites are located in the municipality of Sáchica (figure 31). It is also notable the small number of sites in the municipality of Sutamarchán. This could be due to the geological context but also because of a lack of knowledge and exploration, especially in the highest parts of the municipality to the east. After discussions with the municipal tourism office during the field works, it is possible that this situation will change, since some places with potential geological interests could be included in a more in-depth inventory in the future.

Other geological sites may be discovered to the northeast of the study area, on the west margin of the Arcabuco Anticline in Villa de Leyva, since there are ongoing explorations of dinosaur footprints by geologists from Villa de Leyva. Likewise, other sites may be included in the inventory, due to new palaeontological findings or surveys with the local communities that result in new sites with special cultural or symbolic value.



List of geological sites

GZP01 La Fábrica cave
GZP02 The angel's ridge
GZP03 La Romera hole
GZP04 Sutamarchán blue wells
GZP05 El Hayal waterfall and cave
GZP06 Sáchica pliosaur
GZP07 Ritoque Formation key locality
GZP08 El Fósil museum
GZP09 La Yesera hill
GZP10 La Cabrera hill
GZP11 La Periquera waterfall
GZP12 Pliosaur excavation
GZP13 Key site of the Paja Formation
GZP14 Key site of the San Gil Group
GZP15 Travertine deposit
GZP16 Arcabuco Formation sequence
GZP17 Sáchica hot spring waterfall
GZP18 Ritoque gullies
GZP19 Quebrada Arriba gullies

LEGEND

- Municipal borders
- Urban centres
- Roads
- Main water course
- Secondary water course

Thematic areas

- Karst landforms
- Erosion landforms and procceses
- Hydrological features and associated landforms
- Palaeontological record
- Mesozoic sedimentary formations

Coordinate System
WGS 1984
Angular Unit: Degree (0,0174532925199433)
Prime Meridian: Greenwich (0,0)
Datum: D_WGS_1984
Spheroid: WGS_1984
Semimajor Axis: 6378137,0
Seminor Axis: 6356752,314245179
Inverse Flattening: 298,257223563

Elaborated by:
Juan Esteban Quintero Marín

Figure 31. Geological sites map of the study area.

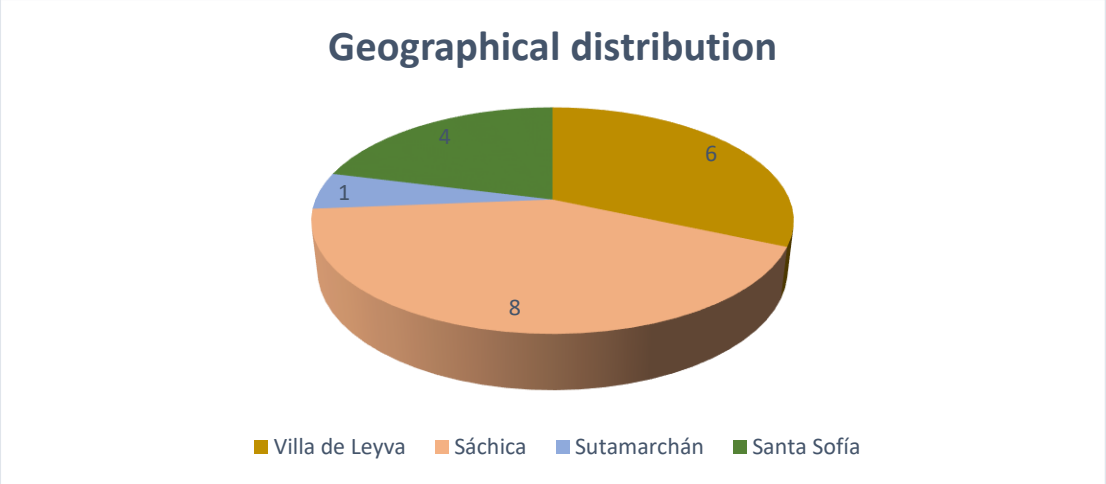


Figure 32. Distribution of geological sites by municipality.

3.8.3.3. Thematic areas

The thematic areas proposed have a practical purpose, which is to facilitate the grouping of geological sites and their future interpretation, use and dissemination. In general, there is an even distribution of geological sites between the different thematic areas (figure 33). Of the 19 geological sites, Paleontological Record and Mesozoic Sedimentary formations are the ones with more sites. In a broader inventory, paleontological sites will likely remain the most important thematic area, not only in frequency but also in importance, since this is the most relevant geological interest of the region. On the other hand, there are no geological sites representing the 'Tectonic structures' theme within the study area. Some of the most spectacular structural-related outcrops are located on the Sáchica-Tunja road outside the boundaries of the study area, in the municipality of Samacá. Similarly, it is also possible that new thematic areas will be defined within the study area, related to discoveries or to a more specialized inventory that adds new sites to the inventory. Other thematic area categories that eventually could be considered in the region are, for instance, soils and recent deposits, and quarrying/mining sites associated with mining-historical heritage.

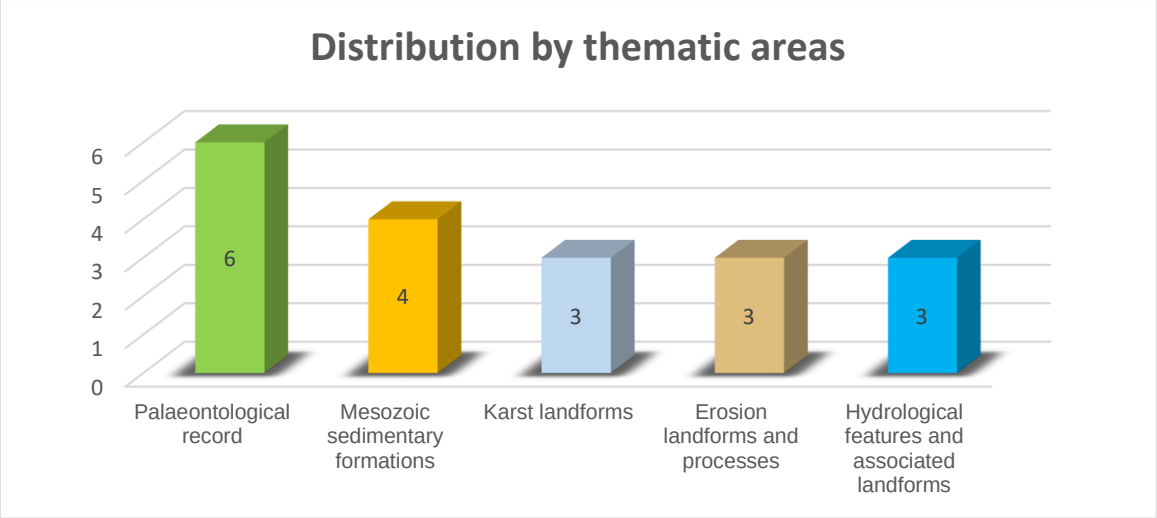


Figure 33. Distribution of geological sites by thematic areas.

It is also interesting to analyse which thematic areas gather more geological sites with high educational, touristic or scientific value (figure 34): Paleontological record, Mesozoic sedimentary formations, and Karst landforms. Concerning fossils, this is known *de-facto* but this information could give clues as to which themes the interpretative and touristic materials elaborated in a geopark project could be oriented to. It is also noticeable that the touristic potential is a strength in the region since 70% of the sites possess high or medium touristic potential.

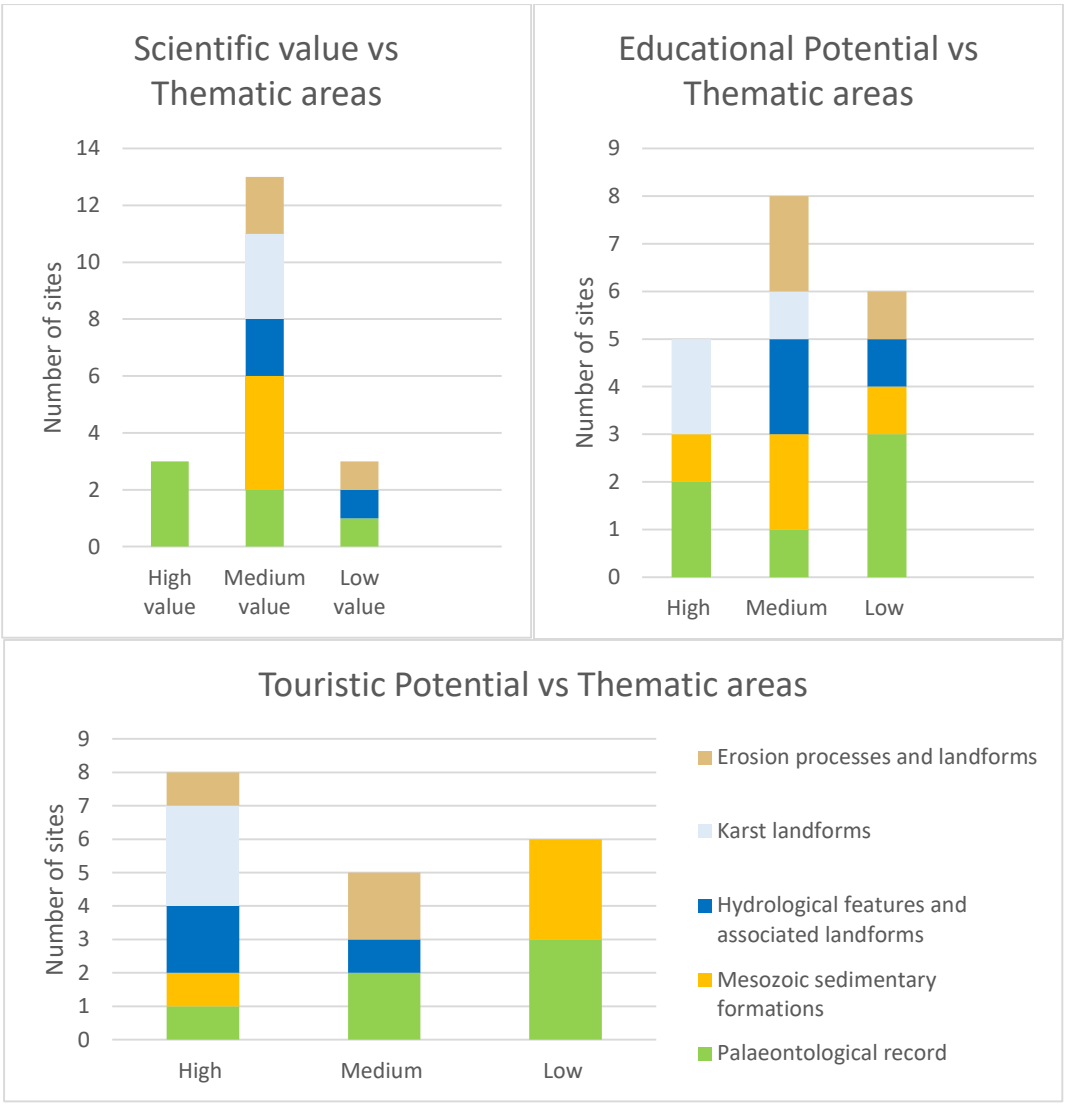


Figure 34. Thematic areas vs Scientific value, Potential of Educational Use and Potential of Tourism Use.

3.8.3.4. Conclusions on the inventory and quantitative assessment

In the first place, it is important to point out that the inventory presented in this thesis is a preliminary list based largely on the bibliographic and documentary revision. It is necessary to complement this first inventory with further fieldwork and additional interviews with strategic stakeholders. Overall, the results of the quantitative assessment were helpful to confirm some remarks and observations done during the bibliographic revision and fieldwork phases. The results are reasonable since several geological sites widely recognized for their scientific or cultural interest and their touristic or educational potential were highlighted by the assessment. The methodology applied focuses on the practical potential of use of these sites, which has to be considered to correctly interpret the results. Therefore, the geological sites with low values have often some impediments that hinder their use.

The analysis of the inventory shows that there is an even distribution of geological sites in terms of thematic areas, and SV, PTU, and PEU values. Nevertheless, the sites with high scientific value belong uniquely to the "Paleontological record" thematic area. Besides, the sites with high touristic potential include all the thematic areas on the inventory, which shows an opportunity to disseminate and promote sites of diverse geological nature through geotourism.

The geographical distribution displays an unexpected accumulation of geological sites in Sáchica. The administration of this municipality can consider this as an opportunity to promote the town and appropriate the geological importance of the region, which is usually granted to Villa de Leyva. Furthermore, as was mentioned, it is necessary to conduct further inventories in Sutamarchán, considering the few reported geological sites, but also the indications of possible additional sites that were collected during the fieldwork of this master's thesis.

Finally, it is necessary to mention that for this dissertation, the quantitative assessment is just a complementary tool to assess some of the values and potentials of geological sites and to have some summarized information useful to make management decisions, but a comprehensive selection of sites, according to the purpose, should be done by an inter-disciplinary team that considers not only the technical criteria but also other human-centred values such as cultural and spiritual value, as well as the point of view of local communities.

Chapter 4. Geoconservation diagnosis

The preceding chapter provided an overview of the geodiversity and geoheritage in the region, its values, and a preliminary inventory of geological sites, which helps to answer the first element in a geoconservation strategy: what is it there? which elements may be worth protecting? In the context of a geoconservation analysis and strategy, it is now important to examine the threats and conservation problems that could affect the geological sites and the geodiversity more broadly. This will allow the identification of key problems and so the establishment of conservation measures and actions to reduce these threats. The conservation diagnosis is done on two scales: geological site level, and general level (figure 35).

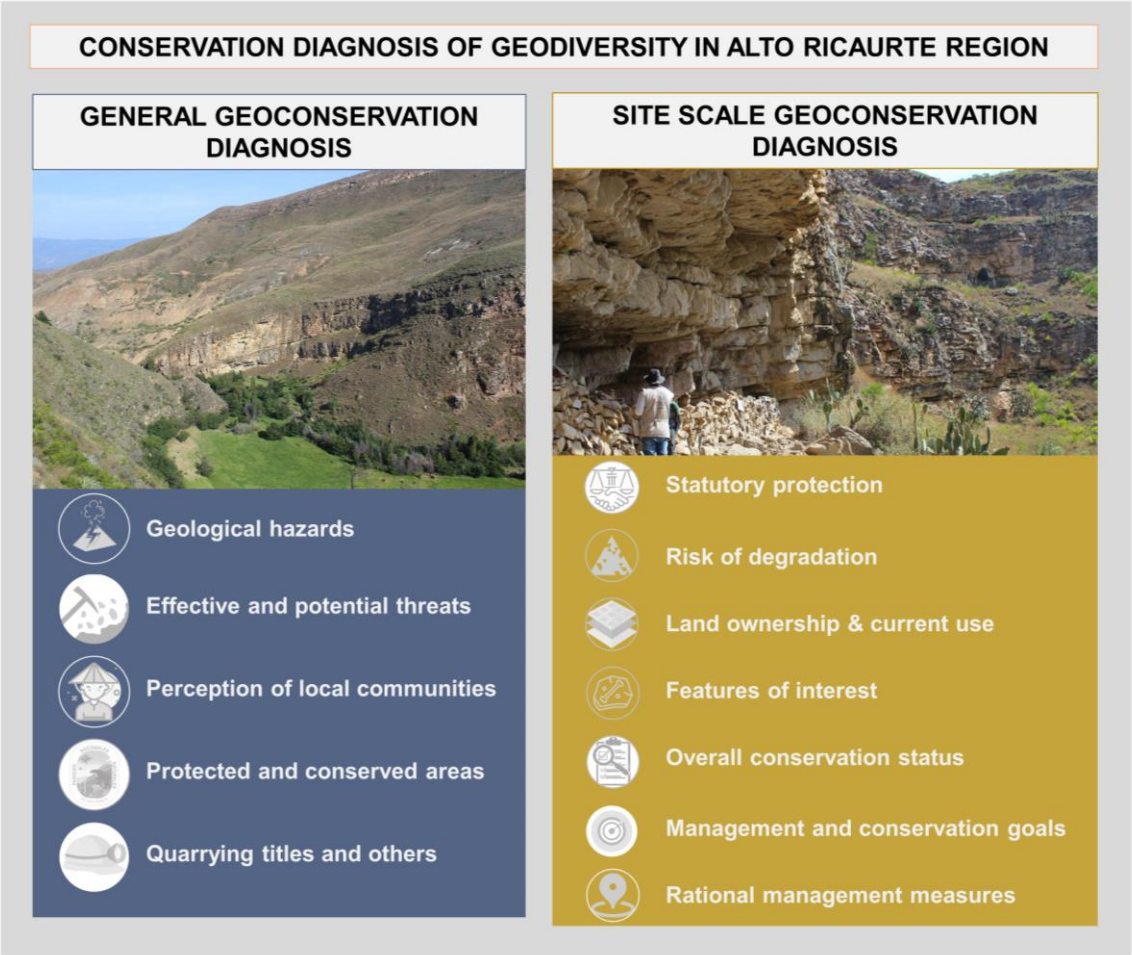


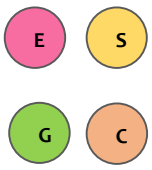
Figure 35. The two scales of analysis of the geoconservation diagnosis in Alto Ricaurte: broad (geodiversity diagnosis) and geosite level diagnosis.

It is proposed that the analysis at the geo-site scale be done through a descriptive form (Geoconservation status form) which gathers all the relevant information regarding geoconservation at this scale. On the other hand, the broader geoconservation diagnosis analyses all the potential threats, conservation issues, activities and socio-economic problems that could affect the geodiversity in the area. In addition, this chapter provides an analysis of the perception of conservation issues by local people, as another important source of conservation problems that are not reported formally or in academic documents, and which can represent a real obstacle to conservation actions or decisions, as it will be discussed further down.

4.1. Geoconservation diagnosis of geological sites

This section analyses the conservation status of geodiversity at a geological site level. As discussed in the previous chapter, the study area possesses geological elements of international scientific relevance and diverse cultural and spiritual links with the local communities. These values make some of the sites worthy of protection, and it is, therefore, important to make a diagnosis of each of these sites: Which are the main geological elements to be protected? What are the conservation condition and the statutory protection status? What are the conservation and management objectives for each of these sites? To systematically register this information for each site, a "Geoconservation status form" was prepared (table 12).

Table 12. Template of the 'Geoconservation status form' prepared for this study

<table>
<tr><th colspan="5">GZP00 Unnamed Geological Site 5.60000, -72.000</th></tr>
<tr><td colspan="5">Description
Insert a brief description of the context of this geological site: geographical geological context, short geological description, accessibility, visibility, safety conditions, the potential of use and observations.</td></tr>
<tr><td>Classification
According to the reference or methodology used</td><td>Management classes
 

E: Education
S: Science
G: Geotourism
C: Conservation</td><td>Statutory protection
Yes? Not? Which one?</td><td>Current use
Wasteland? Tourism? Crops? Conservation?</td><td>Land property
Private or Public</td></tr>
<tr><td colspan="5">Features of primary interest
Describe the physical or tangible elements that constitute the main interest of the geological site.</td></tr>
</table>

Features of secondary interest Describe the physical or tangible elements that constitute the secondary interest of the geological site (if applies)	
Relationship with cultural or biodiversity elements Mention historical, cultural, archaeological or biological elements found at the site (rock art, fauna or flora species, legends or folklore, etc.).	
Overall conservation status Provide a general description of the level of degradation of the site: weathering, vegetation cover, damaged or lost elements, potential threats observed, and proximity to threatening activities. Favourable / Favourable with alterations / Unfavourable	
Degradation risk Include fragility description (intrinsic), vulnerability description (external threats) and risk of degradation	
Management and conservation goals Following the proposal by Wimbledon et al. (2004), describe through goals the ideal situation in which the geological site would preserve its main features of interest. Example: "The abundance and diversity of the fossils in the site will be enough for being visible by future tourists and students visiting the site for educational purposes" "Illegal and informal extraction of fossils in the site will be minimum." "The site will have easy, signalized and safe access"	**Rational management measures** List specific and achievable measures that will help to reach the conservation goals stated before. Example: "Creation of a management plan focused on the paleontological resource." "Limit vehicle access by installing a fence" "Annual monitoring of the physical integrity and indicators on the abundance and state of the rock layers"
Notes	
Photographic record Insert a relevant photographic register of the geological site, its context and main features.	

The Geoconservation Form of one geological site is presented here as an example. The forms for the other sites are in the Appendix 1.

GZP16 Arcabuco Formation Sequence 5.637177, -73.558817				
Description It is a valley in which the Chíquiza stream opens its way in a relatively wide valley of great scenic attraction, surrounded on the right bank by high escarpments of the Arcabuco Formation that are part of the Arcabuco Anticline, and which represent the only Jurassic rock formation outcropping in the area. On the same site is the Sáchica Rock Art Site, of great archaeological interest. Access to the site is after a 10 min walk from an unpaved road. Safety conditions must be considered as there are some rockfall processes at the site.				
Classification Geological site Thematic area: Mesozoic sedimentary sequences	**Management classes**  	**Statutory protection** No	**Current use** Ecotourism, grazing	**Land ownership** Private

Features of primary interest

The main features of interest in the site are the layers of quartz sandstones, sandstones and phyllites that evidence the transitional environment during the Jurassic.

Features of secondary interest

Relation with other heritage

The outcrop is a famous archaeological site known as "Sáchica pictograms", related to the Muisca culture.

Overall conservation status

Favourable. The outcrop is made up of very competent materials that are not subject to deterioration. For this reason, and because of the large size of the site, the general state of conservation of the site is good. Some specific conservation problems of the site are related to tourism activities, which should be controlled as there are fire marks and graffiti on the rocks. The growth of vegetation covering some parts of the outcrop may accelerate the weathering process.

Risk of degradation

Fragility: No major natural hazards are evident at the site. Some collapses, vegetation and lichen growth on the rocks are evident.

Vulnerability: Some activities that have affected and may affect the site are tourism bonfires, graffiti, rock plundering by amateurs, and quarrying, which for example brings dust that covers the associated rock art. The site has an active mining title until 2026, although at the present quarrying is not directly affecting the site.

Risk of degradation: medium

Management and conservation goals	**Rational management measures**
The exposures of rock layers in the site will be enough to enable a good interpretation of the features in the site.	Creation of a management plan (including the land on top of the outcrop).
The site will have signalization to access, as well as signals warning about the presence of a geological feature of interest in the place.	Signalization of the site and access route.
In the medium term, farmers, tourism guides and neighbours will be aware of the presence of a geological site and the area.	Coordinate with the neighbours of the site to develop annual vegetation control activities on the site.
The polygon of the area will be delimitated, including the portion for touristic and agronomy activities.	Make zoning of the geological site, including delimitation of the area for tourism and livestock activities, and make efforts to include it in the land-use plan of the municipality.
In the medium term, the polygon of the site will be included in the "protection" category in the local land-use plan.	Fences in the rock art site.
The rock art sites will be difficult to reach by visitors to guarantee their physical integrity.	Installation of a panel about the Jurassic period.
Activities and programs related to the Jurassic period, based on the paleo-environmental information provided by these rocks, will exist.	To execute educational programs with the ecotourism agencies that use this site, as well as in local schools, to raise awareness about the geology of the site.
	Annual monitoring of the physical integrity and visibility of the features of primary interest.

Notes

N/A

Photographic record

4.2. Geodiversity threats and conservation problems

This section describes the main threats to geodiversity and conservation issues that currently affect or may affect the geological elements in the study area.

4.2.1. Recreation and tourism pressure

The study area is a busy touristic destination with hundreds of tourists, particularly on weekends throughout the entire year, with Villa de Leyva being one of the most touristic towns in Colombia. Tourists visiting Alto Ricaurte appreciate not only the colonial architecture, museums and traditions but also the natural resources in the surroundings, with a visible increase in ecotourism and nature tourism activities in the last years. This tourism is an increasingly important economic activity but can lead to damages on biodiversity and geodiversity (Gray, 2004).

