Universidade do Minho
Escola de Ciências

Camilo Vergara Daskam

Contributions to geoconservation in Cajón del Maipo Aspiring Geopark (Chile)

julho de 2022

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CONTRIBUTIONS TO GEOCONSERVATION IN CAJÓN DEL MAIPO ASPIRING GEOPARK (CHILE)

Abstract

Cajón del Maipo Aspiring Geopark is a mountainous territory located in the Andes Cordillera of central Chile, with an area of almost 5,000 km^2 and less than 20,000 inhabitants. Located 48 km from Santiago, the country's capital, it is a very popular nature and adventure tourist destination. It has a geological heritage of high scientific, touristic, and educational values, including active stratovolcanoes, tectonic structures, glacial morphologies, and marine fossils. However, the geoheritage is unappreciated and poorly managed. At the same time, the area is under pressure due to urban expansion, hydroelectric and mining megaprojects, mass tourism, and climate change.

This dissertation, developed in the context of the Cajón del Maipo Geopark project, seeks to promote geoconservation and local sustainable development. Its objectives include to characterize the territory and the project, to understand the geoheritage values of the area, and to identify needs and opportunities related with the geopark. The methodology, which has a practical approach, included a review of scientific and technical documents, the analysis of the geoheritage inventory, and strategic planning using the Logical Framework Approach. Based on this diagnosis, a portfolio of concrete initiatives is proposed, which are framed within the pillars of action of the geopark, aiming to contribute to sustainable local development and geoconservation.

It is hoped that these contributions, in addition to generating direct and indirect results and impacts, can be replicable and/or adaptable in other territories that are working on the development of geoparks.

Keywords: Chile, geoparks, geoconservation, geoheritage, local development

CONTRIBUIÇÕES PARA A GEOCONSERVAÇÃO NO GEOPARQUE ASPIRANTE CAJÓN DEL MAIPO (CHILE)

Resumo

O Geoparque Aspirante Cajón del Maipo é um território montanhoso localizado na Cordilheira dos Andes do Chile central, com uma área de quase 5000 km^2 e menos de 20.000 habitantes. Localizado a 48 km de Santiago, a capital do país, é um destino turístico popular de natureza e aventura. Tem um património geológico de alto valor científico, turístico e educativo, incluindo estratovulcões ativos, estruturas tectónicas, morfologias glaciares e fósseis marinhos. No entanto, o património geológico é subutilizado e mal gerido. Ao mesmo tempo, a área está sob pressão devido a expansão urbana, megaprojectos hidroeléctricos e mineiros, turismo de massas e alterações climáticas.

Esta dissertação, desenvolvida no contexto do projeto Cajón del Maipo Geopark, procura promover a geoconservação e o desenvolvimento local sustentável. Os seus objetivos são caracterizar o território e o projeto, conhecer o valor do património geológico e identificar as necessidades e oportunidades relacionadas com o geoparque. A metodologia, que tem uma abordagem prática, incluiu uma revisão de documentos científicos e técnicos, análise do inventário de geossítios e planeamento estratégico utilizando a Abordagem de Quadro Lógico. Com base neste diagnóstico, é proposta um conjunto de iniciativas concretas, enquadradas nos pilares de ação do geoparque, e que visam contribuir para o desenvolvimento local sustentável e a geoconservação.

Espera-se que estas contribuições, para além de gerarem resultados e impactos diretos e indiretos, possam ser replicáveis e/ou adaptáveis noutros territórios que estejam a trabalhar no desenvolvimento de geoparques.

Palavras-chave: Chile, geoparques, geoconservação, geopatrimónio, desenvolvimento local

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1. Introduction

Chile, located on the Pacific margin of South America, is a long, thin strip of land with unique geological features that make it a valuable natural laboratory. This is partly explained by its location in a subduction zone of oceanic plates under the South American continent, which causes intense seismic activity, the presence of dozens of active volcanoes, and the development of an abrupt relief that ranges from sea level to more than 6000 m altitude in the Andes Mountain range (Benado *et al.,* 2019). This dissertation addresses one of the most representative territories of Andean geology in central Chile, Cajón del Maipo, an aspiring UNESCO Global Geopark (UGGp).

Cajón del Maipo has the potential to become a reference in the study and teaching of Earth Sciences, not only because of its exceptional geological conditions but also because of its strategic location, a few kilometres from the city of Santiago and its seven million inhabitants. This proximity to the capital, of course, does not only have positive consequences. The greed for natural resources demanded by the growth of the country's most important city has meant that this area has historically been exploited for its natural resources, including mining, hydroelectricity, water, deforestation, and intensive cattle ranching. This way of inhabiting the territory has led to serious socio-environmental conflicts and evident environmental degradation (Folchi and Godoy 2016, González 2017).

The pressure on the territory have progressively increased, with the recent development and proposal of hydroelectric and mining megaprojects (e.g, Alto Maipo Hydroelectric Powerplant, Escalones Copper Mine[1]), which are added to the significant effects of climate change in the area, expressed in severe alterations in the hydrological regimes (*e.g.,* Farías-Barahona *et al.* 2020, Shaw *et al.* 2021).

It is in this complex context that the Cajón del Maipo geopark project is being developed, which seeks to propose a new vision of local development, promoting the conservation and enhancement of its natural and cultural heritage through research,

[1] Revista Cajón del Maipo: Megaproyecto minero Escalones. https://revistacajondelmaipo.cl/2022/05/22/megaproyecto-minero-escalones-el-goliat-que-se-enfrenta-a-la-comunidad-del-cajon-del-maipo/

conservation, education and geotourism, with the ultimate goal of moving towards regional sustainability through the creation of a UNESCO Global Geopark.

1.1 Objectives and motivation

This dissertation, developed in the context of the Cajón del Maipo geopark project, seeks to contribute to the geoconservation of this territory through the formulation of realistic and concrete proposals. The proposed initiatives seek on the one hand, to contribute to the declaration of a UNESCO Global Geopark in the area, but their fundamental aim is to contribute to the sustainable development of local communities and the conservation of their natural and geological heritage.

The specific objectives are:

1. To characterize the Cajón del Maipo aspiring geopark, including the main aspects related to the territory and the project.
2. To characterize the geoheritage value of the area, identifying values, threats, needs and opportunities related to geoconservation.
3. To propose concrete initiatives that contribute to sustainable local development and geoconservation.

The motivation for this thesis is based on the personal convictions of the author, who has been working since 2017 towards the creation of a UGGp in Cajón del Maipo, first as a manager and currently as a scientific coordinator. Hence, together with other people of the territory, the Foundation for the Sustainable Development of the Cajón del Maipo (FUNDESO for its acronym in Spanish) was created in 2019. All outlined initiatives presented in this dissertation are intended to be promoted by this entity during the next 2 years, with the support and participation of other relevant actors and stakeholders. It is hoped that these ideas, in addition to generating direct and indirect results and impacts, may be replicable and/or adaptable in other territories of the country, of the region, and of the world that are working on the development of aspiring geoparks.

1.2 Methods

As indicated, this dissertation aims to contribute with applicable and replicable initiatives in a real context. Therefore, the approach is more practical than theoretical in each of its aspects. A conceptual map representing the overall methodological