Some of the impacts related to tourism activity in the Alto Ricaurte region are the deterioration of geological elements due to fossil collection and increasing erosion, solid waste, slope destabilization, destruction of trails and geoconservation infrastructures, soil compaction and gullying. In some of the natural gullies of Sáchica and Villa de Leyva, for instance, trampling by tourists can increase the erosion processes (figure 36). Gullies and other landforms are at risk due to 4x4 vehicles or ATVs, very popular for renting among tourists in Villa de Leyva. Moreover, irresponsible tourism is largely perceived as a potential threat to geodiversity and geoheritage according to the survey conducted during the fieldwork.

Figure 36. Tourists in the Ritoque Gullies site (GZP18). Climbing and trampling by tourists are possibly accelerating the natural erosion process that created the feature. Photo: VillaHit Films, https://www.youtube.com/watch?v=PqnGnwDtLNs

SITES VULNERABLE TO THIS THREAT: GZP01, GZP02, GZP05, GPZ16, GZP17, GZP18, GZP19

4.2.2. Land development and urban expansion

Colombia is a developing country, in which big infrastructure and urban projects will increase over time. Some rural areas in Alto Ricaurte have displayed a substantial increase in urban development and new constructions. These works affect the landscape quality and aesthetics, and might even mask some geological features (figure 37).

Figure 37. Construction of *gampling* to the north of Villa de Leyva. There are several locations where this type of infrastructure is beginning to appear in the landscape. In some cases, it could represent a threat to landscape quality or could mask geological features and landforms.

Another issue concerning new constructions is related to the discovery of new fossils. Excavations and soil surveys can reveal new paleontological objects, which is what happened with the example of Sachicasaurus vitae (Paramo-Fonseca et al., 2018). Nevertheless, during the fieldwork, it was detected that sometimes local people prefer not to notify the authorities about an eventual finding due to fear of facing legal or administrative issues (see section 4.2.6).

Although infrastructure development like road cuts has also resulted in exposures of interesting geological features, such as the folded sedimentary sequences in the road Sáchica-Villa de Leyva, these human interventions may also represent a threat to geodiversity. Some of the man-made structures most likely to occur in the region are the construction and widening of roads, removing and re-profiling land surfaces, embankments, pipelines and new large constructions due to urban expansion. These infrastructures will result in changes such as aesthetics, removal and damage of soils, modification

and loss of landforms, sediments, structures and fossils (Gray, 2004). It is worth mentioning that most of these changes are irreversible.

SITES VULNERABLE TO THIS THREAT: GZP09, GZP10, GZP12, GZP13, GZP14, GZP15, GZP17, GZP19

4.2.3. Agriculture and live stocking

According to Gray (2004), there is likely to be little damage to geodiversity in areas that have had a long and successful history of cultivation. However, in some cases, the physical integrity of slopes and landforms can be affected by increased erosion and movements of soil in areas with unsustainable land management. In the Alto Ricaurte region, 69% of its population are peasants whose economy is mostly based on agricultural and livestock production systems (Casas et al., 2017). Similarly, there is an increase in monocultures, which can bring deforestation, loss of soil quality, and social degradation (Ministerio de Cultura, 2015). Tomato greenhouses have become very popular in recent years causing a genuine change in the mountainous landscape in the region (figure 38). In addition to the visual impact, polluted runoff water from crops can affect geological sites related to water dynamics, such as at La Fábrica Cave site (GZP01), where some bad smells in waters coming from agronomic activities upstream can affect the integrity of this karst ecosystem.

Figure 38. A: Tomato monocultures near Sáchica. This type of crop, which is invasive in the landscape, has been increasing in recent years. B: Soils being prepared for the installation of industrial cannabis crops in greenhouses around Roa, Sutamarchán.

Some other damages to geodiversity that unsustainable farming can produce in the region are increasing erosion, loss of soil, modification or loss of landforms, and changes in the hydrological systems, among others.

SITES VULNERABLE TO THIS THREAT: GZP01, GZP03, GZP04, GZP05, GZP11, GZP17

4.2.4. Vegetation growth and deforestation

Both natural vegetation growths and human afforestation can represent a threat to geodiversity because of the partial or complete masking of sites by vegetation. In the Hoyo La Romera site, for instance, a local inhabitant stated that vegetation growth has masked the site over the years (figure 39). On the other hand, deforestation can alter the natural erosion rates of some features and change

soil biota (Gray, 2004). The area under study, as previously described, possesses large areas of arid and deforested soils, notably in the southern parts (Villa de Leyva, Sáchica and east of Sutamarchán). Although this arid landscape is one of the signatures of the region, vegetation growth and loss should be managed in the areas surrounding the geological sites. Finally, deforestation can affect geological sites associated with water flow such as waterfalls, streams and springs.

Figure 39. Hoyo La Romera karstic site (GZP03). According to the locals, the mouth of the cave has been masked by vegetation in the last years.

SITES VULNERABLE TO THIS THREAT: GZP03, GZP05, GZP07, GZP16

4.2.5. Collection of geological specimens

Fossils, minerals and rocks are often aesthetic specimens and have long attracted collectors (Gray, 2004). This collection is often not regarded as significant but it can have long-term impacts on a site. Sometimes, large amounts of rocks and soils are removed in pursuit of the "perfect" specimen, resulting in the loss of other materials and fossils (Gray, 2004). In the study area, extraction and selling of fossils is an actual problem (Casas et al., 2017), even if the impact of decades of illegal collecting and trading of fossils has not been documented. As walking in some of the notable paleontological sites in the area, it is easily noticeable the large number of broken rock concretions spread on the

ground (figure 40). This is a consequence of traders and fossil hunters who try to discover good samples inside the concretions.

Figure 40. Split rock concretions near Sáchica. According to some locals, the main fossil deposits in the region have been plundered by fossil traders, and now it is difficult to find concretions with fossils on the ground surface.

University visits to paleontological deposits are common and it is not a secret that students are sometimes encouraged to find worthy samples to take with them. According to testimonies heard during the field work, this issue was worst in past years when fossils were being sold on streets and roads to foreigners. Nowadays this practice is no longer present. Similarly, the illegal collection of samples was also reported in La Fábrica cave, where several speleothems have been secretly removed by visitors, or in the Arcabuco Formation Sequence site, where rock blocks with rock art have been removed. The problem of removal of specimens has to be addressed with diverse strategies that may include education and awareness, physical intervention, surveillance and even legal actions against the responsible for these actions.

SITES VULNERABLE TO THIS THREAT: GZP01, GZP09, GZP10, GZP16

4.2.6. Tenure and land ownership

All geological sites identified in this study are located on private land. In Colombia, this represents a management problem since, in general, official authorities cannot invest money in developing projects in private areas. Many important sites are at the mercy of their owners' decisions. Therefore, in the context of a geopark project, any intervention regarding prevention, conservation, mitigation,

monitoring, etc, should be arranged with the landowner. For instance, in the municipality of Sáchica, the site of the Sachicasaurus vitae was on church-owned land. Only in February 2022, 13 years after the discovery, this land has been finally conceded through the National Land Agency (Agencia Nacional de Tierras) to the municipal administration to manage it (figure 41). These wastelands cover almost 10,4 hectares, and according to the mayor of Sáchica Hugo Buitrago, the area is going to be used to construct a Paleontological Educative Park (Parque Educativo de Paleontología).

Figure 41. A: On February 18, 2022, the major of Sáchica Hugo Buitrago received the property of two wasteland lots to be managed by the municipal administration. For more details, see https://www.ant.gov.co/poblacion-del-municipio-de-sachica-en-boyaca-se-beneficiara-con-la-entrega-de-dos-titulos-de-propiedad-por-parte-de-la-agencia-nacional-de-tierras/ B: Site of excavation of the *Sachicasaurus vitae*. This area is located on land assigned to the municipality, and according to conversations with officials of the Mayor's Office, the plan is to move the skeleton to here, the original site of discovery.

As pointed out in section 4.2.6, private land ownership can also be a problem as locals are often doubtful about reporting paleontological findings which can lead to problems. During the fieldwork, we documented the case of Mr Jorge Zuluaga, a veteran geologist who reported the finding of a skeleton on his property at Loma La Cabrera. After the excavation and preparation of the specimen – a juvenile plesiosaur later classified as *Stenorhynchosaurus munozi* (Paramo-Fonseca et al., 2016) – an in situ museum was built less than 50 m from Mr Zuluaga's house. After some time, the museum structure collapsed, the fossil was moved, and the debris after the collapse remain on Mr Zuluaga's property, representing a threat due to the instability of the construction but also a waste of space and visual damage to his rural property (figure 42). Anonymous respondents to our survey also manifested that quarries and companies are scared to report paleontological findings because their operations may be stopped for years or months, resulting in a loss of money that a private company cannot take.

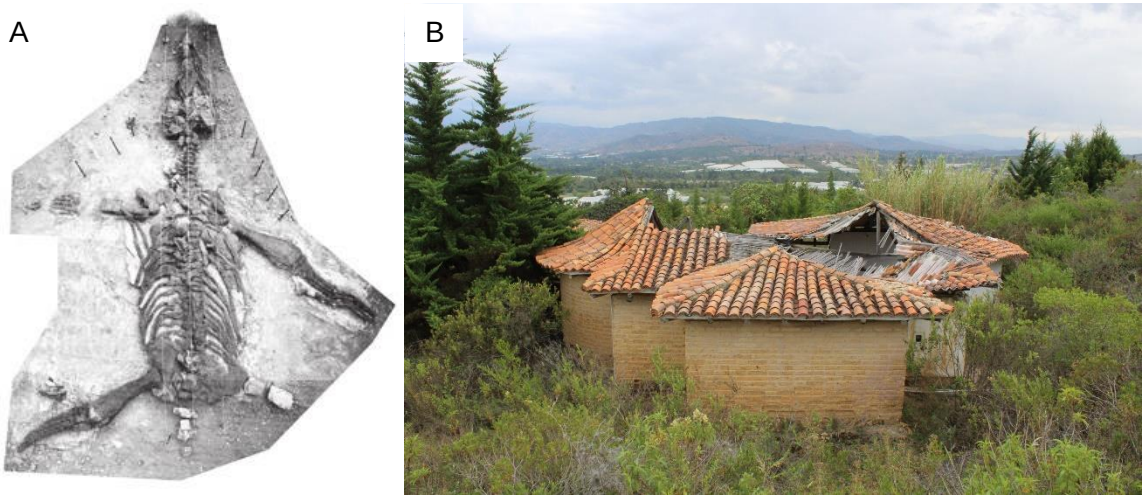


Figure 42. A: *Stenorhynchosaurus munozi* skeleton, the Plesiosaur found in a private property in La Cabrera (Paramo-Fonseca et al., 2016). B: Ruins of the museum built *in situ*.

Even if there is a document providing guidelines on the procedure to follow after such a finding (Decree 1353 of 2018), locals are not aware of this protocol. In any case, land tenure has been identified as one of the main issues regarding the management and conservation of geological sites in the region. Some recommendations regarding this matter are provided in Chapter 5.

SITES VULNERABLE TO THIS THREAT: GZP02, GZP04, GZP06, GZP07, GZP15, GZP16, GZP17, GZP19

4.2.7. Quarrying and extraction of construction materials

Mining and quarrying are ancestral activities in the Alto Ricaurte region, developed traditionally for a long time. To a large extent, problems generated by mining or quarrying arise according to the size and type of exploitation, the location, and the management that is applied to it. Currently, there are active mining titles that include mainly quarrying construction materials but also mining for gems. These titles are often found near or in sites such as rock art or fossil deposits (Casas et al., 2017) (figure 43). Most exploitation of non-renewable resources in Alto Ricaurte is for construction materials from sedimentary rocks such as marble, limestone, sandstone, etc. The travertine quarry in Villa de Leyva is perhaps the biggest mine in the area, and no strong impacts from this activity have been documented. Nevertheless, the site was where important Quaternary fossils were found, such as mastodon bones (Galvis & Valencia, 2009). Among some of the interviewees, there is a preoccupation with further paleontological discoveries in the quarry that are not being reported by the company. Quarrying was also identified as a threat in the Cascada La Periquera site, where local guides mentioned some activities upstream in the municipality of Arcabuco.

Figure 43. Current quarrying title for construction materials (red circle) next to the Arcabuco Formation geological and archaeological site (GZP16). Source: the author.

The review of national databases on mining and materials extraction showed that there are 53 quarries and mines operating in the study area: 48 in Sáchica, 3 in Villa de Leyva, 1 in Santa Sofía and 1 in Sutamarchán (figure 44). Most of the current titles are small–scale mining and quarrying applications related to construction materials such as sand, gravels, clays and limestone, but also anhydrite and

gypsum. It is also possible to observe that there are a significant number of applications for exploitation titles in the area (figure 45). By zooming in on some locations it is possible to observe problematic overlaps between geological sites of importance and current applications and developments (figure 46).

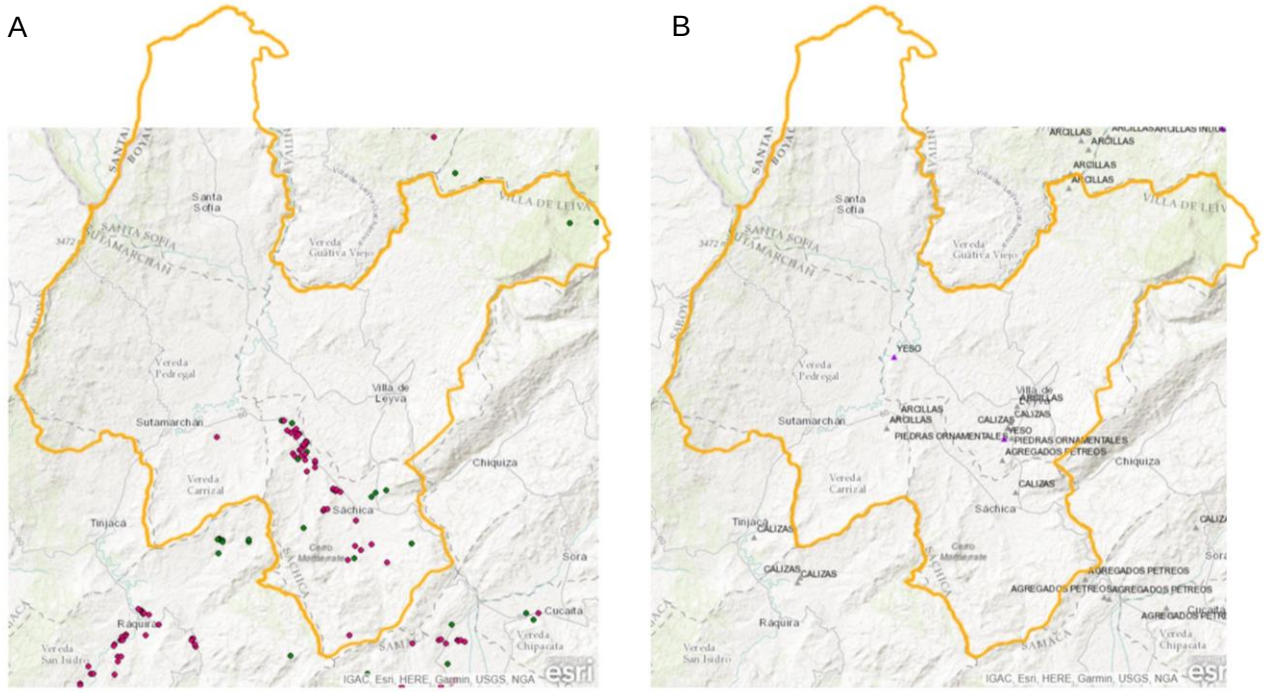


Figure 44. Mining census data consulted as of March 2022. A: mining census. B: extracted material. Pink: No mining title. Orange polygon: study area. Source: Sistema de Información Minero Energético Colombiano, http://sig.simec.gov.co/UPME_MI_minas/

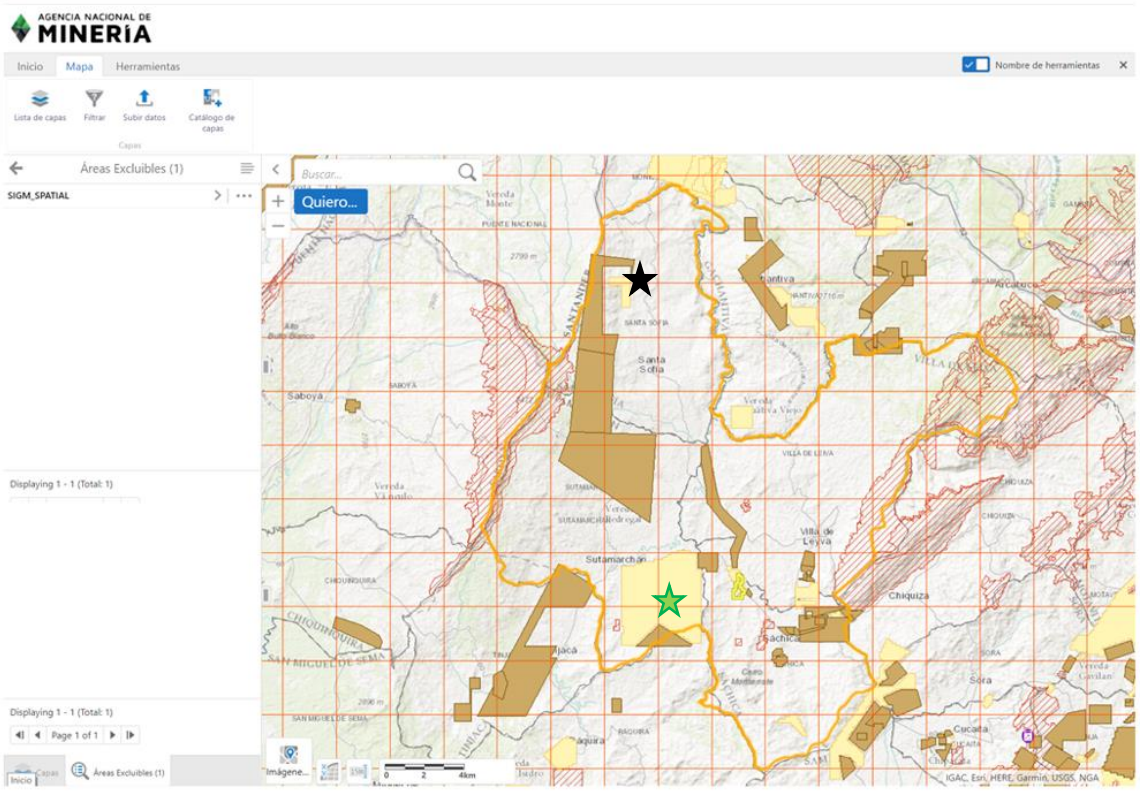


Figure 45. Overview of mining titles and applications in the study area. Brown: current titles. Cream: title applications. Stripped red: excluded areas. The excluded areas include the Iguaqué Flora and Fauna Sanctuary National Park, El Infiernito Archaeological Park, and some unidentified "special excluded" urban and rural polygons. In Sutamarchán, there is a 16 km^2 application for medium-scale emerald exploration (green star). In Santa Sofía, there is a coal mining application of around 1 km^2 (black star). Orange polygon: study area.

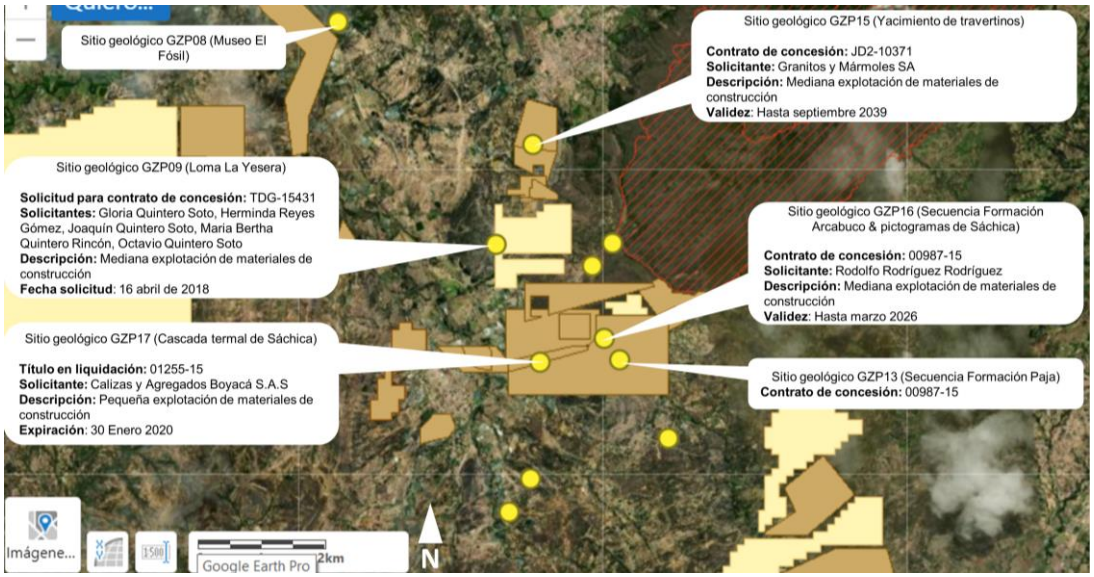


Figure 46. Zoom to cross-referencing between mining titles and applications and inventory of geological sites (yellow circles). The text boxes show geological sites that are located in polygons of mining claims or titles. In the case of El Fósil Museum (GZP08), a geological heritage site of international relevance, mining does not overlap but is only a few metres away.

Even if mines and quarries are not one of the major threats to geodiversity in the area, due to the lack of legal protection on most of the sites, mineral exploitation must continue to be considered as a threat, due to the risk of new mining titles granted to companies that may degrade or destroy the geodiversity and geoheritage in the region.

SITES VULNERABLE TO THIS THREAT: GZP01, GZP02, GZP03, GZP05, GZP09, GZP11, GZP12, GZP15, GZP16, GZP19

4.2.8. Graffiti, advertising and vandalism

Several geological sites, especially those associated with karst and rock art, have been damaged by graffiti and vandalism (figure 45). The motifs sometimes cover ancient pictograms and have destroyed archaeological heritage.

Similarly, rock exposures in road cuts are often used as a canvas for political advertising. This problem was particularly noticed on the Villa de Leyva-Samacá road (figure 47). Alarmingly, these actions are sometimes on important geological sites, such as the key exposure of the Churuvita Formation (figure 48).

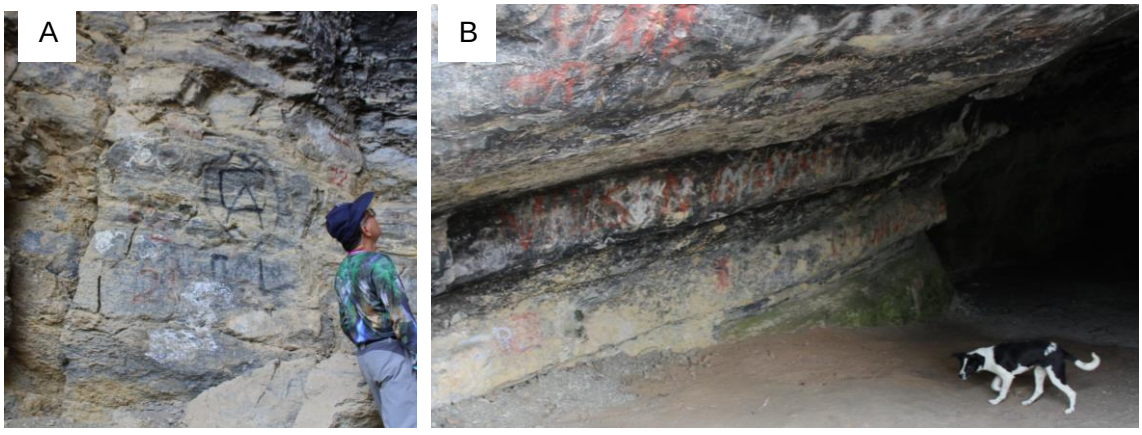


Figure 47. Graffiti affects sites of archaeological interest. A: El Hayal (GZP05). B: La Fábrica cave (GZP01).

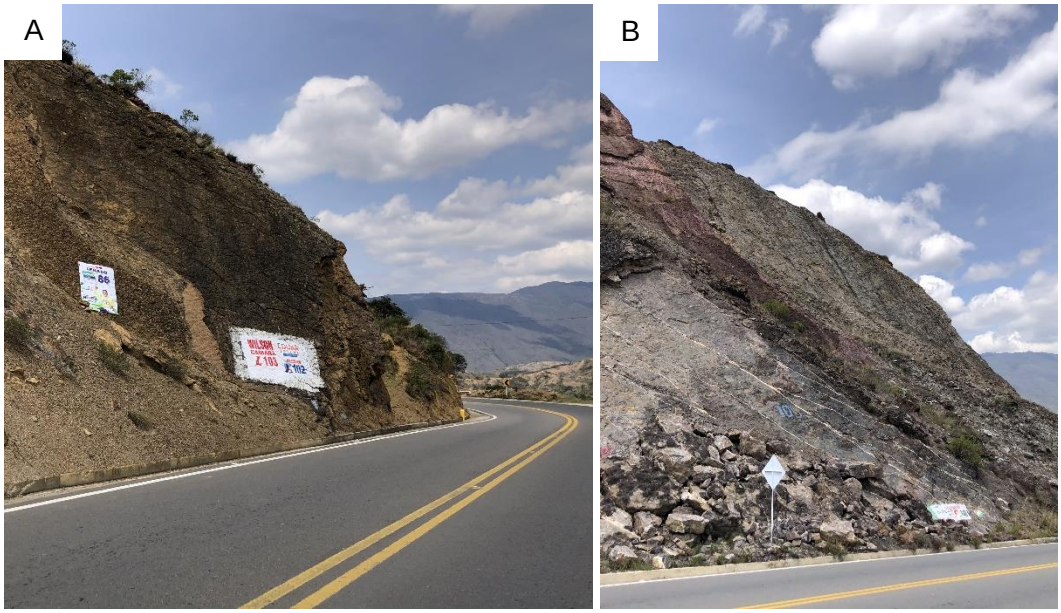


Figure 48. A: Political advertising affecting rock outcrops on the Sáchica-Samacá road. B: reference section of the Churuvita Formation.

SITES VULNERABLE TO THIS THREAT: GZP01, GZP03, GZP05, GZP13, GZP14, GZP16

4.2.9. Fire

Fire, either natural or induced by man, can have significant impacts such as the burning of peats and organic soils, destabilization of slopes and landforms after vegetation removal, erosion, landslides, among others. In the Alto Ricaurte region, there is a high frequency of fires, and they are considered a potential threat to the paramo ecosystems (Martelo-Jiménez & Ríos, 2022), which occur predominantly in places with dry vegetation, in low rainfall periods and are triggered by human activities such as residues from garbage burning, agriculture and bonfires. The predominantly dry climate condition, the high frequency of fires, the deterioration of the soils, the loss of natural vegetation cover and the drying up of wetlands and streams, increase the drying effect, resulting in desertification processes in the region (Casas et al., 2017). Several fires have occurred in Morro Negro in recent months (figure 49), which are still visible. Geological sites located in this mountain, such as Ritoque Gullies could eventually be afflicted by this threat.

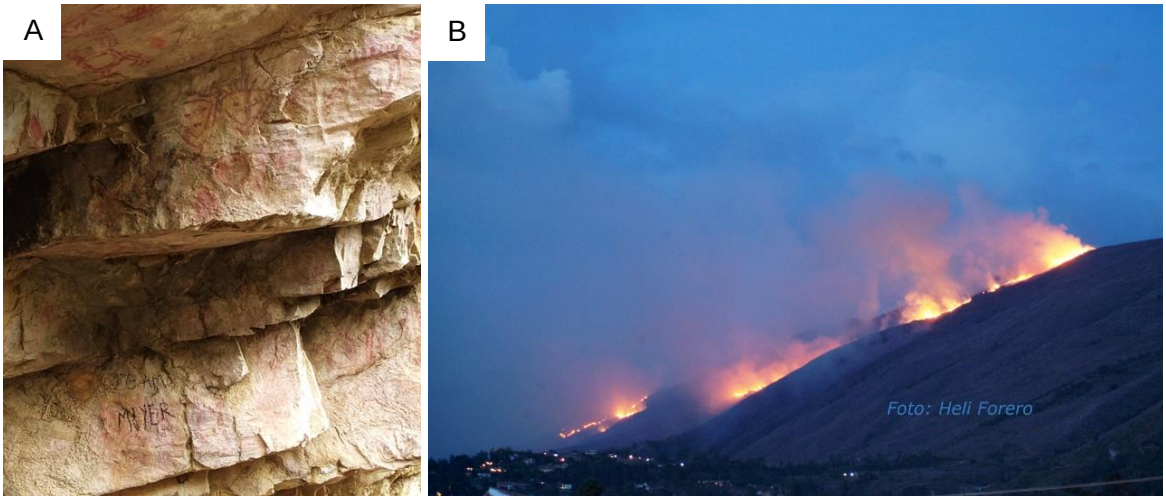


Figure 49. A: The Arcabuco Formation site (GZP16) shows several fire scars caused by bonfires. B: Forest fire in the Iguaqué National Park within the study area. Source image: Heli Forero, https://villadeleyvayyo.files.wordpress.com/2015/09/dscf0579.jpg

SITES VULNERABLE TO THIS THREAT: GZP07, GZP09, GZP10, GZP12, GZP16, GZP17, GZP18, GZP19

4.2.10. Lack of awareness

The lack of knowledge and information about the vulnerability of abiotic resources and their non-renewable nature is one of the most important threats to local geodiversity. As can be noted below, some threats are linked to ignorance, both by communities, stakeholders, decision-makers and visitors. This issue results in inappropriate development actions and a generalized lack of management of local georesources. As Gray (2004) emphasizes, as a result of low awareness, geological conservation measures are often lacking, including integration into important land-use planning, legislation, policy and practice.

Due to the outstanding heritage of the Alto Ricaurte region, some educational activities and workshops with the local communities are promoted by different institutions. The presence of several museums has also raised the community's awareness. Even so, the low awareness concerning the vulnerability of the abiotic nature keeps being a problem. Therefore, further and long-term education projects and actions should be consummated to protect the geological heritage of the region.

SITES VULNERABLE TO THIS THREAT: All

4.3. Geological risks

There is little formal information about geological hazards in the Alto Ricaurte region. However, some phenomena of hydro-meteorological (storms, floods), geological (earthquakes, landslides), and mixed origins such as erosion, torrential floods, etc., can occur.

According to an official report from the regional government, the Alto Ricaurte region has, in general, low susceptibility to natural hazards such as flooding and landslides. Nevertheless, in some mountainous areas located in the east of the polygon close to Arcabuco Anticline, and on the western slopes of Santa Sofía and Sutamarchán, susceptibility to landslides becomes more important. For instance, 50% of the area of Santa Sofía municipality is located in areas with high susceptibility to landslides (Departamento de Boyacá, 2011). Even if the region is not classified with high susceptibility to flooding events, some reports about flooding in Villa de Leyva in recent years caused the sewerage system to collapse and affected the urban area. The areas adjacent to the Sutamarchán riverbed are also at intermediate risk of flooding, including part of the urban centre of Sutamarchán.

In addition, landslides, mudslides, and rockfalls have been reported on some of the roads in the study area, so these should also be considered as potential hazards. Finally, regarding earthquakes, Alto Ricaurte region is located in a zone with intermediate seismic hazard according to Instituto Distrital de Gestión de Riesgos y Cambio Climático (IDIGER).

The Colombian nation has generally poor and ineffective disaster risk management policies, so none of these geological hazards can be neglected. These natural events could eventually affect not only important geodiversity sites but also human lives, so geohazards must be considered as a component of geodiversity diagnosis and management.

4.4. Community perception of threats and sites vulnerability

To complement the analysis of threats in the study area, some surveys and interviews were done. The surveys aimed to identify the community perception about threats and conservation needs regarding geological sites in the study area. These surveys were applied in the four municipalities using the questionnaire shown in table 13. The interviews were spoken surveys that sought to know in-deep about the conservation and management issues related to geological sites in the region, as well as to explore the local cultural and spiritual values of local geodiversity and geoheritage. These extended

interviews were conducted with managers of museums, tourist operators and owners or managers of lands with geological sites. The names of the interviewees will be kept secret for privacy reasons.

Table 13. Questionnaire used the surveys among locals

1. Did you know that there are one or more sites of significant geological interest in the region? | Yes | No |
2. Are you aware of Decree 1353 of 2018 on the Integrated Management of the Nation's geological and palaeontological heritage? | Yes | No |
3. Do you know about the Zaquenzipa Geopark project? | Yes | No |
4. Do you consider that important or special geological sites in the region (rocky outcrops, rock shelters, soils, caves, waterfalls, valleys, hills, fossil deposits, old quarries, etc.) deserve strategies for their conservation? | Yes | No |
5. In your opinion, who should be responsible for the management and conservation of these geological sites? | The municipal administration | Corpoboyacá (Regional Environmental Authority) | The owner of the site or land | The Zaquenzipa Geopark project | Other |
6. What is your opinion about the geological sites in the region being frequently visited by tourists? Would you prefer the sites to remain unspoiled and little-visited?
7. Which of the following threats, in your opinion, affects the most or could affect geological sites in the region? | Mining or quarrying | Construction of works or infrastructure | Urban expansion | Deforestation or reforestation | Extensive agriculture or livestock farming | Mass tourism | Illegal collection of specimens (rocks, fossils, etc.,) | Lack of knowledge of the geological site and its significance | Ignorance of Decree 1353 of 2018 on the Nation's geological heritage | Visual affectation with graffiti, murals or publicity | Other:
8. Is there any geological site that, in your opinion, has experienced a high degree of degradation in recent years, or is in danger of being degraded? Which one? Why?
9. In your opinion, what actions or measures can be taken to avoid these threats?
10. Do you consider that the geological sites of greatest importance to the region should be protected by law, just as the State protects areas where there are important or special species of flora and fauna? | Yes | No | Why?

4.4.1. Survey results

The survey results are shown in figure 50. It is worth mentioning that, due to logistical reasons during the fieldwork, the number of surveys conducted did not reach the minimum number to be statistically representative as a sample of the population. Therefore, this information is not going to be used for the conclusions of this dissertation. Nevertheless, the author considers that, although not statistically

representative, it deserves to be shared as it gives some clues about the perception of local communities. Besides, only questions 1 to 4 and 10 were plotted. The other questions are open-ended or multiple-choice hence the graphical representation is less informative.

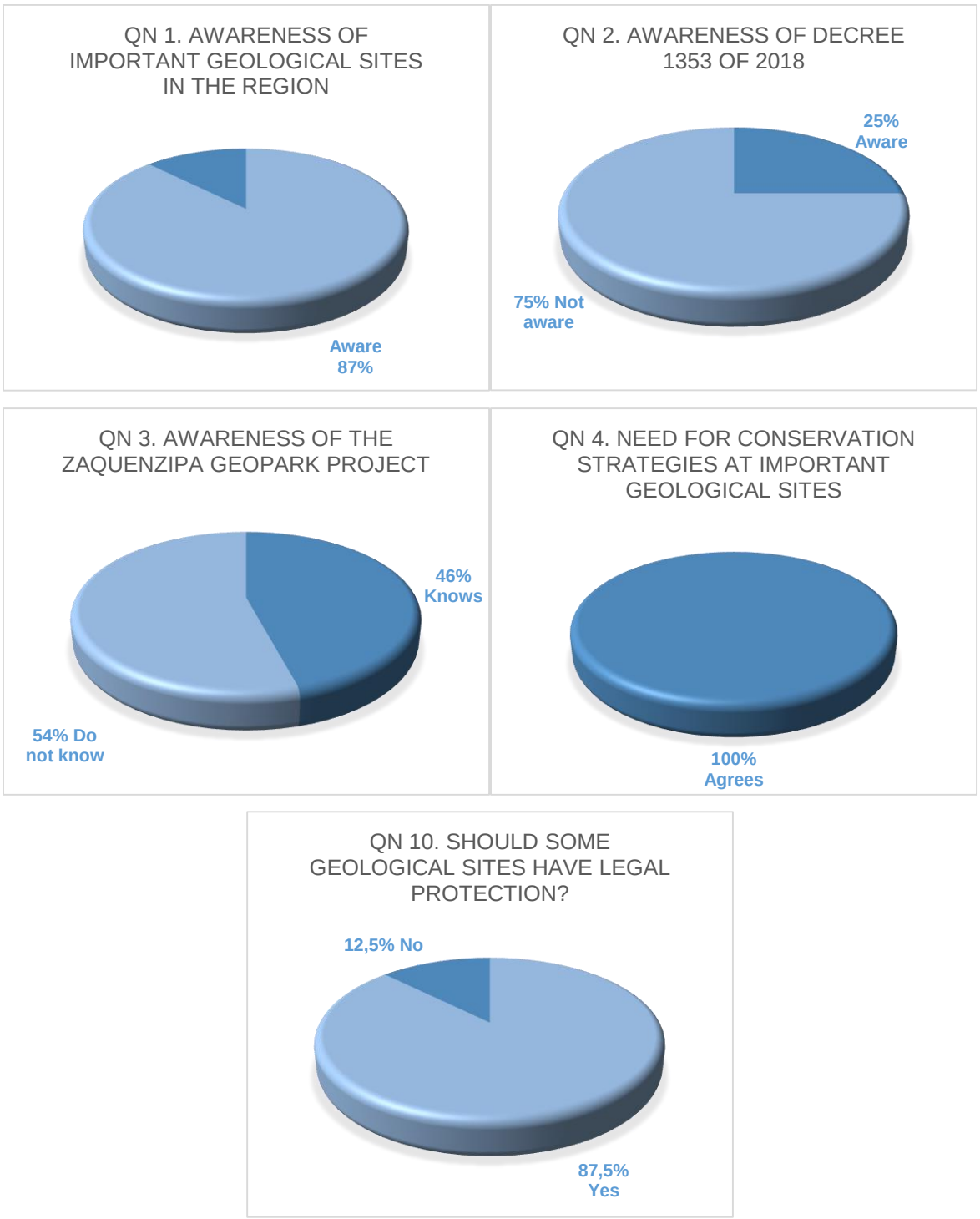


Figure 50. Pie charts representing the outcome of the survey for questions 1,2,3,4 and 10.

The charts show that all respondents agree with the need for conservation strategies at special or important geological sites. Also, most of them believe that these sites should be protected by law, although most respondents are unaware of the decree for the protection of the geological heritage of the Nation and more than half of them do not know about the geopark project.

Regarding question No. 5 and who should take care of the management and conservation of geological sites in the region (multiple answers possible), 65% believe it should be the municipal administration, 39% the landowner 30% the regional environmental authority, and 26% believes it should be everyone, including the geopark project administration.

The top 3 threats to geodiversity and geoheritage according to respondents (question 7, multiple answers possible), ordered descendant, are:

1. Quarries and mines exploitation (48%)
2. Big-scale cattle raising and agriculture (35%); unawareness of geological sites and their importance (35%)
3. Urban expansion (26%)

After these, tourism, illegal fossil collection, deforestation and ignorance of the Decree No. 1353 of 2018 were also acknowledged by 17% of interviewees. Regarding geological sites that have gone through degradation in the recent years, some of the sites mentioned were: Cresta del Gallo; La Hoya sector in Gachantivá; the blue wells of Villa de Leyva due to trash and wastes; the El Calvario hill; the outcrops in the Villa de Leyva-Tunja road due to erosion; La Chapa cave; La Cuevoteca cave; San Patricio cave, La Tripona paramo; the hills and gullies in Roa, Sutamarchán, and the travertine deposit due to the quarry.

It is also worthy to mention that 50% of the respondents think that the best way to avoid these threats is through education, awareness or sensitization, and 35% believe that the best way is through implementing measures, control and effective laws.

As a discussion of the survey responses, a few points could be highlighted:

- More than half of the surveys were conducted near geological sites or at locations or events related to nature conservation issues, which is likely to have biased the results presented.

- Respondents, even if being from localities apart from tourism or nature conservation activities, and engaged in another economic activity, are fully aware of the presence of important geological sites in the Alto Ricaurte region.

- Some surveys provided information on geological sites of tourist or educational interest not present in the literature review. Thus, it is important to consider the method of surveys and interviews with social actors as a valid method to complement inventories of geological sites. Also, it is useful to expand knowledge about the values of geodiversity and geological sites, and their threats.

- There is general concern about some of the threats affecting the geological sites and the inability of the state and institutions to address them. In particular, threats from mining or quarrying activities and the increase in extensive agriculture.

4.5. Summary of geoconservation challenges and priorities in Alto Ricaurte

From a broad perspective, after the analysis presented in this chapter, the most relevant physical threats to the geodiversity of the region are land ownership, land development and expansion, quarrying of construction materials, tourism pressure and lack of awareness. These major threats are almost fully aligned with the top 3 threats to geodiversity according to the locals interviewed (section 4.4.1).

The first issue, land ownership, is seen as a general issue that can represent a serious obstacle when making practical decisions on the management and conservation of the sites. Almost the totality of the geological sites inventoried is part of private property lands. In Colombia, due to legal issues, it is almost impossible for public institutions or administrations to invest money in private properties. Therefore, any physical intervention of the site such as recovery actions, fencing, installation of panels, adapting access paths, etc., would have to be consulted and agreed upon with the landowners. Given the low awareness of the importance of geodiversity and geoheritage and society, landowners would probably not agree to invest their budget in the management of geological sites. Thus, the challenge remains for municipal administrations, environmental authorities, or members of the geopark project, to raise awareness and reach agreements with the owners of these lands. The second issue is related to the constant growth of Colombian urban areas and economic activities, which in the region of study can be seen as new touristic installations, new holiday homes and condominiums, and invasive greenhouse crops that make extensive use of the soil. This threat can affect any category of the site

but it becomes especially relevant in the case of the paleontological record. Most of the finds of the palaeontological heritage of international value have been casual and fortuitous. Therefore, there is a high chance of more important fossils remaining underground. In this sense, the sudden expansion of activities into lands that had previously a less degrading type of use, can cover potential paleontological sites or destruct them forever, depending on the activity. Besides, this expansion can represent huge changes in the landscape, affecting its scenery, as is the case of tomato greenhouses.

Quarrying and extraction of construction materials were not considered initially as a matter of preoccupation, since there are no big mining infrastructures in the area. Nevertheless, the analysis of the current mining titles and applications has shown that there are mining titles in sites with high scientific relevance such as the Loma La Yesera paleontological site, or in geological sites considered as national heritage due to other reasons such as the Secuencia Formación Arcabuco, which holds an archaeological site, possess spiritual value and high geotourism potential. Mining and quarrying activities can co-exist in the region with a geopark project. Nevertheless, for these activities not to affect important geological sites, it becomes necessary to delimitate polygons for all the sites and work on protection tools so the quarrying activities do not overlap with geological site areas. Furthermore, stakeholders and citizens must organise themselves in processes of oversight and control, putting pressure on local administrations and environmental authorities to guarantee the integrity of these heritage sites over time.

Tourism activities can cause minor damage to all kinds of geological sites (increased erosion, solid waste, destruction of geoconservation infrastructures), but are particularly damaging in the case of gullies, as being fragile, and palaeontological sites, which have suffered extensive plundering of the samples. The challenge in this regard lies first and foremost in awareness-raising, starting with tourist guides and agencies, hotels and other tourism chains, as well as the tourists who frequent the sites. Next, it is important to advance in the delimitation and zoning of geological sites, to restrict the areas of tourist movement, as well as physical protection measures that can protect more vulnerable sites. As it can be seen, delimitation of the geological sites would facilitate their conservation given the most important threats to geodiversity in the study area. In conclusion, some urgent geoconservation priorities to face these threats could be:

1. To spatially delimit the polygon of all geological sites.

2. To include the polygons of the geological sites in the land use planning of the municipalities

3. To inform and raise awareness among landowners about the geological sites present in their properties.

4. In touristic geological sites, to delimitate the areas available for tourism activities, a restrict access to vulnerable elements.

These and other specific actions for the benefit of geoconservation in the Alto Ricaurte region are discussed in the next chapter.

Chapter 5. Geoconservation proposals for a UGGp project in Alto Ricaurte region

As discussed in previous chapters, the region comprising the municipalities of Sáchica, Santa Sofía, Sutamarchán and Villa de Leyva has a geological heritage of local, national and international interest, communities and social actors interested in geotourism, geo-education and geoconservation, and in recent years has expanded the background for a possible application as a UGGp, together with some neighbouring municipalities of Alto Ricaurte region. Furthermore, the geodiversity of the area is exposed to different threats of varying magnitude, which put the integrity of several of the most important and iconic geological sites in the area at real risk of degradation or destruction. Thus, action is urgently needed.

Taking this context into account, this chapter presents some initial proposals to start working on the geoconservation of the region, which is the basis for developing geoeducation, geotourism, and advancing sustainable territorial development. The geoconservation strategy proposed for the study region is presented below. This proposal has been constructed from the perspective of a geopark project, assuming that the main topics and specific actions towards geoconservation can be led by stakeholders or a working team in Earth Sciences.

5.1. A geoconservation strategy in the Alto Ricaurte region: How?

The geoconservation proposals done in this dissertation are mainly based on the bibliographical revision of geoconservation methodologies (sections 2.1, 2.2) with some adjustments that seek to adapt it to the territory and to give an important role to the perception and knowledge of the local communities (see section 5.2). The geoconservation strategy proposed for the Alto Ricaurte region is based on six general steps presented next (figure 51) and explained in the following sections.

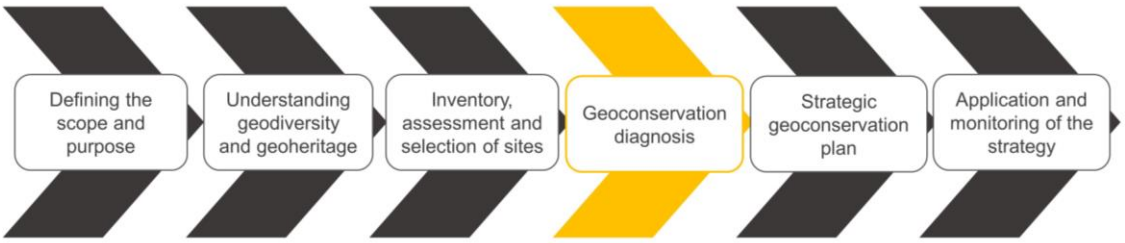


Figure 51. Proposed geoconservation strategy for the Alto Ricaurte region, highlighting the geoconservation diagnosis stage.

Furthermore, this dissertation is an example of the application of the strategy, as described in table 14.

Table 14. Geoconservation strategy for Alto Ricaurte region

Step		Example in this dissertation
1	Defining the scope and purpose	Chapter 1
2	Understanding geodiversity and geoheritage	Sections 3.4, 3.5, 3.6
3	Inventory, assessment and selection of sites	Section 3.7
4	Geoconservation diagnosis	Chapter 4
5	Strategic action plan on geoconservation	Section 5.1.5
6	Application and monitoring of the strategy	Future

5.1.1. Defining the scope and purpose

This step aims to answer the following questions: Where? When? For what purpose? It involves delimitating the area of interest, considering the time factor to set realistic and reachable goals, and identifying the ultimate aim of the geoconservation strategy. In this case study, the aim is to design geoconservation proposals for the municipalities of Sáchica, Santa Sofía, Sutamarchán, and Villa de Leyva, in the medium term (2 to 5 years), which main purpose is to set a strategy to be followed to take initial conservation measures compatible with the activities of geotourism, education, and culture in the region, and with the perspective of a UGGp. The ultimate purpose of the global strategy is to keep the geological sites in good condition despite the activities undertaken in these sites.

5.1.2. Understanding geodiversity and geoheritage

“It is impossible to protect what we do not know”. In this step, the main objective is to characterize the geodiversity and the geological heritage of the considered region. The main questions to answer are:

What do we know about the geodiversity in the area? How can we categorise it to better manage its elements and disseminate them? What are its values, and what are the most representative sites according to the values? What are the cultural and spiritual relations between geodiversity and the locals and their traditions? Considering the scientific, educational, touristic, and cultural importance, what sites could be considered as geoheritage of the region?

5.1.3. Inventory and selection of sites

After getting an overview of the natural geological geodiversity, its scientific importance, and its usefulness for humans, a systematic inventory of geological sites must be accomplished, including complete documentation about the sites, as well as an assessment of the main values and interests of sites (qualitative or quantitative). Some of the main questions to be addressed are:

Which are the selected geological sites and elements that better represent the geodiversity in the area? What is their scientific importance? Why are they important to the locals? What are the main values, interests, cultural relationships, and potentials of the geological sites inventoried? What are their accessibility, security conditions, and potential for use?

Usually, this information is collected through a descriptive form, which facilitates the management and systematisation of the information.

5.1.4. Geoconservation diagnosis

For this dissertation, an important and separate step in a geoconservation plan is to collect the maximum amount of information about the state of conservation of the geodiversity, its main threats, and the protection and conservation status of the geological sites identified. The geoconservation diagnosis refers to a general perspective of the status of the geodiversity in the region, but it may also include the specific conservation diagnosis of geological sites ("on-site" diagnosis). The use of a "geoconservation status" form (section 4.1) may be useful for registering site information systematically. It is also important to consider the perspective of the local communities, as they usually have a historical context of the evolution of the sites and close knowledge of the activities that have created damage. Therefore, interviews and surveys within the local communities and their perception of the threats are essential. In short, some aspects to describe in the geoconservation diagnosis are:

- **General**

- Threats to geodiversity (effective and potential)
- Conservation problems
- Geological hazards
- Perception of local communities
- Mining licenses and titles

- Protected areas
- Summary of geoconservation challenges and priorities

▪ **On-site** (see section 4.1 "Geoconservation diagnosis of geological sites")

- Description of the site
- Management classes
- Statutory protection
- Land property and current use
- Features of interest
- Relation to biodiversity or cultural elements
- Overall conservation status
- Risk of degradation
- Management and conservation goals
- Rational management measures
- Photographic record
- Notes

5.1.5. Strategic action plan on geoconservation

After the description, characterization, and diagnosis phases have been accomplished, it is time to define the conservation action lines which will respond to the conservation priorities obtained during the diagnosis. The "Strategic action plan on geoconservation" is the core of the geoconservation strategy. This step contains the proposal for the practical implementation of the geoconservation actions. After analysing the overall possible conservation actions and strategies described in the literature, they were grouped into six main topics or "pillars" (figure 52). It is important to mention that these pillars are underpinned by a real and organised management that would allow the implementation of the proposed objectives. Note that these principal topics should not be understood as separated units since their aims can overlap (figure 53). Table 15 shows the six geoconservation pillars proposed for a geoconservation strategy in the Alto Ricaurte region.

Table 15. Geoconservation pillars and sub-topics to be considered in a geoconservation strategy in Alto Ricaurte region

A. KNOWLEDGE
A.1. Geodiversity and geoheritage
A.2. Mapping
A.3. Conservation diagnosis
A.4. Managing information and systematization
B. TERRITORIAL PLANNING AND POLICIES
B.1. Land use planning
B.2. Site management plans
B.3. Protected areas
B.4. Multi-scale and inter-administrative cooperation
B.5. Conservation of paleontological heritage
C. CONSERVATION OF GEOHERITAGE
C.1. In situ conservation diagnosis
C.2. Geosite surface and boundaries
C.3. Infrastructure
C.4. Maintenance and recovery actions
C.5. Visitor management
C.6. Monitoring
C.7. Private collections
D. EDUCATION AND AWARENESS
D.1. Dissemination in local communities
D.2. Geoeducation projects and programs
D.3. Training courses and seminars
D.4. Promotion of geodiversity
E. GOVERNANCE AND SOCIAL INCLUSION
E.1. Development of partnerships and alliances
E.2. Directory of social actors
E.3. Community-based projects
E.4. Shared governance (IUCN)
E.5. Community science
E.6. Funding
F. OUTREACH AND AWARENESS
F.1. Geotourism as a regional product
F.2. Divulgation and communication tools
F.3. Geodiversity and environment
F.4. International approach

Figure 52. Geoconservation pillars composing the Strategic action plan on geoconservation.

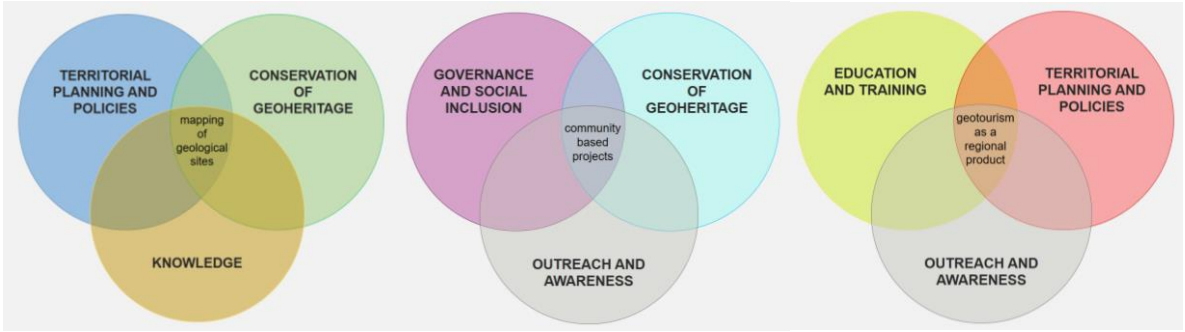


Figure 53. It should be understood that the pillars of the geoconservation strategy are not separate lines of action as their objectives are connected and should be worked on as a whole. Three examples of themes that join several geoconservation topics are presented.

The way of presenting the strategic action plan on geoconservation is inspired on the Geodiversity Action Plans in the UK and on the Geodiversity Management strategies in Spain, as a table displaying specific objectives and actions necessary to reach each objective, which in turn are going to contribute to the strategic action plan (table 16).

Table 16. Detailed strategic action plan on geoconservation for Alto Ricaurte.

A. KNOWLEDGE	
Objective	**Specific actions**
A.1 To increase the understanding of geodiversity and geological heritage in the region	Make a systematic inventory of geological sites, based on desk research and fieldwork. Include the identification of new sites in poorly explored areas such as west of Sutamarchán and Santa Sofía. Contact relevant researchers, professors and institutions to formulate joint projects that help to fully characterise the geodiversity and geoheritage in Alto Ricaurte. Contact institutions, museums, and private collectors to work on an inventory of ex situ geological heritage in the region. Promote projects and research that help to better understand the links between geodiversity, biodiversity, archaeology and other tangible and intangible cultural assets. To contact and recruit undergraduate students in Earth or environmental sciences to develop degree projects in the study area.
A.2 To produce maps useful for the management and dissemination of geodiversity	Produce a GIS geodatabase including all the relevant information for the management of geodiversity and geoheritage. Work on a project to delimitate the boundaries of all geological sites, including buffer zones. Offer internships and volunteering programs in the geopark to university students to develop thematic maps (e.g. geotouristic map, inventory map, geoarchaeology map, etc.).
A.3 To produce a geoconservation diagnosis of the geopark area	Identify all the potential threats to geodiversity and geoheritage. Design and use a geoconservation status form to diagnose all the geological sites inventoried. Produce maps on potential threatening activities such as operating quarries, mining titles, infrastructure projects, pipelines, etc. Perform surveys, interviews and workshops to include the perception of the local communities. Identify the assigned land use category by local administrations for each one of the geological sites. Check all the statutory protection areas present, including national, regional and local categories.
A.4 Defining strategies for systematic information management	Produce a GIS geodatabase including all the relevant information for the management of geodiversity and geoheritage. Create an open-access online database with the existent bibliography on the geodiversity and geoheritage.

	Introduce geodiversity and geoheritage in the municipal information systems and files.
B. PLANNING AND LAND USE POLICIES	
B.1 Incorporate geodiversity in the land use planning documents of the municipalities	Conduct workshops to showcase international projects that demonstrate the usefulness of geodiversity and geology in rural development (e.g. by contacting existing Spanish-speaking geoparks to show their experience) Cooperate with the municipalities to include the concepts of geodiversity and geoheritage as a technic, social and institutional component within the land use planning strategy (Esquema de Ordenamiento Territorial). Include geoheritage surfaces and geoheritage protection areas in the "protection" category of land use in the Esquema de Ordenamiento Territorial. From the geopark management team, working with the municipal authorities to ensure that geoheritage is considered in important decision-making processes and projects.
B.2 To start developing site management plans	Incorporate the Geoconservation Form as a tool to developing geological site management plans. From the geopark geosciences team, constructing the site management plans for high-priority sites.
B.3 To articulate the regional protected areas in the conservation of geological heritage	Socialize the results of projects and research on geodiversity with the Flora and Fauna Sanctuary of Iguaqué staff. Cooperate with the Flora and Fauna Sanctuary of Iguaqué administration to include geodiversity management and geoconservation in the next management plan of this protected area. Establish agreements with the protected areas to cooperate for the conservation of the geological sites. To cooperate with the national park administration to include the geodiversity and geoheritage in the website, leaflets, and interpretative panels of the Santuario de Fauna y Flora de Iguaqué and the Páramo de Merchán
B.4 To encourage multi-scale and inter-administrative cooperation for geodiversity	Promote geoconservation research, projects and dissemination with the neighbour municipalities, Boyacá department administration, and national authorities such as the Ministry of Environment. Establish new agreements and protocols between the municipal administrations, the Colombian Geological Survey, and the departmental and national environmental authorities, regarding the conservation, use and management of geoheritage. Raise awareness and propose cooperation projects with the environmental authorities at different scales: municipal (Environment Secretariat), departmental (Corpoboyacá, Secretary of Environment and Sustainable Development, Secretary of Planning) and national (Ministry of Environment).
B.5 To advance specific guidelines for the conservation of fossils	Collaborate with the municipal administrations to fund the development and diffusion of a "Citizen's handbook" for the casual/fortuitous finding of fossils. Socialise the regulations on palaeontological heritage included in Decree 1353 of 2018.
C. CONSERVATION OF GEOHERITAGE	

C.1 To perform an *in situ* conservation diagnosis	To improve and define a "geoconservation status" descriptive form for the geopark project.
C.2 To define geosite surface and boundaries	From the geopark geosciences team, prioritize the delimitation of geological sites in the inventory, by defining their boundaries. Produce a map showing the polygons of the geological sites. Define a critical zone and a buffer zone for each geological site, as well as visit zones for sites with the geotourism management class.
C.3 To adapt, when necessary, infrastructures to protect geological sites	Contact land owners to negotiate the installation of physical protections in sites, when needed.
C.4 To develop actions for maintenance and recovery of geological sites	Assign personnel from an official entity (municipal administrations, environmental authorities) to geological site maintenance tasks (cleaning, vegetation clearing, etc.), when required. Contact landowners to negotiate frequent recovery and maintenance actions in geological sites. Create a "geological site adoption/patronage" program to include people interested in maintenance tasks.
C.5 To work on visitor management actions on the geological sites	Define a set of rules for visitor behaviour in geological sites. Work, from the geopark management team, on an organised plan of scheduled visits, pre-bookings, guided tours, etc., to the region, in cooperation with the current ecotourism agencies and the owners of tourist destinations.
C.6 To promote monitoring activities	Contact the SGC, universities, institutes, environmental authorities and museums to develop monitoring schemes for each geological site. Create a citizen science programme to monitor geological sites.
C.7 To include private collections in the geoconservation strategy	Inventory the *ex situ* geological elements laying in private collections and museum Establish and sign agreements with tenants that guarantee the protection of ex situ elements Produce replicas of important pieces that are in hands of private collectors
D. EDUCATION AND AWARENESS	
D.1 To disseminate geodiversity and geoheritage topics in local communities	Develop socialization workshops with strategic organisations such as Vigias del Patrimonio, Juntas de Acción Comunal, etc., on the topics of geodiversity, geoheritage and geoconservation, including the Decree 1353 of 2018. Design tools and materials that help to promote and disseminate the knowledge and importance of geodiversity and geoheritage. Promote local events in the main square of the municipalities, to raise awareness of geoheritage. Socialize the geodiversity database with the local communities.
D.2 To establish geoeducation projects and programmes	Contact universities with formation of students interested in geoeducation (UNAL, UPTC) to formulate and raise funds for geoeducation projects.

	Support and promote current geoeducation projects and activities developed by local institutions such as the museums.
D.3 To carry out training courses and seminars on geodiversity and geoheritage	Invite research groups (Observatorio Nacional de Patrimonio Geológico, Grupo de Investigación en Geología Ambiental GEA, among others) and people with expertise on geodiversity and geoheritage, to make frequent workshops and talks. Make a directory of the undergraduate and graduate theses that have been developed on geology, environment, culture, etc., in the Alto Ricaurte, and invite their authors to online socialisation sessions with stakeholders and interested locals. Promote online workshops and seminars to discuss geodiversity and geoheritage in the region, inviting professors, students and experts that have experience in the Alto Ricaurte region. Form eco-tourism and nature tourism staff, local guides, museum employees, etc., on topics of geodiversity and geoheritage. Invite the Colombian Geological Survey to make dedicated training courses and seminars on geodiversity and geoheritage, including the Decree No. 1353 of 2018.
D.4 To promote the image and importance of geodiversity and geoheritage	Suggest including a section for geodiversity on the website of all public and private institutions involved in the geopark: municipalities, governor's office, environmental authorities, museums, nature reserves, etc. Dedicate a municipal budget line to promote the geodiversity of the area with events, sessions, etc.
E. GOVERNANCE AND SOCIAL INCLUSION	
E.1 To develop partnerships and alliances	Sign cooperation agreements with key institutions, entrepreneurship and associations for the management and dissemination of geodiversity and geoheritage. Create a “Geodiversity guardians” group to promote social empowerment.
E.2 Generate a network of contacts and interested people	Create and annually update a database of social actors, stakeholders and representatives of interested institutions. Create a communication and dissemination group (e-mail, Telegram, others) for the directory of social actors. Promote socialisation events to strengthen networking and cooperation between social actors.
E.3 To foster community-based projects	Open, in the municipal chambers, consultancies for the creation of brands, products and services associated with geotourism. Create the “Adopt a Geosite” project. Create a group of experts to make a Bank of Projects list, to be developed in the future by the community involved in the geo-park project.
E.4 Shared governance	Develop a “geopark forum” for each one of the municipalities, in which decisions are discussed and taken after considering community contributions. Create a Technical Commission with local experts on environment, palaeontology, tourism, and other topics relevant to the geopark. Propose a management model with yearly or biannual alternation of important roles.
E.5	Create a citizen science programme to monitor geological sites.

To promote community science projects	Seek funding for a local project on the recovery and gathering of folklore associated with geodiversity, local knowledge and ethno-geology. Produce a note press or publication on the local and indigenous knowledge and values of geodiversity. Organise free field trips for interested communities, in which Earth sciences, environmental sciences, culture, etc., can be discussed.
E.6 To raise funds for Geoconservation oriented projects	Involve the municipal administrations in the geopark governance and management, and solicit funds for education, conservation and tourism projects, as a part of their investment in the geopark initiative. Apply to national and international calls to get a budget for geoeducation, geotourism and geoconservation projects. Some institutions/calls to consider are U.S. Agency for International Development (USAID), NatGeo Grants, FONTUR, Capital Semilla, iNNpulsa, MinCultura, MinCiencias, SENA, Extensión Solidaria UN, among others. In addition, seek advice from government agencies or universities regarding funding calls and opportunities.
F. OUTREACH	
F.1 To boost geotourism as a regional product	Include geotourism concepts and products in the municipal Tourist Development Plans. Incorporate geotourism as a rural tourism/nature tourism category and sponsor and disseminate it through rural tourism projects and activities. Produce and disseminate the "Alto Ricaurte Geoturístico" brand. Define a visual identity for the geotourism brand, including colours, fonts, slogan, etc. Identify potential local products and brands to be included in a Geoproducts catalogue. Promote markets and events to disseminate the geo-products in the region. Design thematic and specialized geotourism routes (e.g. scientific, museums, school, geoarchaeological, cave routes). To identify new interpretation opportunities in geological sites, and produce geo-products and geo-services related.
F.2 To implement diverse divulgation and communication tools	Start the geopark podcast to disseminate knowledge, stories, experiences and projects from the region. Identify the sites that may need interpretative panels to support their interpretation and diffusion. Formulate a joint project to fund the design and elaboration of interpretative panels. Participate eventually in radio and television programs from the region.

	Contact TVAgro, Canal Boyacá, Señal Colombia, Boyacá Radio, Radio 1, and other dissemination means, to produce programs and documentaries on the geodiversity of the area. Contact faculties and schools to cooperate to produce a documentary on the geoheritage of the area: Social Communication (University of Boyacá), Visual Arts (UPTC), and others. Publish dissemination notes about geodiversity in local newspapers such as Huellas, Vigias, El Diario Boyacá, etc. Habilitate temporary exhibitions in museums, cultural centres and other places, regarding the geodiversity and geoheritage of the region.
F.3 To highlight the relationship between geodiversity and environmental issues	Propose a reform of the reference titles for the awarding of environmental titles, including a study of the effects on geodiversity and geoheritage. Promote conferences and workshops, with institutional authorities, on the topic of EIA and geodiversity. Promote talks, workshops and events related to geological risks and climate change.
F.4 To consider international approaches to geodiversity management	Contact the group of people interested in the UNESCO World Heritage nomination and discuss the feasibility of this postulation for Alto Ricaurte. Contact UNESCO Global Geoparks, nature reserves, World Heritage sites, regions, etc, with a similar geological, cultural, or geographical context to Alto Ricaurte, and learn about conservation methods they have applied.

5.1.6. Application and monitoring of the strategy

The implementation of the geoconservation proposals presented in this dissertation is in the hands of the stakeholders, municipal administrations, and managers of the geopark project, which can use these recommendations as a starting point to begin specific actions for geoconservation in Alto Ricaurte. Besides, the advances on the geoconservation of the strategy should be monitored through performance indicators, percentages of progress and targets achieved.

Monitoring is performed in order to record any changes regarding the conservation status of the sites in time. This method is not only restricted to physical qualities. According to Crofts et al. (2020), monitoring of geological sites or geoheritage features may be conducted for a wide number uses, including to evaluate the current conditions of specific sites or features, evaluate the management effectiveness of a site, and provide information on the surveillance, protection and safety of a site. This information may then be used to evaluate the management plan and report results in different instances such as meetings with funders, annual reports, etc. Following these authors, indicators will

be SMART': Specific, Measurable, Achievable/Attainable, Relevant and Timely. The IUCN Guidelines for Geoconservation in Protected Areas also provide a division of indicators on 6 types:

1. Context indicators. What is the condition of the site? Is the site under threats?

2. Planning indicators. How many planning objectives was accomplished? %

3. Inputs. Have some resources been allocated to the management of the sites? How many people is working in these issues?

4. Process. How many emergencies? Were they well sorted? What failed? How many incidents in geosites?

5. Outputs. What was done? Products achieved? Academic? Services?

6. Outcomes. Conservation progress in the big picture?

5.2. Final remarks

The process of studying and describing the geodiversity of the region, reviewing existing geoconservation methodologies, and conceiving a comprehensive geoconservation strategy for the Alto Ricaurte region, involved some reflections about aspects that were implicitly included in this dissertation and that may be worth mentioning explicitly. These highlights will be summarized in the following paragraphs.

In Colombia, it is rather common to find inventories of geoheritage and geological sites with almost no context of the geodiversity in the study area. This type of work corresponds with the "geological monuments" approach (Sharples, 2002) in which isolated geological sites are identified in a given area, mostly due to their high scientific or educational value. Since the context of the geodiversity is not given, it can be difficult to assess if the sites inventoried are the most representative. Besides, this approach ignores the diverse values of geodiversity (ecological, spiritual, cultural) and it is separated from nature conservation, which makes geoheritage dissemination more complicated, as well as its inclusion in protected areas and land management policies. In this dissertation, it was essential to have an overview of the geodiversity of the region, including:

1. Geodiversity description and classification (geodiversity categories or thematic areas)
2. Geodiversity values (scientific, educational, touristic, cultural, ecological, spiritual, etc.)
3. Conservation diagnosis (general threats, conservation issues, statutory protection, in situ conservation, risk of degradation, geological risks, etc.)

Having this "big picture" helps to better perceive the potentials and opportunities of local geodiversity, and can provide basic information to start working on communication and dissemination of geodiversity, regardless of the advances in identifying the geological heritage.

Another topic to be addressed is the participation of local communities. This dissertation concludes that social actors and stakeholders must be included in each of the phases of a management or geoconservation strategy (inventory, assessment, conservation, promotion, and outreach). Often, the role of the local communities is considered only important in the dissemination stage, as socializing or "training" the local communities given the result of the research or project. From the author's perspective, the locals can contribute to each of the stages (table 17). As pointed out in section 3.6, this social inclusion can take on particular relevance in Latin America, with its large percentages of indigenous people, rurality, and associated traditions.

Finally, since this section is particularly about geoconservation, it is also worth to highlight that nowadays the most important role of geodiversity and geoheritage is perhaps to be an excuse to discuss current social issues in which geologists have an important role such as climate change, geological risks, and natural resources management. Hence, even if it is important to protect geoheritage as it is a non-renewable resource and it is part of our legacy for future generations, in the current context of planetary crisis, geoconservation becomes important to protect sites in which humans can better understand Earth's systems and their fragility, connect with a part of nature that has been disregarded, and hopefully raise their awareness about the issues mentioned and about the importance of the conservation of nature.

Table 17. Possible contributions of local communities to different stages of a geodiversity/geoheritage management strategy.

Stage	Contributions of the local knowledge
Geodiversity characterization	Knowledge about the cultural and spiritual significance and value of geodiversity and geological sites. Knowledge about the economic uses of geodiversity in the region (local products, agriculture, construction, extraction of materials, etc). Knowledge of non-reported geological materials or resources.
Geoconservation diagnosis	Historical review of geodiversity threats and degradation. Historical review of destructed and disappeared sites. Socio-economic problems and limitations related to geodiversity use (e.g. land property and use, economic needs, lack of awareness, war).
Inventory and selection of geological sites	Field guidance to geological sites. Knowledge of sites with touristic, educational or cultural value not reported in the literature. Provide a community perspective on which geological sites are most important according to culture, identity, traditions, etc.
Management and geoconservation actions	Involvement of local communities in geological site conservation, maintenance and monitoring. Conservation of private geological collections and ex situ heritage. Community-based governance. Provide information to design geoconservation and management guidelines realistic and in accordance with the local socio-economic conditions.
Promotion and outreach	Community participation in Geoeducation projects and programs. Development of geoproducts and services that may help to raise awareness. Participation or production of dissemination activities such as documentaries, podcasts, social media content, etc.

Chapter 6. Conclusions and recommendations

The history of geoconservation in Colombia has recently witnessed some milestones such as the publication of Decree No. 1353 of 2018, the creation of biannual geoheritage meetings and the establishment of a Colombian geoconservation network. The next achievements are foreseen to be related to the designation of UNESCO Global Geoparks in Colombia. This and other published works have demonstrated the scientific importance of international relevance of geological heritage in Alto Ricaurte region and its linkages with society and local communities, which can be described under the approaches of geodiversity values and geosystem services. Considering the interest of some sectors of the Alto Ricaurte society in obtaining UGGp status, this dissertation should be recognised as a contribution to a topic that is perhaps a weak point for an eventual nomination: geoconservation. In this sense, social actors and stakeholders will be able to consider the outputs of this work to develop geoconservation projects and activities, which will directly contribute to the application dossier and nature conservation and sustainable local development based on geoconservation.

The description and characterisation of the geodiversity showed that the area has several geodiversity elements in addition to palaeontological heritage, which is highly recognised in the region. Karst elements, hydrological features, and erosional landscapes, for example, are geodiversity elements present in the study area. This dissertation has demonstrated the scientific, educational, touristic and cultural value that these elements hold, and their potential for different uses.

The inventory resulted in 19 geological sites distributed by thematic areas and through a multi-labelled classification including four main management classes: science, education, geotourism, and conservation. These sites were also assessed qualitatively and quantitatively and the analysis of the inventory shows an uneven geographical distribution of sites; relatively high potential for touristic use compared to the potential of educational use and scientific value; a high representation of geological sites related to the Mesozoic sedimentary formations, especially palaeontological elements. The analysis of the inventory also confirmed the high scientific, educational and touristic potential of several sites, and was useful as a systematic way to gather the information, visualize it, and check patterns and trends. It is recommended to conduct further surveying and workshops with the locals that may add sites to the inventory, especially in areas with few geological sites such as the west of the polygon of study.

The geoconservation diagnosis in Alto Ricaurte was a crucial step to elaborate some geoconservation proposals and was done at two different levels: general diagnosis of geodiversity and on-site geoconservation diagnosis of geological sites. Community perception of geodiversity threats and conservation issues were considered as a relevant input. The on-site analysis was executed with the aid of a customized geoconservation status form. The application of this form made it possible to easily identify, for each site, which elements were of main interest, the goals of conservation measures at these sites, and the specific management actions to achieve these goals and thus to protect the main geological elements. On the other hand, the general analysis shows that the main geoconservation issues in the study area are land ownership, land development and expansion, quarrying of construction materials, tourism pressure and the lack of awareness. Another fundamental aspect of the overall geoconservation diagnosis was the analysis of current land uses and projected areas that may influence geodiversity conservation. In favour of geoconservation, there is a National Natural Park in the study area that could be an ally to advance the management of the sites within its boundaries, as well as cooperate for the dissemination of geological heritage and regional geodiversity.

The overlap between some geological sites of scientific, touristic or educational relevance [such as Loma la Yesera site or Sáchica rock art site in the Arcabuco Formation] with mining applications and titles shows the urgency to work on the delimitation of features to be protected, along with policies to promote their co-existence with quarrying activities, in order to avoid possible destruction of geological sites in the area.

The proposed geoconservation strategy for the Alto Ricaurte region is based on several philosophical bases such as the comprehension of the diverse values of geodiversity and its services to society, the allowance of natural processes to operate in their way, and the interdependency of geodiversity, biodiversity and culture, mainly recognising the value and usefulness of local knowledge for the different stages of the geoconservation strategy. The proposed geoconservation strategy includes six main steps: 1. Defining the scope and purpose; 2. Understanding geodiversity and geoheritage; 3. Inventory, assessment and selection of sites; 4. Geoconservation diagnosis; 5. Strategic action plan on geoconservation; 6. Application and monitoring of the strategy.

The strategic action plan on geoconservation is based on six pillars: knowledge, territorial planning and policies, education and training, conservation of geoheritage, governance and social inclusion, and outreach and awareness. These pillars should not be perceived as individual lines of work, but six main themes of a joint, comprehensive and interlinked strategy, including not only in situ protection measures but also actions related to territorial development, geodiversity knowledge, community participation, and outreach, which correspond to the geoconservation priorities identified in this work, and which are essential to advance the overall geoconservation strategy. It is recommended for any UGGp project in the region to take this plan into account and to build on it through the construction of projects to develop the specific actions of the strategy including responsible parties, budget, stakeholders, timeline, etc.

The proposed strategy and actions presuppose a real, organised and efficient management structure within a possible UGGp in the region, as this is the only way to implement the actions that allow achieving the proposed objectives. Thus, it should not be forgotten that geoconservation works closely with management and that the latter is urgent and necessary for the successful development of a geoconservation strategy in the Alto Ricaurte region.

Appendices

Appendix 1. Geoconservation status forms for the 19 geological sites (in Spanish)

Appendix 2. Quantitative assessment method (in Spanish)

Appendix 3. Relevant figures, Spanish version

Appendix 4. Geomorphological map covering part of the study area (in Spanish)

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Appendix 1. Geoconservation status forms for the 19 geological sites

Clases de manejo

E Educación

C Conservación

S Ciencia

G Geoturismo

GZP01 Cueva La Fábrica 5.705762, -73.577303

Descripción del sitio

Cueva de origen kárstico-fluvial, con formación activa de estalactitas y estalagmitas, modelada en rocas de la Formación Rosablanca. Posee 7 galerías de las cuales 4 son turísticas, siendo la más grande la Galería del Sol, con 18 m de profundidad. En el sitio se desarrolla el "proyecto ecoturístico multicultural La Fábrica", administrado por privados que buscan un balance entre el turismo y la conservación de la cueva. El acceso es por carretera destapada desde el municipio de Santa Sofía y una posterior caminata de 25 minutos.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Formas kársticas	E S G C	No	Turismo y conservación	Privada

Rasgos de interés primario

El sistema de galerías modeladas en las rocas calcáreas de la Formación Rasablanca, incluyendo sus espeleotemas, fósiles, y afloramientos rocosos de interés.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

Algunas evidencias apuntan a que era un sitio importante para los Muisca, ya que se ha encontrado arte rupestre, guacas, y se ha identificado un antiguo espacio de ceremonias en la parte exterior de la cueva, en el que hay algunos paneles interpretativos sobre el tema.

Algunos locales creen que los espeleotemas tienen propiedades de sanación, ya que en el pasado consideraban que los espeleotemas se podían hervir y después beber el agua residual para curar males y dolores.

Fauna: falsa coral, murciélago, armadillo, tinajo, otros.

Estado de conservación general

Favorable con algunas alteraciones. Han ocurrido algunos colapsos de material en la cueva. Si bien no hay grandes alteraciones en las galerías y sus formas, se pueden observar múltiples cicatrices de espeleotemas que han sido robados. Además, hay algunos grafitis en las paredes exteriores.

Riesgo de degradación

Fragilidad: Se han registrado colapsos de roca. La cueva puede sufrir inundaciones. Además, los espeleotemas tienen una alta fragilidad natural.
Vulnerabilidad: Extracción y robo de espeleotemas; contaminación proveniente de actividades agrícolas aguas arriba; residuos sólidos y quemas al exterior de la cueva; turismo intensivo.
Riesgo de degradación: Medio.

Metas de manejo y conservación	**Medidas racionales de manejo**
La calidad del agua que atraviesa la cueva no estará afectada por polución de actividades industriales o agrícolas, y podrá mantener los sistemas geológicos y biológicos de la cueva en buenas condiciones, así como la posibilidad de visitas sin malos olores o riesgos para la salud de visitantes. La integridad de los espeleotemas permanecerá en el tiempo, y ningún otro espeleotema será extraído de la cueva.	Coordinar, con Corpoboyacá u otra institución capacitada, un plan de monitoreo mensual de la calidad del agua que atraviesa la cueva. Realizar, de la mano de la administración de la cueva, talleres de concientización con los locales, vecinos y comunidades escolares, acerca del valor y la vulnerabilidad de los rasgos y espeleotemas en la cueva.

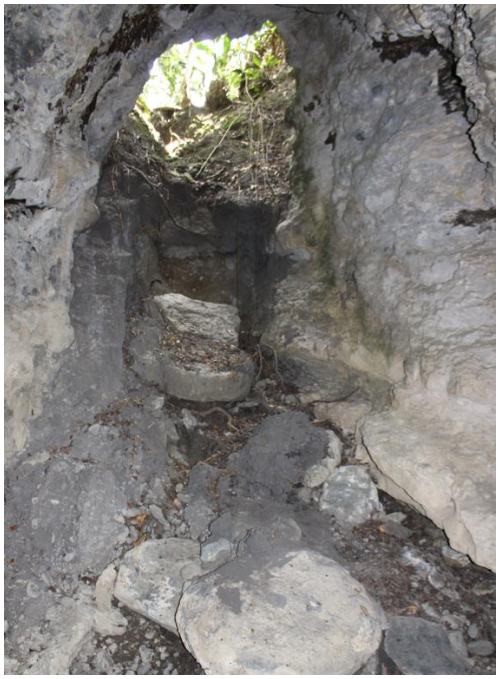
La cueva contará con un sistema completo de señalización (acceso, ruta de evacuación, nombre y características de las galerías) e información de buenas prácticas para el visitante. El polígono de la cueva será delimitado en superficie e incluido en la categoría protección del Esquema de Ordenamiento Territorial del municipio de Santa Sofía. Los dueños, visitantes y vecinos de la cueva estarán bien informados acerca del valor y la fragilidad del sistema kárstico de La Fábrica.	Realizar, de la mano del SENA, Corpoboyacá, dependencias de las Alcaldías, u otra institución capacitada, talleres de buenas prácticas de actividades agrícolas en los alrededores de la cueva, incluyendo temas como deforestación, uso de pesticidas, hidrología superficial, manejo de estiércol y otros residuos, y cómo estos afectan la cueva. Invertir, desde la administración particular de la cueva, en la actualización y diversificación de la señalización de la cueva, así como de su material interpretativo, resaltando también los elementos geológicos.

Registro fotográfico

Notas

Los administradores de la cueva toman medidas para la conservación de la cueva, como no realizar visitas en algunas galerías y el control del número de visitantes; además poseen buena voluntad para llevar acciones de geoconservación en el lugar. Actualmente están trabajando en La Fábrica como un proyecto de turismo y conocimiento multicultural. Esta atracción ecoturística debe ser incorporada como un aliado prioritario del proyecto de geoparque en el Alto Ricaurte.

Registro fotográfico



GZP02 Paso del Ángel 5.750367, -73.581879

Descripción del sitio

Geoforma afilada, estrecha y empinada que separa dos cursos de agua subparalelos, y que se ha formado por la erosión de lutitas y lodolitas de la Formación Rosablanca. Debido a la diferencia de altura entre la geoforma y los cauces de agua en el fondo, el sitio posee interés paisajístico. Actualmente hay un parque turístico cuyas mayores atracciones son canopy sobre uno de los cañones adyacentes y senderos para transitar.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Formas y procesos erosivos	G	No	Turismo	Privada

Rasgos de interés primario

El elemento paisajístico formado por la estrecha divisoria de aguas.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

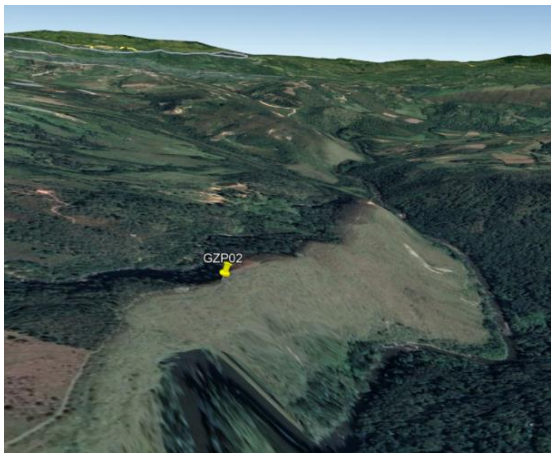
Favorable con alteraciones. La geoforma alcanza solo unos centímetros de anchura en algunas secciones, esta estrechez natural seguramente se agudizó debido al tránsito de turistas durante años, y parece inminente el colapso de algunos tramos en los que se realizan actualmente visitas. Sin embargo, tras un incidente reciente, se han instalado sendas y caminos elevados para transitar.

Riesgo de degradación

Fragilidad: La geoforma es frágil y vulnerable al avance de la erosión natural, a colapsos por causas naturales o eventos meteorológicos extremos.
Vulnerabilidad: Actividades turísticas intensivas.
Riesgo de degradación: Medio.

Metas de manejo y conservación	**Medidas racionales de manejo**
Los vecinos, visitantes y locales tendrán conocimiento sobre el interés geomorfológico y paisajístico del sitio y su especial vulnerabilidad. El elemento paisajístico continuará evolucionando en sus tasas naturales de erosión. La evolución morfológica del sitio será monitoreada. Las actividades turísticas en el sitio se realizarán de manera que no se ponga en riesgo la integridad física de la geoforma, posiblemente sin intervenciones directas sobre la misma. Las actividades turísticas se realizarán garantizado condiciones totales de seguridad para los visitantes del sitio.	El proyecto de geoparque y las partes interesadas contactarán la administración del sitio para capacitar el personal respecto interés geomorfológico de la geoforma y su fragilidad natural. El carácter geológico del sitio y su fragilidad serán considerados en el material interpretativo y turístico como sitios web, infografías, folletos, vallas explicativas, etc. La administración del sitio se asesorará con el Servicio Geológico Colombiano o el equipo geológico del proyecto geoparque, para adaptar las actividades turísticas considerando la fragilidad del lugar. Cualquier intervención como instalaciones físicas, siembra de árboles, etc., serán consultadas previamente. Los administradores o guías turísticos del sitio serán asesorados para realizar un monitoreo fotográfico periódico del lugar, evidenciando posibles procesos de retroceso o destrucción del sitio.

Registro fotográfico



GZP03 Hoyo La Romera 5.729726, -73.580838

Descripción del sitio

Dolina de colapso desarrollada en calizas de la Formación Rosablanca, con estalactitas, estalagmitas y columnas en su interior. Sitio de karst inactivo. Actualmente se realizan actividades de ecoturismo como descenso a la dolina mediante rappel y visitas al interior. El acceso al sitio es por carretera destapada desde Santa Sofía, y hay portería para el control de acceso.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Formas kársticas	G	No	Turismo	Privada

Rasgos de interés primario

La cavidad y los espeleotemas que se encuentran en su interior.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

Hay algunos mitos locales asociados al sitio, por ejemplo, que conecta con otros lugares en la región o que en el fondo pasaba un río. Según algunos locales, el nombre "La Romera" viene de la palabra "ramera", ya que, en el sitio, según la leyenda, los indígenas lanzaban a las mujeres que eran infieles. Además de estos elementos del folclor, no se reporta algún interés cultural, arqueológico o ecológico especial.

Estado de conservación general

Favorable, con alguna vegetación que obstaculiza la visión integral de la cavidad.

Riesgo de degradación

Fragilidad: No se reportan colapsos. Puede haber movimientos de suelo y derrumbes en temporada de lluvias, que caerán al fondo obstaculizando la entrada a la cueva.
Vulnerabilidad: El turismo masivo al interior de la cueva, así como actividades humanas en superficie que arrojen residuos a la cavidad.
Riesgo de degradación: Medio.

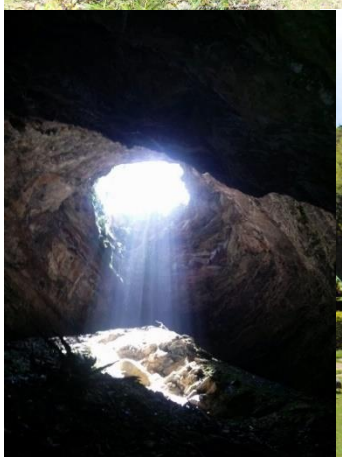
Metas de manejo y conservación	**Medidas racionales de manejo**
Los dueños, vecinos y visitantes del lugar reconocerán el sitio como parte de la geodiversidad de la región, así como su vulnerabilidad. Las condiciones estéticas y de visibilidad de la cavidad serán consideradas en la estrategia de administración y manejo del sitio. Las condiciones de humedad, temperatura y calidad del aire de la cueva al interior serán mantenidas. La seguridad de los visitantes en la parte superior será mejorada, ya que hay riesgo de caídas.	El proyecto de geoparque o las partes interesadas realizarán talleres de sensibilización acerca del carácter geológico de la cavidad, y este será incluido en el material informativo y divulgativo del sitio, aludiendo al sitio como parte de un sistema kárstico en la zona de estudio, vinculado a otros lugares icónicos como El Hayal. La administración del sitio cooperará con las autoridades ambientales para un monitoreo bimestral o trimestral de las condiciones ambientales de la cueva. La administración tendrá un programa de mantenimiento y limpieza de la cavidad, incluyendo manejo de vegetación, residuos sólidos, y otros. Se instalará protección física adecuada en la parte superior de la cavidad, para garantizar la seguridad de todos los visitantes. Además, se señalizará la ruta de evacuación.

Notas

El sitio posee muy buenas instalaciones en cuanto a servicios de alimentación, hospedaje, ocio, servicios sanitarios, y sitios de esparcimiento en superficie. Sin embargo, la señalización en carretera para llegar al lugar es insuficiente.

No hay alusiones al carácter geológico del sitio, lo cual podría incluirse en materiales interpretativos y divulgativos en la oferta turística.

Registro fotográfico



Fuente imagen: 90 grados, https://90gradosvilladeleyva.com/viajes/hoyo-de-la-romera/

GZP04 Pozos azules de Sutamarchán 5.597264, -73.621448

Descripción del sitio

Serie de pozos semi-profundos formados por la erosión lateral y de fondo en el lecho de un afluente del río Sutamarchán. Afloran arcillolitas oscuras de la Formación Paja, en las que es posible encontrar fósiles. Es un sitio frecuentado por turistas, y el acceso es por carretera destapada a lo largo de 4 km desde Sutamarchán.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Rasgos hidrológicos y formas asociadas	G	No	Turismo	Privada

Rasgos de interés primario

El lecho del río y su zona de influencia a lo largo de la sección en la que se encuentran los pozos.

Rasgos de interés secundario

Afloramientos rocosos con fósiles, que pueden tener algún interés estratigráfico o paleontológico.

Relación con elementos culturales o de la biodiversidad

Es un sitio de turismo tradicional para los habitantes de Sutamarchán.

Estado de conservación general

Favorable.

Riesgo de degradación

Fragilidad: Baja.

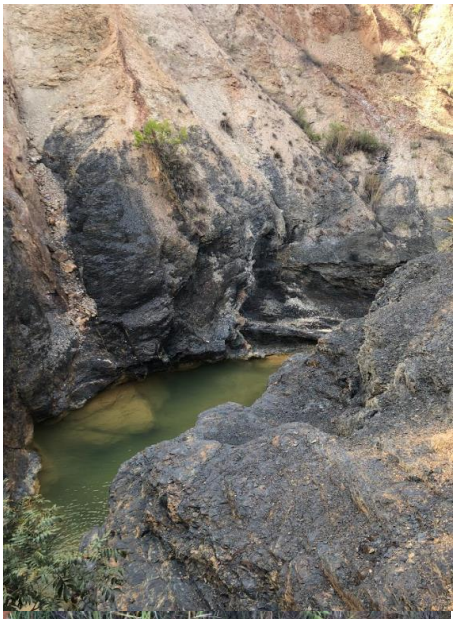
Vulnerabilidad: Expolio de material rocoso, expansión urbana o de fincas circundantes, actividades aguas arriba que puedan traer residuos sólidos o polución al sitio.

Riesgo de degradación: Bajo.

Metas de manejo y conservación	**Medidas racionales de manejo**
El sitio tendrá un plan de manejo geoturístico. Los dueños, vecinos y visitantes del lugar tendrán conciencia de los elementos geológicos de interés en el sitio. Las actividades humanas que tengan lugar aguas arriba no afectarán el estado de conservación de los pozos azules, en especial en cuanto a cuantidad y calidad del agua. El acceso al sitio será fácil. No se realizarán actividades ilegales de extracción de rocas o fósiles en las paredes rocosas cercanas a los pozos azules. El sitio de los pozos azules será incluido en paquetes geoturísticos como un sitio de recreación en el que es posible conversar acerca de temas geológicos, como las rocas oscuras que afloran, los fósiles, o la formación de los pozos.	Se gestionará con los dueños del terreno y la administración municipal la adecuación del sitio como atractivo geoturístico, incluyendo señalización, zonas de descanso, ruta de evacuación, y promoción del lugar. Realizar, de la mano del SENA, Corpoboyacá, dependencias de las Alcaldías, u otra institución capacitada, talleres de buenas prácticas de actividades agrícolas aguas arriba, incluyendo temas como deforestación, uso de pesticidas, hidrología superficial, manejo de estiércol y otros residuos, y cómo estos podrían afectar los pozos azules. Se instalará una valla o panel acerca del protocolo a seguir en caso de hallazgo fortuito de fósiles en el sitio.

Notas

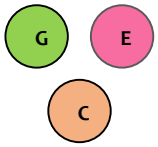
Registro fotográfico



GZP05 Cascada y cueva El Hayal 5.597264, -73.621448

Descripción del sitio

Abrigo rocoso y cascada de 30 m desarrollados sobre un gran escarpe de rocas color amarillento que corresponde a calizas de la Formación Rosablanca, con evidente interés paisajístico y geomorfológico. El sitio está asociado a patrimonio arqueológico y es una de las principales atracciones turísticas en Santa Sofía. El acceso es por carretera destapada a 6 km de Santa Sofía y 15 min a pie del sitio de parqueo.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Formas kársticas		No	Ecoturismo	Privada

Rasgos de interés primario

El conjunto paisajístico creado por el escarpe calcáreo, el abrigo rocoso, y la gran cascada.

Rasgos de interés secundario

Otra pequeña cavidad se encuentra en el mismo escarpe de roca, a menos de 50 m de la famosa cascada.

Relación con elementos culturales o de la biodiversidad

En el interior de la cueva se han encontrado evidencias de actividad prehispánica. La galería bajo la cascada es considerada un lugar sagrado para la cultura indígena muisca. Hay evidencias de arte rupestre. Es un importante sitio turístico de la región y un referente paisajístico de Santa Sofía.

Estado de conservación general

Favorable. El conjunto de este elemento geomorfológico está, en general, en buenas condiciones. No se aprecian actividades antrópicas que puedan causar alteraciones, ni procesos naturales que puedan provocar daños o destrucción del lugar.

Riesgo de degradación

Fragilidad: Poca, se observan algunos colapsos de roca.
Vulnerabilidad: Escorrentía proveniente de invernaderos, con potencial de traer residuos sólidos o disueltos. Actividades turísticas de camping o fogata han resultado en alteración del patrimonio arqueológico asociado, así como profanación en búsqueda de tesoros.
Riesgo de degradación: Medio

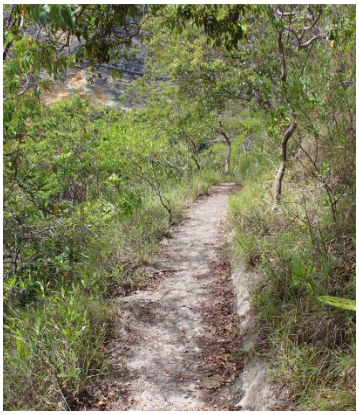
Metas de manejo y conservación	**Medidas racionales de manejo**
La calidad del agua que cae en la cascada debe permanecer en condiciones óptimas para ser apreciada por turistas, sin generar olores ni traer residuos disueltos o sólidos. El escarpe rocoso mantendrá su evolución natural y sin obstáculos visuales para su apreciación. A medio plazo, los propietarios de tierras, agricultores y otros locales serán conscientes de la presencia de un sitio con un importante valor paisajístico y espiritual que merece ser protegido. A medio plazo, el sitio estará contemplado en las herramientas de ordenamiento territorial de Santa Sofía. Aumentar el potencial geoturístico del sitio El Hayal.	Concertar con Corpoboyacá u otra autoridad ambiental o académica, un plan de monitoreo mensual de la calidad del agua de la cascada. Incluir el polígono del sitio en la categoría de "protección" del Esquema de Ordenamiento Territorial del municipio de Santa Sofía. Promover la cooperación y comunicación entre los dueños del Hayal y sitios naturales similares en Colombia, con el fin de generar ideas acerca de posibles medidas de gestión y conservación del sitio. Desde el proyecto de geoparque, cooperar con los dueños del sitio para diseñar un plan de gestión del sitio (incluyendo los terrenos aguas arriba que puedan afectar el sistema kárstico). Cooperar con los dueños para instalar señalización y material interpretativo sobre la formación de la cueva y sus características geológicas/geomorfológicas.

	Realizar talleres de sensibilización y concientización con las comunidades y agricultores que trabajan aguas arriba y en los alrededores de la cueva. Diseñar un guion geoturístico basado en la formación geológica del lugar, el folclor y los mitos y leyendas asociadas al sitio del Hayal, que permitan promocionar y difundir más el sitio.

Notas

Registro fotográfico



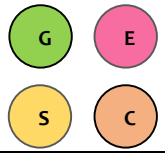





GZP06 Pliosaurio de Sáchica 5.566722°, -73.534138°

Descripción del sitio

Pequeño centro de exposición que alberga los restos petrificados del *Sachicasaurus vitae* (nuevo género y especie), descubierto en 2009. El espécimen se encuentra casi completo, en buenas condiciones de conservación, y es considerado el Pliosaurio más grande del mundo, por lo que se trata de un elemento patrimonial ex situ de relevancia internacional. El lugar que alberga los restos se encuentra a 2,6 km por carretera destapada del casco urbano de Sáchica, a unos 500 m del lugar original de hallazgo.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Patrimonio geológico ex situ Área temática: Registro paleontológico		No	Conservación	Alcaldía de Sáchica

Rasgos de interés primario

El esqueleto bien conservado y casi completo de 10 m de longitud del *Sachicasaurus vitae.*

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

El esqueleto del *Sachicasaurus vitae* tiene cierta importancia para los habitantes de Sáchica, ya que es considerado por algunos sectores de la población como un tesoro y motivo de orgullo para el municipio.

Estado de conservación general

Favorable. Según las descripciones paleontológicas, es un esqueleto tridimensional bien conservado. El lugar de exhibición de los restos, sin embargo, parece algo rudimentario, sin monitoreo de las condiciones ambientales o vigilancia continua del sitio.

Riesgo de degradación

Fragilidad: No se observan condiciones de origen natural que puedan afectar especialmente el sitio.
Vulnerabilidad: El sitio es vulnerable a robo de una o varias de las piezas paleontológicas, y a las condiciones ambientales que puedan afectar los restos como humedad o crecimiento de mohos.
Riesgo de degradación: Bajo.

Metas de manejo y conservación	**Medidas racionales de manejo**
El estado de conservación del espécimen será lo suficientemente bueno para realizar estudios científicos relevantes, recibir visitas y turistas en el futuro. El espécimen de *Sachicasaurus* se trasladará a una instalación cercana al lugar original de hallazgo, y se construirá un centro interpretativo o museo para su custodia, con el fin de conservar y promocionar el espécimen. Sáchica será reconocida a nivel nacional como el hogar del Pliosaurio más grande del mundo, siendo este sitio destino para aficionados, turistas y académicos de todo el país, convirtiéndose en una importante fuente de ingresos para el municipio. El Pliosaurio formará parte del inventario nacional del patrimonio geológico.	Promover, desde la administración municipal, la construcción de un museo paleontológico o centro educativo en el lugar del hallazgo del espécimen. Mientras tanto, permitir visitas guiadas de escuelas, universidades o interesados para promover el sitio. Desarrollar una marca municipal basada en el Pliosaurio de Sáchica, promocionando los geoproductos locales, así como patrocinando publicidad especializada con fondos de la administración municipal. Crear una veeduría ciudadana para vigilar y participar en el proceso de proceso de musealización y puesta en valor del fósil.

Notas

Registro fotográfico

GZP07 Sección tipo Formación Ritoque 5.605428, -73.519066°

Descripción del sitio

Sitio donde la Formación Ritoque fue definida por el geólogo Fernando Etayo en 1968. El lugar se encuentra adyacente a un camino frecuentado para senderismo, accesible solo a pie tras al menos 30 minutos de recorrido.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Secuencias sedimentarias del Mesozoico	S	No	Pastoreo	Privada

Rasgos de interés primario

La sección del afloramiento rocoso con interés estratigráfico e histórico al ser el sitio en el que se definió la formación por primera vez.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

La sección rocosa parece estar en condiciones "normales" de alteración, sin embargo, hay abundante vegetación baja creciendo en algunas partes del afloramiento, obstaculizando la visión y probablemente acelerando la meteorización de la roca expuesta.

Riesgo de degradación

Fragilidad: Caídas y colapsos de roca, crecimiento de vegetación, crecimiento de líquenes.
Vulnerabilidad: Baja, no hay actividades humanas potencialmente peligrosas para la integridad del sitio.
Riesgo de degradación: Bajo.

Metas de manejo y conservación	**Medidas racionales de manejo**
La sección rocosa de interés estará delimitada espacialmente y será considerada en los planes de manejo del territorio como un polígono de interés científico. La sección rocosa de interés se mantendrá limpia, despejada, con total posibilidad de visualización y en condiciones de integridad suficientes para realizar estudios científicos en el futuro. El afloramiento rocoso será conocido y utilizado como sitio de visita en planes de turismo científico y turismo geológico. El sitio estará en el inventario del proyecto de geoparque. La importancia geológica e histórico-geológica del sitio será reconocida por los locales, visitantes interesados, y usuarios habituales del sendero.	Dentro del proyecto geoparque se trabajará en la delimitación técnica de este sitio, y se hará la socialización con la Alcaldía Municipal de Villa de Leyva para difundir su importancia. Se creará un programa de mantenimiento periódico del sitio, por ejemplo, a manos de voluntarios o guías de turismo que frecuenten el sendero adyacente. Incluir el sitio en el inventario de geositios del proyecto geoparque. Se instalará señalización y un panel temático acerca del carácter científico del sitio. Se puede considerar hablar de la historia de la geología en la zona de estudio y los aportes que se han realizado por geólogos como Fernando Etayo al panorama geológico y paleontológico internacional, gracias a secciones rocosas estudiadas en el Alto Ricaurte.

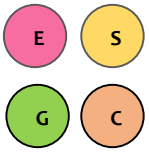
Notas

Registro fotográfico

GZP08 Museo El Fósil 5.637177, -73.558817

Descripción del sitio

Esqueleto petrificado de *Monquirasaurus boyacensis* (antes *Kronosaurus boyacensis*), nuevo género y especie. Está excepcionalmente bien conservado in situ y prácticamente completo. Los restos se encuentran en un museo paleontológico que lleva funcionando hace varias décadas y es ahora un referente turístico de Leyva. El museo fue construido in-situ sobre el sitio de hallazgo del fósil, custodiado y administrado por la Junta de Acción de la vereda Monquirá, y es un ejemplo de clase mundial de gestión comunitaria de patrimonio geológico de relevancia internacional. El acceso es directo por carretera pavimentada.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Registro paleontológico		No	Geoturismo a cargo del Museo El Fósil, actividades educativas, conservación y ciencia	Junta de Acción Comunal vereda Monquirá

Rasgos de interés primario

El esqueleto bien conservado y casi completo, de 10 m de longitud, del *Monquirasaurus boyacensis.*

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

El Museo El Fósil es un elemento muy importante para la Junta de Acción Comunal que lo administra, siendo parte de su historia e identidad, así como parte de la identidad turística del municipio de Villa de Leyva.

Estado de conservación general

El espécimen de *Monquirasaurus* tiene un buen estado de conservación in situ, con los rasgos principales visibles, enteros y bajo constante vigilancia y monitoreo de las condiciones ambientales. El fósil no posee una de sus extremidades inferiores.

Riesgo de degradación

Fragilidad: No posee condiciones particulares de fragilidad.
Vulnerabilidad: La superficie del esqueleto puede ser vulnerable a las condiciones atmosféricas como humedad o radicación solar. El museo debe contar con altos estándares sismo resistentes para evitar un colapso, así como protección contra incendios y expolios, al ser amenazas potenciales sobre los restos.
Riesgo de degradación: Bajo.

Metas de manejo y conservación	**Medidas racionales de manejo**
El estado de conservación del espécimen seguirá en condiciones suficientemente buenas para realizar estudios científicos relevantes y recibir visitas de turistas y estudiantes en el futuro. El Museo El Fósil será reconocido internacionalmente como un excelente ejemplo de gestión y conservación del patrimonio geológico con relevancia mundial. El esqueleto del *Monquirasaurus* será conocido en la comunidad académica como un representante del patrimonio geológico nacional, y su importancia será difundida a públicos no expertos.	Las condiciones ambientales y el estado de conservación del espécimen serán monitoreados anualmente no sólo por el museo sino por una autoridad externa como como el Servicio Geológico Colombiano, para con el fin de preservar su estado de conservación en el tiempo. El museo El Fósil será promovido por autoridades municipales, departamentales y nacionales como patrimonio geológico y ejemplo de conservación, educación y turismo de clase mundial, tanto en contextos académicos como en contextos de divulgación de la ciencia.

Notas

Registro fotográfico

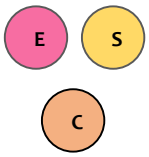

PLANO RUTA DE EVACUACIÓN
MUSEO EL FÓSIL


EL KRONOSAURIO
Kronosaurus Boyacensis Hampe (1992)
MUSEO EL FÓSIL
Clase: Reptilia
Familia: Pliosauridae
Edad: Aptiano (115 millones de años aproximadamente)
Localidad: Villa de Leyva, Boyacá
Los Kronosaurios eran reptiles marinos de la familia de los Pliosaurios, poseían una gran cabeza semejante en la forma a la de un cocodrilo, cuello corto y cuatro amplias aletas. Con 12 metros de longitud, tan solo su cráneo alcanzaba a medir hasta 3 metros. Tenía grandes dientes cónicos afilados que alcanzaban hasta los 25 centímetros. Se alimentaban de otros reptiles marinos, peces y moluscos.

GZP09 Loma La Yesera 5.605166, -73.535906

Descripción del sitio

Colina que forma parte del *Lagerstätte* de la Formación Paja. Existe un alto grado de conocimiento científico del sitio en términos de tesis y publicaciones, debido a su interés paleontológico y estratigráfico. El lugar es conocido por la abundancia y diversidad de fósiles fácilmente observables y extraíbles. Se encuentra al pie de una carretera pavimentada, pero para acceder se debe franquear una portería privada.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Registro paleontológico		No	Finca privada	Privada

Rasgos de interés primario

Las secuencias rocosas que poseen amonitas, moluscos y otros fósiles que han permitido reconstrucciones bioestratigrafías y poseen diversos tipos de interés.

Rasgos de interés secundario

La colina posee un interés paisajístico, al mostrar una amplia variedad cromática y diferencia de relieve respecto al paisaje circundante.

Relación con elementos culturales o de la biodiversidad

Elementos de la historia local con relación a extracción de materiales en el pasado.

Estado de conservación general

Favorable con alteraciones. El lugar no presenta mayores alteraciones, pero ha sufrido expolio de fósiles.

Riesgo de degradación

Fragilidad: El sitio no posee condiciones de fragilidad particulares.
Vulnerabilidad: La extracción ilegal de fósiles y la expansión urbana pueden ser amenazas potenciales sobre el sitio. El lugar posee una solicitud de concesión minera para explotación de materiales de construcción, por lo que esta amenaza debe ser considerada como relevante.
Riesgo de degradación: Medio.

Metas de manejo y conservación	**Medidas racionales de manejo**
La abundancia y diversidad de los fósiles en el yacimiento serán suficientes para realizar estudios científicos relevantes en el futuro, y serán visibles para futuros estudiantes y geoturistas que visiten el yacimiento con fines de aprendizaje.	Definir la ruta de acceso, instalar señales y un panel para mejorar la divulgación científica sobre la importancia paleontológica del lugar.
La extracción ilegal e informal de fósiles en el yacimiento será inexistente.	Realizar una zonación del sitio geológico, definiendo el área para visitas y prohibiendo las visitas en el resto del sitio.
El sitio geológico La Yesera será reconocido local y regionalmente como un lugar importante para la ciencia, y estará contemplado como área de conservación en el Esquema de Ordenamiento Territorial de Villa de Leyva.	Promover la declaración del sitio como patrimonio geológico de la Nación.
La Yesera será un polígono delimitado en el espacio, conocido a nivel nacional por formar parte del inventario de patrimonio geológico de la Nación y amparado por el actual decreto.	Crear un plan de gestión centrado en el recurso paleontológico.
Las visitas al yacimiento de Loma la Yesera serán planeadas y gestionadas.	Coordinar con los dueños del lote para que los encargados de la finca realicen actividades periódicas de limpieza y control de la vegetación en la sección del afloramiento definida para visitas.
El yacimiento de La Yesera tendrá un acceso fácil y seguro para visitantes de cualquier edad.	Desarrollar un plan de monitoreo anual de la integridad física, incluyendo indicadores sobre la abundancia y el estado de las capas fósiles.
	El recorrido hasta el lugar específico para realizar visitas será claro y señalizado, incluyendo ruta de evacuación.

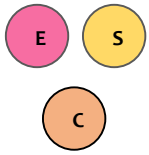
Notas

Registro fotográfico

GZP10 Loma La Cabrera 5.650787, -73.562364

Descripción del sitio

Sitio de gran importancia ya que se han hallado reptiles marinos del Cretácico inferior en rocas de la Formación Paja. Forma parte del *Lagerstätte.* El yacimiento paleontológico no se ha delimitado, así que inicialmente se ha considerado toda la colina como el sitio geológico. La mayor parte del sitio está ocupada por fincas y otras propiedades privadas, sin afloramientos rocosos extensos.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Registro paleontológico		No	Fincas privadas, pastoreo, agricultura en invernaderos	Privada

Rasgos de interés primario

Las rocas expuestas y enterradas de la Formación Paja, en las que se han encontrado fósiles incluyendo reptiles marinos.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

Favorable. Los elementos de interés se encuentran sin alteraciones evidentes.

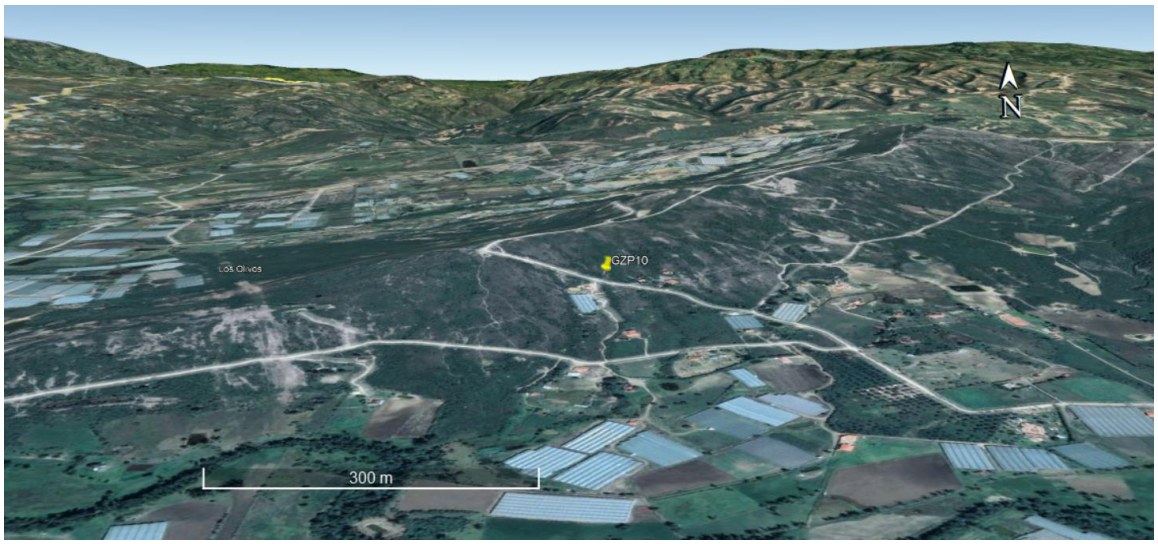
Riesgo de degradación

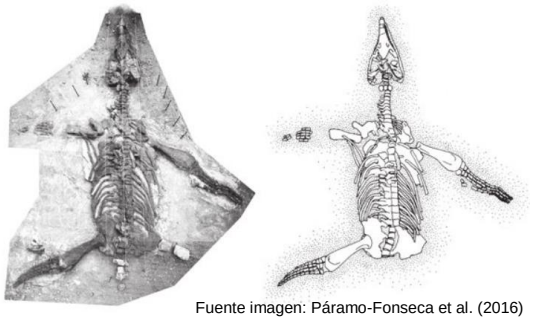
Fragilidad: No se observan procesos naturales que puedan afectar significativamente los elementos de interés.
Vulnerabilidad: La extracción ilegal de muestras fósiles y la expansión urbana podrían afectar la integridad de este sitio.
Riesgo de degradación: Medio.

Metas de manejo y conservación	**Medidas racionales de manejo**
La abundancia y diversidad de los fósiles en el yacimiento serán suficientes para realizar estudios científicos relevantes en el futuro.	Desarrollar un proyecto para la exploración paleontológica y delimitación del yacimiento de La Cabrera.
El yacimiento paleontológico de La Cabrera estará delimitado espacialmente como un sitio de interés científico, y considerado en los planes y proyectos de desarrollo territorial.	Socializar la importancia científica de La Cabrera con las autoridades del municipio de Villa de Leyva, así como con los habitantes y vecinos del lugar.
Los habitantes de La Cabrera y vecinos serán conscientes y estarán apropiados del patrimonio geológico que ha sido descubierto en el lugar.	Generar, desde alguna autoridad ambiental o del gobierno, un protocolo de hallazgo fortuito de elementos paleontológicos y socializarlo con los habitantes de La Cabrera. Los hallazgos paleontológicos en La Cabrera serán socializados con los habitantes de la zona y sus vecinos. Se promoverán talleres didácticos en las escuelas para promover el interés en los fósiles que se han encontrado.

Notas

Registro fotográfico





Fuente imagen: Páramo-Fonseca et al. (2016)

GZP11 Cascada La Periquera 5.716998, -73.521337

Descripción del sitio

Serie de cascadas desarrolladas sobre limolitas de la Formación Ritoque, aflorando en medio de un abundante bosque, con especial interés cultural y geomorfológico. En el sitio se desarrollan actualmente actividades de ecoturismo. Se encuentra a 13 km por carretera semi-pavimentada del casco urbano de Villa de Leyva.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Rasgos hidrológicos y formas asociadas	G C	No	Ecoturismo, conservación	Privada

Rasgos de interés primario

El elemento paisajístico conformado por la serie de cascadas.

Rasgos de interés secundario

Fósiles.

Relación con elementos culturales o de la biodiversidad

El sitio tiene importancia espiritual asociada a la cultura Muisca, al considerarse, según el folclor local, un lugar de purificación para los indígenas antes de ascender a la laguna sagrada de Iguaqué. Las cascadas aún son frecuentadas por locales y turistas como sitio de retiro espiritual. También hay leyendas locales acerca del misticismo del sitio y visiones o apariciones sagradas.

El nombre proviene de la palabra *pericos*, y se refiere a guacamayas que según los locales antes eran abundantes en el lugar.

Estado de conservación general

Favorable. Los elementos de interés se encuentran sin alteraciones evidentes.

Riesgo de degradación

Vulnerabilidad: No se observan procesos intrínsecos que puedan afectar significativamente el sitio.
Fragilidad: El valor paisajístico del sitio podría verse afectado por malas decisiones de manejo, como construcción de grandes instalaciones, deforestación, entre otros, así como por las actividades aguas arriba como agricultura extensiva o extracción de materiales, que deterioren la calidad del agua que baja por las cascadas.
Riesgo de degradación: Bajo.

Metas de manejo y conservación	**Medidas racionales de manejo**
La calidad del agua que corre por las cascadas será buena, sin residuos sólidos o disueltos que generen olores, alteraciones visuales, o degradación de la fauna y flora. Los senderos y miradores de las cascadas estarán completamente señalizados y aportarán información acerca del interés geomorfológico, cultural y espiritual del sitio. Los senderos de La Periquera estarán en condiciones óptimas de seguridad, que garanticen que ningún adulto o menor de edad pueda caer accidentalmente.	La administración del parque La Periquera implementará, de la mano de alguna institución o autoridad ambiental, un plan de monitoreo mensual de la calidad del agua. Se hará un plan de mejora de la infraestructura y señalización en los senderos, con el fin de mejorar las condiciones de seguridad. Se instalará material interpretativo que hable acerca de la geomorfología del sitio y de su valor espiritual asociado a la cultura Muisca.

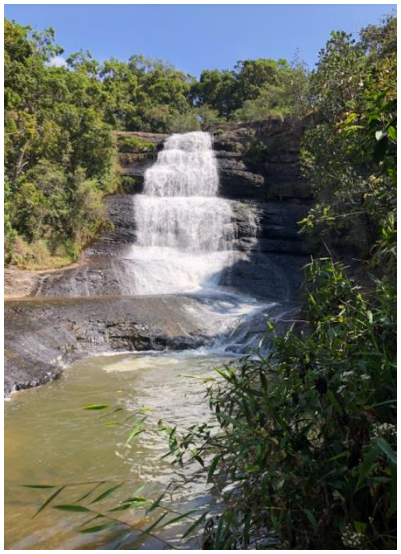
Notas

El sitio se encuentra en el límite entre los municipios de Villa de Leyva y Gachantivá.

Hay buenas instalaciones físicas para la recepción de turistas, así como señalización. Sin embargo, podría incluirse información referida a la geomorfología del sitio.

Registro fotográfico


RUTA DE EVACUACIÓN
EVACUATION ROUTE
LA PERIQUERA
RNT N°55623
Municipio de Villa de Leyva
Rio La Cebada
Municipio de Gachantivá



GZP12 Excavación Pliosaurio 5.571643, -73.530972

Descripción del sitio

Lugar de hallazgo del pliosaurio *Sachicasaurus vitae* (nuevo género y especie). El yacimiento es de importancia científica ya que contiene el contexto estratigráfico y paleontológico de este descubrimiento de talla mundial. El acceso es por carretera destapada desde Sáchica.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Registro paleontológico	S C	No	Pastoreo; paso de tubería industrial	Pública (desde 2022)

Rasgos de interés primario

El afloramiento rocoso en el que se encontraron los restos del *Sachicasaurus*.

Rasgos de interés secundario

Los locales han reportado el hallazgo de la cabeza de un segundo reptil marino en el sitio.
Hay yeso fácilmente observable y extraíble; el sitio era una antigua yesera.

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

Desfavorable. El sitio parece estar abandonado, con aguas estancadas en superficie y crecimiento de vegetación. Se observan rastros de expolio de muestras rocosas, probablemente en búsqueda de fósiles.

Riesgo de degradación

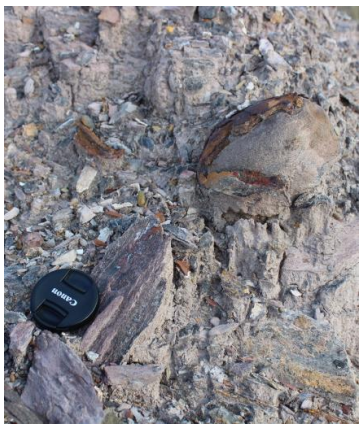
Vulnerabilidad: No se observan condiciones especiales de vulnerabilidad en el sitio.
Fragilidad: El sitio puede fácilmente perderse por movimiento de tierras para construcción o corte del terreno, expansión urbana o agrícola, y cualquier otra actividad que encubra o altere drásticamente el sitio de hallazgo del fósil en superficie.
Riesgo de degradación: Alto.

Metas de manejo y conservación	**Medidas racionales de manejo**
El lugar de excavación del *Sachicasaurus* permanecerá en condiciones de conservación suficientemente buenas para realizar estudios estratigráficos, sedimentológicos, y paleontológicos en el futuro. El lugar de excavación del *Sachicasaurus* será un terreno de propiedad pública, y estará protegido de actividades que puedan causar su destrucción como canteras, agricultura o ganadería extensiva, expansión urbana o industrial, etc. Este sitio geológico será un destino de turismo científico y geoturismo en el municipio de Sáchica, y servirá para aumentar la conciencia acerca del patrimonio geológico de la zona.	Desde el proyecto de geoparque y las partes interesadas, se promoverá el traslado de los restos del *Sachicasaurus* a este lote, y se creará un museo o centro de interpretación geológica y paleontológica asociado a los restos. El sitio de excavación del *Sachicasaurus* y su contexto geológico serán delimitados espacialmente, y este polígono estará incluido como suelo de protección en el plan de desarrollo del municipio.

Notas

La propuesta de un museo o interpretación debe gestionarse con método y creatividad, ya que la región posee ya un museo con características muy similares en Villa de Leyva. Sería ideal definir un eje temático especial para este museo, o un "valor agregado", además de promover el *Sachicasaurus* como el Pliosaurio más grande del mundo y como marca del municipio de Sáchica.

Registro fotográfico



GZP13 Sección de referencia Formación Paja 5.588615, -73.518138

Descripción del sitio

Se trata de un afloramiento rocoso en el corte de carretera de la vía Sáchica-Samacá, a unos 3.0 km de Sáchica cerca al desvió hacia Chíquiza. El afloramiento es un sitio de referencia de la Formación Paja.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Secuencias sedimentarias del Mesozoico	S E	No	Ninguno	Privada

Rasgos de interés primario

La sección de afloramiento rocoso que aflora en el margen de la carretera, compuesto por arcillolitas y lutitas con gran contenido fosilífero y estructuras sedimentarias.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

El afloramiento se encuentra, en general, en buenas condiciones, meteorizado en superficie y con crecimiento de vegetación en algunas zonas. Se observan algunas pinturas con publicidad política sobre la roca, que disminuyen el interés paisajístico del lugar y pueden encubrir rasgos estratigráficos importantes.

Riesgo de degradación

Fragilidad: Las rocas de esta sección rocosa pueden sufrir derrumbes o colapsos.
Vulnerabilidad: La sección rocosa es vulnerable a la alteración visual con publicidad o grafiti, a expansión urbana o de la carretera, y al expolio de muestras con fósiles por parte de amateurs y estudiantes.
Riesgo de degradación: Medio.

Metas de manejo y conservación

Las condiciones de integridad serán suficientemente buenas para elaborar estudios científicos relevantes, así como para realizar visitas académicas o educativas.

El sitio geológico estará plenamente identificado, descrito, delimitado y zonificado según sus secciones más relevantes desde el punto de vista geológico.

El sitio geológico hará parte del inventario de sitios geológicos del Alto Ricaurte, y las autoridades municipales y locales conocerán acerca de la importancia científica del lugar.

El sitio será utilizado por estudiantes de Ciencias de la Tierra, científicos y amateurs, para realizar actividades de educación e interpretación, y estas estarán apoyadas por material de interpretación in situ.

Medidas racionales de manejo

El polígono de interés de la Formación Paja en esta sección será delimitado y zonificado en zonas de importancia según los rasgos geológicos y paleontológicos presentes. Se dará prioridad a los sitios de mayor importancia y se delimitarán las zonas para visitas universitarias o educativas.

El sitio estará incluido en el inventario de sitios de un posible proyecto geoparque, y se velará por el mantenimiento del sitio: limpieza, control de vegetación, eliminación de grafitis y publicidad, probablemente a través de un programa de voluntarios.

Se elegirá una sección del afloramiento para interpretación, y se instalará un panel interpretativo al otro lado de la carretera, para resaltar asuntos paleontológicos, estratigráficos y sedimentarios del lugar.

El interés científico del sitio y su importancia serán socializados con la Alcaldía del municipio de Sáchica y con las autoridades ambientales competentes, con el fin que el sitio sea considerado en el futuro en los proyectos y planes de desarrollo del territorio.

Notas

Se debe tener en cuenta la seguridad de los visitantes en caso de hacer alguna intervención para instalaciones de interpretación del sitio. Idealmente, construir una plataforma o lugar con barandas de protección al otro lado de la carretera, en algún lugar en el que el espacio lo permita.

Registro fotográfico

GZP14 Sección de referencia Grupo San Gil 5.577418, -73.511062

Descripción del sitio

Afloramiento rocoso en el corte de la carretera Sáchica-Samacá, en el que se encuentra la sección tipo de la Formación San Gil Superior (calizas, arcillas y areniscas). Contiene restos de bivalvos y material carbonoso.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Secuencias sedimentarias del Mesozoico		No	Ninguno	Privada

Rasgos de interés primario

La sección de afloramiento rocoso que aflora en el margen de la carretera Sáchica – Samacá y constituye el tipo de la Formación San Gil Superior.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

Favorable con alteraciones. El afloramiento se encuentra en general en buenas condiciones, con meteorización en superficie. Hay murales para uso publicitario que pueden cubrir rasgos de interés.

Riesgo de degradación

Fragilidad: Las rocas de esta sección rocosa pueden sufrir derrumbes o colapsos.
Vulnerabilidad: La sección rocosa es vulnerable a la alteración visual con publicidad o grafiti, a expansión urbana o de la carretera, y al expolio de muestras por parte de amateurs y estudiantes.
Riesgo de degradación: Medio.

Metas de manejo y conservación	**Medidas racionales de manejo**
Las condiciones de integridad serán suficientemente buenas para elaborar estudios científicos relevantes, así como para realizar visitas académicas o educativas. El sitio geológico estará plenamente identificado, descrito, delimitado y zonificado según sus secciones más relevantes desde el punto de vista geológico. El sitio hará parte del inventario de sitios geológicos del Alto Ricaurte, y las autoridades municipales y locales conocerán acerca de la importancia científica del lugar. El sitio será utilizado por estudiantes de Ciencias de la Tierra, científicos y amateurs, para realizar actividades de educación e interpretación, y estas estarán apoyadas por material de interpretación in situ.	El polígono de interés del Grupo San Gil en esta sección será delimitado y zonificado en zonas de importancia según los rasgos geológicos presentes. Se dará prioridad a los sitios de mayor importancia y se delimitarán las zonas para visitas universitarias o educativas. El sitio estará incluido en el inventario de sitios de un posible proyecto geoparque, y se velará por el mantenimiento del sitio: limpieza, control de vegetación, eliminación de grafitis y publicidad, probablemente a través de un programa de voluntarios. Se elegirá una sección del afloramiento para interpretación, y se instalará un panel interpretativo al otro lado de la carretera, para explicar asuntos estratigráficos y sedimentarios del lugar. El interés científico del sitio y su importancia serán socializados con la Alcaldía del municipio de Sáchica y con las autoridades ambientales competentes, con el objetivo de que el sitio sea considerado en el futuro en los proyectos y planes de desarrollo del territorio.

Notas

Registro fotográfico

GZP15 Yacimiento de Travertinos 5.577418, -73.511062

Descripción del sitio

Acumulación de travertinos Cuaternaria; aflora en una colina en la que actualmente hay una cantera para extracción de travertinos para uso ornamental o de construcción. El acceso al sitio es restringido, y actualmente hay un título minero en vigencia. Hay algunos reportes de fauna cuaternaria: mastodontes, armadillos y dientes caninos del tigre de dientes de sable, que se encuentran en museos paleontológicos de la región.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Registro paleontológico	S E	No	Extracción de materiales de construcción	Privada

Rasgos de interés primario

La formación de travertinos, en su extensión geológica, con potencial paleontológico para hallazgo de fósiles de mega fauna del Pleistoceno.

Rasgos de interés secundario

Es un buen sitio como mirador y punto de observación paisajística y de geoformas.

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

No ha podido ser valorado debido a limitaciones de acceso. De acuerdo a la revisión literaria, la cantera no posee zonas especiales para la preservación, por lo que seguramente el estado de conservación sea pobre debido a la actual explotación de material.

Riesgo de degradación

Fragilidad: No se ha podido valorar.

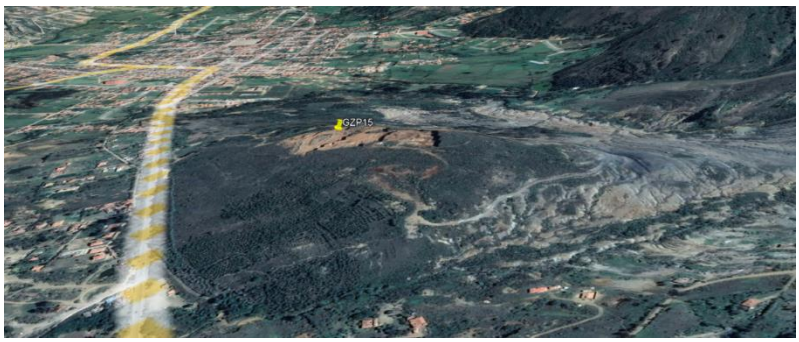
Vulnerabilidad: La mayor amenaza sobre el sitio es la extracción de materiales, ya que hay dos títulos mineros vigentes para explotación de material, el más reciente con vigencia hasta el año 2039.

Riesgo de degradación: Alto.

Metas de manejo y conservación	**Medidas racionales de manejo**
La mina de travertinos tendrá una sección del afloramiento dedicada a actividades de conservación y educación, en la que no se realicen actividades de explotación minera. Los hallazgos paleontológicos hechos en el sitio de la cantera serán reportados por la administración a las autoridades ambientales, gubernamentales, o comunidad científica, y serán entregados para su investigación.	Concertar con la administración de la cantera para definir un polígono de protección dentro del yacimiento de travertinos. Realizar talleres bianuales de sensibilización sobre el patrimonio paleontológico con los dueños y operarios de la cantera. Desarrollar un protocolo de hallazgo fortuito del patrimonio paleontológico y socializarlo con la administración y los operarios de la cantera.

Notas

Registro fotográfico



GZP16 Secuencia Formación Arcabuco 5. 591794, -73.52037

Descripción del sitio

Se trata de un valle en el que la quebrada Chíquiza abre su paso en un valle relativamente amplio y de gran atractivo paisajístico, rodeado en la margen derecha por altos escarpes de la Formación Arcabuco que hacen parte del Anticlinal de Arcabuco, y que representan la única formación rocosa del Jurásico aflorando en la zona. En el mismo sitio se encuentra el "Sitio de arte rupestre de Sáchica", de gran interés arqueológico. El acceso al sitio es tras unos 10 min a pie desde una vía sin pavimentar. Las condiciones de seguridad deben considerarse ya que hay algunos procesos de caída de rocas en el sitio.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Secuencias sedimentarias del Mesozoico		No	Ecoturismo, pastoreo	Privada

Rasgos de interés primario

Los escarpes, que contienen la secuencia rocosa y el patrimonio arqueológico asociado.

Rasgos de interés secundario

El sitio posee interés geomorfológico en cuanto a la formación del valle. En el mismo escarpe, unos kilómetros hacia el norte, se han reportado hallazgos de huellas de dinosaurio.

Relación con elementos culturales o de la biodiversidad

El sitio es un reconocido sitio arqueológico conocido como "Pictogramas de Sáchica", relacionado a la cultura Muisca.

Estado de conservación general

Favorable. El afloramiento está conformado por materiales muy competentes y poco deteriorables. Por este motivo, y por el gran tamaño del yacimiento, el estado de conservación general del mismo es bueno. Algunos problemas específicos de conservación del sitio son el crecimiento de la vegetación que cubre algunas partes de el afloramiento y que puede acelerar el proceso de meteorización. En cuanto a las huellas de dinosaurio reportadas aguas arriba, y al patrimonio arqueológico, están expuestos a la degradación por retroceso natural y desgaste en superficie de la roca. Las actividades turísticas también deben ser controladas ya que hay marcas de hogueras y grafitis en las rocas.

Riesgo de degradación

Fragilidad: No se evidencian amenazas naturales importantes en el sitio. Se evidencian algunos colapsos, crecimiento de vegetación y líquenes sobre las rocas.
Vulnerabilidad: Algunas actividades que han afectado y pueden afectar el sitio son las fogatas, la elaboración de grafitis, el expolio de rocas por parte de amateurs, y las canteras, que por ejemplo traen polvo que cubren el arte rupestre asociado. El sitio posee un título de explotación minero activo hasta el 2026.
Riesgo de degradación: Medio.

Metas de manejo y conservación	**Medidas racionales de manejo**
La exposición de las capas de roca será suficiente y estará en condiciones de conservación suficientemente favorables para realizar estudios científicos relevantes.	Creación de un plan de gestión (incluyendo el terreno de la parte superior del afloramiento).
El sitio contará con señalización de acceso, así como con señales que adviertan de la presencia de un rasgo geológico de interés en el lugar.	Señalización del sitio geológico y su ruta de acceso.
A corto plazo, los agricultores, guías turísticos y vecinos serán conscientes de la presencia de un rasgo de interés geológico en el sitio.	Cooperar con los dueños de los lotes vecinos, vigías del patrimonio, y guías, para hacer actividades de control de vegetación.
Se delimitará el polígono de la zona, incluyendo las áreas arqueológicas y las áreas destinadas a actividades turísticas y agronómicas.	Delimitación de la zona para el turismo y para actividad ganadera por parte de las autoridades competentes, y hacer esfuerzos para incluirla en el Esquema de Ordenamiento Territorial de Sáchica.
El polígono de la zona estará incluido en la categoría de "protección" en el Esquema de Ordenamiento Territorial del municipio de Sáchica, y no estará amenazado por la explotación de material.	
Los elementos de arte rupestre serán de difícil acceso para los visitantes a fin de garantizar su integridad física.	Adecuar una barrera o protección física para el yacimiento de arte rupestre.

En el sitio se realizarán actividades didácticas y educativas relacionados con el periodo Jurásico, basadas en la información paleo ambiental que se conozca de estas rocas.	Instalación de un panel sobre el Jurásico. Ejecutar programas educativos con las agencias de ecoturismo que utilizan este sitio, así como en las escuelas locales, con el fin de dar a conocer sensibilizar sobre la geología del yacimiento. Seguimiento anual de la integridad física y la visibilidad de los elementos de interés primario.

Notas

Registro fotográfico

GZP17 Cascada termal de Sáchica 5.588295, -73.529553

Descripción del sitio

Un sitio antropogénico donde manantiales de aguas termales que brotan a pocos metros de distancia han sido forzados a caer por un barranco, formando una pequeña cascada termal con una piscina en el sitio de caída. A unos metros corre la quebrada Chíquiza. Es un sitio visitado para fines turísticos. El acceso es restringido y requiere franquear varias barreras físicas ubicadas en lotes privados.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Rasgos hidrológicos y formas asociadas	G	No	Turismo, pastoreo	Privada

Rasgos de interés primario

El afloramiento natural de aguas termales que ahora corre por la pequeña cascada artificial.

Rasgos de interés secundario

N/A

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

Desfavorable. El curso del afloramiento termal fue desviado para caer por un pequeño barranco, y se ha construido un pozo artificial para el turismo en la caída. La intervención es informal y es posible que el pozo colapse en el futuro.

Riesgo de degradación

Fragilidad: Alta, es posible que el sitio se destruya por algún evento de origen natural.
Vulnerabilidad: Actividades de pastoreo en la parte superior del barranco pueden desestabilizar el sitio. La caída de agua es también vulnerable a cualquier captación o desvío del curso de agua que se haga aguas arriba.
Riesgo de degradación: Medio.

Metas de manejo y conservación	**Medidas racionales de manejo**
El sitio geológico alrededor del afloramiento de aguas termales será desplazado al lugar de afloramiento natural y original aguas arriba. El interés principal del sitio será entonces educativo y científico. El sitio tendrá material interpretativo asociado que explique la génesis de las aguas termales, sus propiedades y su relación con el contexto geológico de la región. El afloramiento de aguas termales será reconocido en la región como un sitio que hace parte de la geodiversidad de la zona. Los guías ecoturísticos que visiten el sitio tendrán el conocimiento suficiente para generar conversaciones acerca del origen geológico del sitio y despertar interés en los visitantes. El sitio se encontrará en condiciones de seguridad suficientes para mantener la integridad de turistas y visitantes, y estará señalizado.	Desde el proyecto de geoparque o las partes interesadas, se realizará un estudio para re-definir el sitio geológico asociado a las aguas termales e incluirlo en el inventario como sitio de interés educativo y científico. Se diseñará una cartilla o infografía acerca de las aguas termales de Sáchica y su posible origen geológico. Este material estará disponible para turistas y se socializará con la administración de Sáchica, los dueños del lote, y los guías turísticos que frecuenten el sitio. En caso de que la cascada termal continúe siendo un destino turístico en la región, es necesario adaptar las condiciones de seguridad; por ejemplo, señalizar la ruta de evacuación en caso de emergencia, y revisar la estabilidad del barranco en el que está la cascada para evitar un desplome.

Notas

Este sitio fue incluido como sitio geológico desde la perspectiva de un posible proyecto de geoparque, pero en realidad corresponde a un sitio geológico de origen artificial en el que se ha aprovechado e intervenido un elemento de origen natural, las aguas termales.

Registro fotográfico


CANON

GZP18 Cárcavas de Ritoque 5.602068, -73.522000

Descripción del sitio

Zona en la que se encuentra un pequeño paisaje erosivo, con barrancos de hasta 2 metros de profundidad. El sitio se encuentra en el camino de un recorrido popular para senderismo, y al ser un punto elevado en el paisaje, es un buen sitio de observación y apreciación paisajística. El acceso es sitio es únicamente a pie.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Procesos y paisajes erosivos	G	No	Turismo, pastoreo	Parques Nacionales (pública)

Rasgos de interés primario

La integridad del paisaje erosivo, con sus pináculos, barrancos, cárcavas, etc.

Rasgos de interés secundario

Alrededor del sitio hay afloramientos de paleosuelos, bloques erráticos que podrían tener origen glaciar, y elementos del paisaje regional a ser apreciados desde el punto de vista geomorfológico.

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

Favorable. Afectado por los procesos de origen natural que dieron origen al sitio. La vegetación que crece en ciertas partes puede ocultar algunos rasgos de interés.

Riesgo de degradación

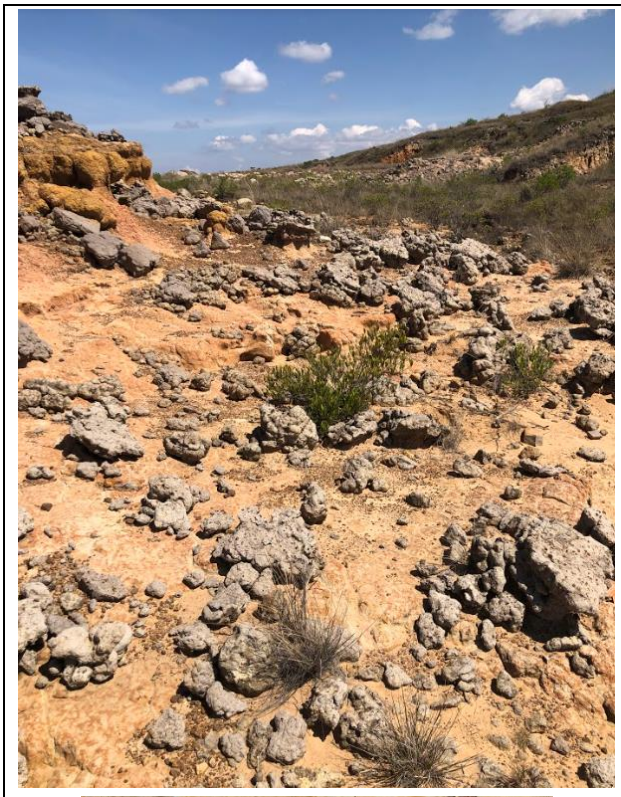
Fragilidad: El avance natural de la erosión en sí mismo, colapsos, incendios, crecimiento excesivo de la vegetación o cambios fuertes en el paisaje a causa de eventos torrenciales podrían afectar el sitio.
Vulnerabilidad: Estas formas de erosión poseen cierta fragilidad y se han desarrollado en materiales no consolidados totalmente, por lo que son vulnerables a desplome a causa de pisadas o actividades humanas, ganadería, turismo motorizado, así como incendios.
Riesgo de degradación: Bajo.

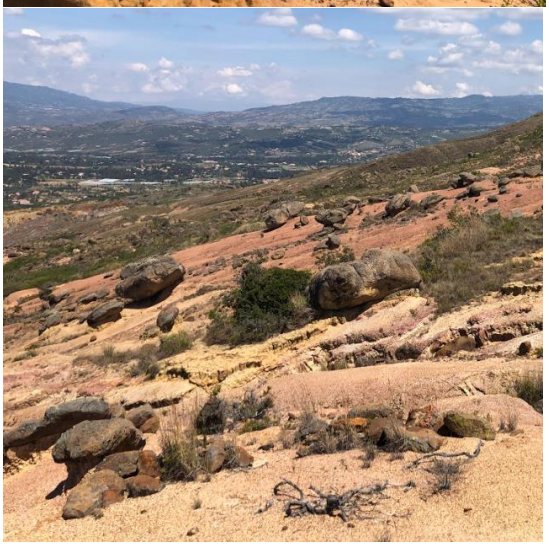
Metas de manejo y conservación	**Medidas racionales de manejo**
El proceso de erosión natural en el lugar continuará, sin ser mitigado o intensificado por actividades o intervenciones humanas. El sitio será considerado en los planes de desarrollo y ordenamiento territorial del municipio de Sáchica. Las actividades educativas y turísticas en el sitio estarán limitadas a las áreas de menos fragilidad. El sitio será reconocido como uno de los principales destinos geoturísticos del Alto Ricaurte.	Diseñar un plan de gestión para el sitio, en el que se incluya su delimitación, zonificación, y articulación con el Esquema de Ordenamiento Territorial y Plan de Desarrollo Turístico del municipio. Gestionar la inclusión del sitio en una categoría de uso del suelo en la que se prohíban actividades de ganadería y turismo intensivo. Cooperar con la alcaldía municipal o el Santuario de Flora y Fauna para la instalación de señalizaciones en el sitio, así como rutas de acceso y evacuación. Realizar actividades periódicas de control de la vegetación y monitoreo del estado de avance de la erosión. Definir y adaptar un "spot fotográfico" para que los turistas tomen sus fotografías, y encerrar con una cuerda el resto del sitio, en el que no pueden pisotear visitantes.

Notas

Hay cierta limitación de uso ya que, en teoría, se trata de un sitio con acceso restringido.

Registro fotográfico





GZP19 Cárcavas de Quebrada Arriba 5.542558, -73.522308

Descripción del sitio

En la vía Sáchica-Arrayán alto, a unos 6 km de Sáchica por la vía sin pavimentar, se toma un desvío hacia este sitio en el que afloran formas erosivas tipo estoraques y pequeños pináculos desarrollados en rocas sedimentarias, de unos 4,5 m de alto. Estas formas poseen interés paisajístico y pueden tener interés didáctico. Debido a que se encuentra en las partes más altas de Sáchica, también es un interesante mirador geomorfológico.

Clasificación	**Clases de manejo**	**Protección legal**	**Uso actual**	**Propiedad del suelo**
Sitio geológico Área temática: Procesos y paisajes erosivos	G	No	Pastoreo	Privada

Rasgos de interés primario

La integridad del paisaje erosivo, con sus pináculos, estoraques, etc.

Rasgos de interés secundario

Es también un punto de observación del paisaje.

Relación con elementos culturales o de la biodiversidad

N/A

Estado de conservación general

Desfavorable. Afectado por los procesos de origen natural que dieron origen al sitio. Se observan marcas de colapsos, derrumbes y orificios creados por la erosión. La vegetación que crece en ciertas partes puede ocultar algunos rasgos de interés.

Riesgo de degradación

Fragilidad: El avance natural de la erosión en sí mismo, colapsos, incendios, crecimiento excesivo de la vegetación o cambios fuertes a causa de eventos torrenciales podrían afectar el sitio.

Vulnerabilidad: Estas formas parecen especialmente vulnerables a la avanzada de la erosión y a otros procesos naturales como aguaceros o ventiscas que puedan destruir el sitio. Actividades humanas como turismo irresponsable, ganadería, incendios, o pisadas pueden destruir el sitio.

Riesgo de degradación: Alto.

Metas de manejo y conservación	**Medidas racionales de manejo**
El proceso de erosión natural en el lugar continuará, sin ser mitigado o intensificado por actividades o intervenciones humanas. Las actividades educativas y turísticas en el sitio estarán limitadas a las áreas de menos fragilidad. El lugar será reconocido por los locales y vecinos como un sitio de interés geológico del municipio de Sáchica, y será usado por escuelas locales para conversar sobre asuntos de Ciencias de la Tierra.	Cooperar con los dueños del lote para tomar medidas de prevención y geoconservación en el sitio. Instalar un panel explicativo acerca de los procesos de erosión en el sitio. Encordar el sitio para que se advierta de su fragilidad y evitar que sea tocado o pisoteado por visitantes. Definir y adaptar un “spot fotográfico” para que los visitantes tomen fotografías, el cual puede tener una valla o señal relacionada a la geología del sitio.

Notas

El acceso al sitio no es fácil debido a las condiciones de la vía destapada.

Registro fotográfico


Canon

Appendix 2. Quantitative assessment method

La valoración cuantitativa puede considerarse un instrumento para disminuir la subjetividad en el proceso de evaluación, clasificación y selección de geositios, y deben ser revisados de manera crítica y como un apoyo para la toma decisiones. La selección definitiva de sitios para actividades de educación, investigación, y turismo debe realizarse tras un proceso completo de conversación, evaluación y selección con la comunidad.

Este método consta de cuatro elementos a evaluar: Valor Científico (VC), Potencial de Uso Educativo (PUE), Potencial de Uso Turístico (PUT) y Riesgo de Degradación (RD). Los parámetros a evaluar y sus pesos fueron seleccionados con base en las metodologías de Brilha (2016) y Servicio Geológico Colombiano (2015), en un esfuerzo por adaptarlos a las condiciones del Alto Ricaurte.

Tabla 1. Criterios a evaluar en la valoración cuantitativa de sitios geológicos (SV, PUE, PUT)

Valor Científico	Potencial de Uso Educativo	Potencial de Uso Turístico
▪ Representatividad (30) ▪ Conocimiento científico (15) ▪ Estado de conservación (10) ▪ Rareza (20) ▪ Diversidad geológica (10) ▪ Limitaciones de uso (15) TOTAL: (100)	▪ Potencial para realizar actividades didácticas (25) ▪ Diversidad geológica (10) ▪ Asociación con otros valores del patrimonio natural o cultural (20) ▪ Estado de conservación (20) ▪ Limitaciones de uso (25) TOTAL: (100)	▪ Potencial para realizar actividades recreativas (25) ▪ Calidad visual del paisaje (15) ▪ Asociación con otros valores del patrimonio natural o cultural (15) ▪ Estado de conservación (10) ▪ Proximidad a áreas o actividades recreativas (10) ▪ Limitaciones de uso (25) TOTAL: (100)

Tabla 2. Criterios y parámetros detallados para la valoración cuantitativa de SV, PUT, PUE

Representatividad (R)	
0	No es útil como modelo para representar, incluso parcialmente, un elemento o proceso geológico.
1	Ilustra de manera razonable un elemento o proceso geológico en el área de estudio.
2	Es un buen ejemplo para ilustrar un elemento o proceso geológico en el área de estudio.
4	Es el mejor ejemplo para ilustrar un elemento o proceso geológico en el área de estudio.
Conocimiento científico (CC)	
0	No hay investigaciones o trabajos científicos publicados acerca del interés principal del sitio.
1	Hay informes técnicos, tesis de pregrado o de especialización publicados, en relación con el interés principal del sitio.
2	Hay tesis de maestría o publicaciones en revistas nacionales indexadas, en relación con el interés principal del sitio.
4	Hay tesis de doctorado o publicaciones en revistas internacionales indexadas, en relación con el interés principal del sitio.
Estado de conservación (EC)	
0	Los elementos geológicos principales están prácticamente destruidos.
1	Desfavorable: los elementos geológicos principales están ocultos o afectados a causa de alteraciones en el sitio.
2	Favorable con alteraciones: hay algunas alteraciones que no afectan significativamente el valor o interés del sitio.
4	Los elementos geológicos principales están bien preservados.
Rareza (R)	
0	Común: hay varios ejemplos similares en la región.
1	El sitio posee elementos o rasgos raros a nivel regional.
2	El sitio posee elementos o rasgos únicos a nivel regional.
4	El sitio posee elementos o rasgos únicos a nivel nacional o internacional.
Diversidad geológica (DG)	
0	Hay un solo tipo de elemento de geodiversidad en el sitio.
1	Además del elemento de geodiversidad principal, hay 1 tipo de interés geológico adicional.
2	Además del elemento de geodiversidad principal, hay 2 tipos de interés geológico adicionales.
4	Además del elemento de geodiversidad principal, hay 3 o más tipos de interés geológico adicionales.
Limitaciones de uso (LU)	
0	Es físicamente imposible utilizar el sitio para propósitos de ciencia, educación, o turismo debido a limitaciones relacionadas con las siguientes variables: protección legal, accesibilidad, propiedad del suelo, visibilidad del sitio, seguridad de los visitantes, instalaciones (alojamiento, comida, servicios básicos), logística.
1	Es difícil utilizar el sitio para propósitos de ciencia, educación, o turismo debido a limitaciones relacionadas con las siguientes variables: protección legal, accesibilidad, propiedad del suelo, visibilidad del sitio, seguridad de los visitantes, instalaciones (alojamiento, comida, servicios básicos), logística.

2	Hay algunas limitaciones que dificultan el uso del sitio. Tras franquearlas, el sitio puede ser utilizado para propósitos de ciencia, educación, o turismo.
4	El sitio no posee limitaciones importantes y puede ser utilizado para propósitos de ciencia, educación, o turismo.
Potencial para realizar actividades didácticas (PAD)	
0	El sitio no posee interés didáctico alguno.
1	El sitio presenta elementos geológicos que hacen parte de un campo de estudio especializado (posgrado).
2	El sitio presenta elementos geológicos que son enseñados en la educación superior.
4	El sitio presenta elementos geológicos que son enseñados en la educación básica (primaria y secundaria).
Asociación con otros valores del patrimonio natural o cultural (ANC)	
0	Ocurrencia de valores culturales (historia, caminos o senderos ancestrales, arte rupestre, interés espiritual o religioso, patrimonio histórico o arquitectónico, otros) o naturales (área protegida, reserva natural o sitio de interés ecológico) a más de 5 km del sitio.
1	Ocurrencia de valores culturales (historia, caminos o senderos ancestrales, arte rupestre, interés espiritual o religioso, patrimonio histórico o arquitectónico, otros) o naturales (área protegida, reserva natural o sitio de interés ecológico) a menos de 5 km del sitio.
2	Ocurrencia de valores culturales (historia, caminos o senderos ancestrales, arte rupestre, interés espiritual o religioso, patrimonio histórico o arquitectónico, otros) o naturales (área protegida, reserva natural o sitio de interés ecológico) a menos de 1 km del sitio.
4	Ocurrencia de valores culturales (historia, caminos o senderos ancestrales, arte rupestre, interés espiritual o religioso, patrimonio histórico o arquitectónico, otros) o naturales (área protegida, reserva natural o sitio de interés ecológico) a menos de 100 m del sitio.
Potencial para realizar actividades recreativas (PR)	
0	No hay potencial evidente para realizar actividades recreativas o turísticas en el sitio.
1	Hay algún potencial para realizar actividades recreativas o turísticas en el sitio.
2	Hay potencial evidente para realizar actividades recreativas o turísticas en el sitio.
4	Actualmente hay actividades recreativas o turísticas en el sitio.
Calidad visual del paisaje (CVP)	
0	El sitio no cumple con ninguno de los criterios mencionados.
2	El sitio posee 1 de los siguientes: 1) Gran amplitud de relieve, 2) Cursos de agua o grandes láminas de agua o hielo, 3) Variedad cromática, 4) Fósiles, minerales o estructuras llamativas.
4	El sitio posee 2 de los siguientes: 1) Gran amplitud de relieve, 2) Cursos de agua o grandes láminas de agua o hielo, 3) Variedad cromática, 4) Fósiles, minerales o estructuras llamativas.
Proximidad a áreas o actividades recreativas (PAR)	
0	Hay áreas o actividades recreativas a más de 10 km del sitio.
1	Hay áreas o actividades recreativas en un radio de 10 km.
2	Hay áreas o actividades recreativas en un radio de 5 km.
4	Hay áreas o actividades recreativas en un radio de 1 km.

Así,

Valor Científico (VC) = [(R*30) + (CC*15) + (EC*10) + (RA*20) + (DG*10) +(LU*15)] / 40

Potencial de Uso Educativo (PUE) = [(PAD*25) + (DG*10) + (ANC*20) + (EC*20) + (LU*25)] / 40

Potencial de Uso Turístico (PUT) = [(PR*25) + (CVP*15) + (ANC*15) + (EC+10) + (PAR*10) + (LU*25)] / 40

Según el resultado obtenido, se consideran los siguientes rangos de clasificación:

0 a 3,2 → **Valor bajo**

3,3 a 6,6 → **Valor medio**

6,7 a 10 → **Valor alto**

Para el cálculo del riesgo de degradación, se recomienda seguir el método de Brilha (2016), el cual se presenta a continuación con algunas modificaciones menores:

Tabla 3. Criterios a evaluar en la valoración cuantitativa de sitios geológicos (RD)

Riesgo de degradación
Posibilidad de deterioro de los elementos geológicos (35)
Proximidad a áreas o actividades con potencial para causar degradación (20)
Protección legal (20)
Accesibilidad (15)
Densidad de población (10)

Tabla 4. Criterios y parámetros detallados para la valoración cuantitativa del RD

Posibilidad de deterioro de los elementos geológicos (PDEG)	
4	Posibilidad de deterioro de todos los elementos geológicos.
3	Posibilidad de deterioro de los elementos geológicos principales.
2	Posibilidad de deterioro de los elementos geológicos secundarios.
1	Posibilidad menor de deterioro de los elementos geológicos secundarios.
Proximidad a áreas o actividades con potencial para causar degradación (PAER)	
4	Sitio localizado a menos de 50 m de un área o actividad con potencial de degradación.
3	Sitio localizado a menos de 200 m de un área o actividad con potencial de degradación
2	Sitio localizado a menos de 500 m de un área o actividad con potencial de degradación
1	Sitio localizado a menos de 1 km de un área o actividad con potencial de degradación.
Protección legal (PL)	
4	Sitio localizado en un área sin protección legal y sin control de acceso.
3	Sitio localizado en un área sin protección legal, pero con control de acceso.

2	Sitio localizado en un área con protección legal, pero sin control de acceso.
1	Sitio localizado en un área con protección legal y control de acceso.
Accesibilidad (A)	
4	Sitio localizado a menos de 100 metros de una carretera accesible con sitio para parqueo.
3	Sitio localizado a menos de 500 metros de una carretera accesible.
2	Sitio accesible por carretera sin pavimentar.
1	Sitio sin acceso por carretera.
Densidad de población (DP)	
0	Sitio localizado en un municipio con más de 1000 habitantes por km^2
1	Sitio localizado en un municipio con 250-1000 habitantes por km^2
2	Sitio localizado en un municipio con 100-250 habitantes por km^2
4	Sitio localizado en un municipio con menos de 100 habitantes por km^2

Así,

Riesgo de degradación (RD) = [(PDEG*35) + (PAER*20) + (PL*20) + (A*15) + (DP*10)] / 40

Según el resultado obtenido, se consideran los siguientes rangos de clasificación:

0 a 4,9 → **Bajo**

5,0 a 7,4 → **Moderado**

7,5 a 10 → **Alto**

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Brilha, J. (2016). Inventory and quantitative assessment of geosites and geodiversity sites: a review. Geoheritage, 8(2), 119-134.

Servicio Geológico Colombiano. (2015). Metodología de valoración del patrimonio geológico y paleontológico – inmueble. Disponible en https://www2.sgc.gov.co/Archivos/metodologia-de-valoracion-de-patrimonio-inmueble-gu-geo-mvp-001-noviembre-060.pdf

Appendix 3. Relevant figures, Spanish version

Geodiversidad en el Alto Ricaurte

Posee valores como…

científico · estético · espiritual

cultural · educativo · económico

Se enfrenta a amenazas como:

- Falta de conocimiento y divulgación
- Expolio de especímenes geológicos
- Recreación y presión turística
- Agricultura y ganadería
- Asuntos de propiedad del suelo
- Grafiti y publicidad
- Canteras
- Expansión urbana

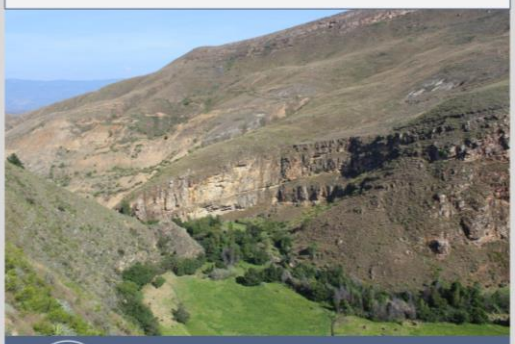
Incluye:

Patrimonio geológico

Elementos de la geodiversidad seleccionados por sus valores extraordinarios ('lo mejor de lo mejor')

DIAGNÓSTICO DEL ESTADO DE CONSERVACIÓN DE LA GEODIVERSIDAD EN LA REGIÓN DEL ALTO RICAURTE

DIAGNÓSTICO GENERAL DE LA GEODIVERSIDAD



- Riesgos geológicos
- Amenazas efectivas y potenciales
- Percepción de las comunidades
- Áreas protegidas y conservadas
- Títulos mineros y otros

DIAGNÓSTICO A ESCALA DE SITITO GEOLÓGICO

- Protección legal
- Riesgo de degradación
- Propiedad y uso del suelo
- Rasgos de interés
- Relación con la cultura o biodiversidad
- Estado de conservación general
- Metas de manejo y conservación
- Medidas racionales de manejo

Algunos servicios que presta la geodiversidad a las comunidades del Alto Ricaurte

Materiales de construcción

Almacenamiento y distribución de agua dulce

Materiales ornamentales

Conocimiento sobre la historia de la Tierra

Inspiración artística

Empleo

Educación

Provisión de hábitat

Turismo y recreación

En un artículo científico presentado por Gill (2017), el geopatrimonio y el geoturismo son considerados como aspectos clave de las ciencias geológicas para alcanzar los Objetivos de Desarrollo Sostenible. Visualizar los servicios que la geodiversidad proporciona a la sociedad puede ayudar a comprender mejor cómo la geodiversidad puede contribuir a estos objetivos.

A la izquierda, algunos de los objetivos directamente relacionados con el estudio del geopatrimonio y la geoconservación.

Elaborado por: Juan Esteban Quintero Marín, 2022

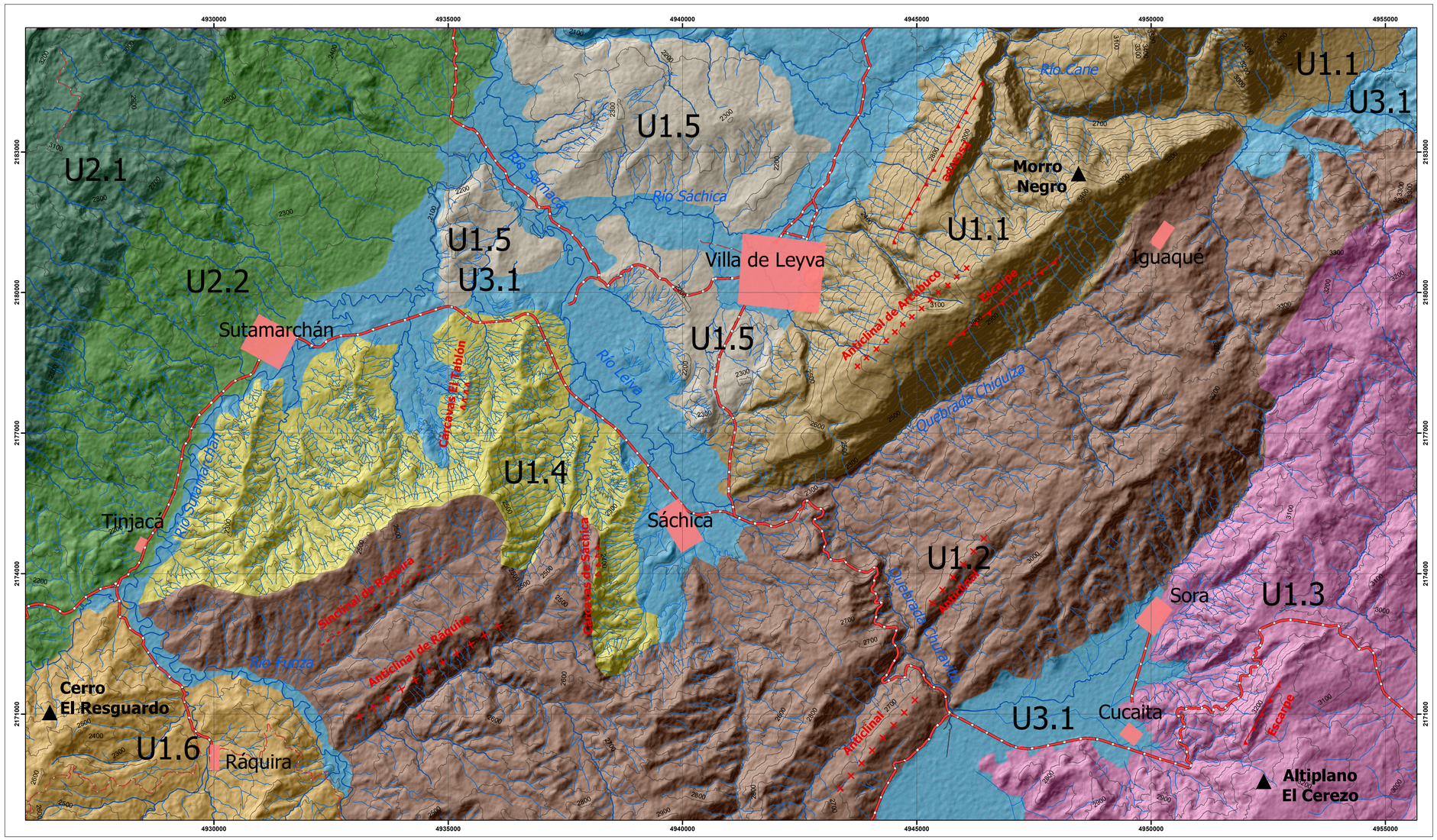

PLAN DE ACCIÓN ESTRATÉGICO PARA LA GEOCONSERVACIÓN
KRONOSAURIO
CONOCIMIENTO
PLANEAMIENTO Y POLÍTICAS TERRITORIALES
CONSERVACIÓN DEL GEOPATRIMONIO
GOBERNANZA E INCLUSIÓN SOCIAL
DIFUSIÓN Y CONCIENTIZACIÓN
EDUCACIÓN Y FORMACIÓN

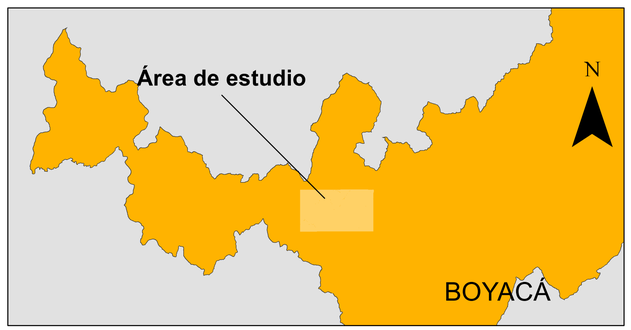
Mapa Geomorfológico

Región del Alto Ricaurte
Boyacá, República de Colombia

ALTO RICAURTE, BOYACÁ, COLOMBIA

Appendix 4. Geomorphological map covering part of the study area (in Spanish)





CONTEXTO GEOMORFOLÓGICO

Cordillera de los Andes
Andes septentrionales
Cordillera Oriental
Altiplano Cundiboyancense
Anticlinorio de Arcabuco

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Máster Europeo en Paleontología, Geopatrimonio & Aplicaciones (PANGEA)
Universidade do Minho
Evolução do Relevo e da Paisagem

Sistema de coordenadas:
MAGNA-SIRGAS / Origen-Nacional
Proyección Transverse_Mercator
False east: 5'000.000
False north: 2'000.000

Leyenda

U1. Anticlinorio de Arcabuco

Bloque estructural al este del valle de Ubaté, elongado en dirección NE-SW, que contiene numerosos sinclinales y anticlinales de menor escala.

U1.1. Anticlinal de Arcabuco: Unidad en la que predomina el antiforme de Arcabuco. Altas pendientes, alta longitud, elongación en dirección NE-SW. Rugosidad baja. Drenajes paralelos a subparalelos.

U1.2. Anticlinales Chíquiza-Sora: Unidad montañosa compuesta por cerros de altura media, pendiente media, longitud media, con una evidente orientación NE-SW. Rugosidad alta. Drenajes dendríticos a subparalelos.

U1.3. Altiplano y escarpes de Boyacá: Unidad de bajas pendientes compuesta por una región casi plana, ligeramente colinada, de grandes altitudes y rugosidad baja. Drenaje subdendrítico a anular. Posee importantes escarpes.

U1.4. Cerros disectados de Carrizal: Unidad montañosa compuesta por lomos o cerros de altura baja, pendiente media, longitud media, elongados en dirección NE-SW, con alta incisión. Rugosidad alta. Esta unidad se caracteriza por su poca vegetación con procesos de erosión muy marcados y activos, así como por su drenaje dendrítico muy denso.

U1.5. Colinas bajas de Zaquenzipa: Se trata de pequeñas colinas aisladas, de altura baja, con drenaje en enrejado de poca densidad, poca incisión, rugosidad baja y sin dirección predominante.

U1.6. Cerros de Ráqura: Localizada al SW de la zona de estudia, se trata de un par de cerros de altura media, poco disectados, rugosidad baja y drenajes subdentríticos.

U2. Altiplano de Chiquinquirá

Amplio valle de origen estructural y topografía plana, limitado por cerros de más de 3000 msnm

U2.1. Vertientes altas del altiplano de Chiquinquirá: Parte alta de una gran vertiente que desciende unos 1000 m desde el valle de Chiquinquirá hasta el valle del Zaquenzipa. Rugosidad media, incisión baja a media, convexa, con drenajes paralelos.

U2.2. Vertientes bajas del altiplano de Chiquinquirá: Parte baja de la vertiente. Rugosidad baja, incisión baja a media, drenajes subdendríticos a subparalelos.

U3. Planicies aluviales

Zonas planas, de baja pendiente, asociadas a los depósitos de los principales cauces de agua.

0 2,5 5
Kilómetros

Escala 1:50.000 1 centímetro = 500 metros

Convenciones

Centro poblado
Orografía
Via pavimentada principal
Via secundaria

Relieve
Curva de nivel índice
Curva de nivel intermedia

Estructuras
Anticlinal
Escarpe
Sinclinal
Cárcavas

Drenajes
Drenaje principal
Drenaje secundario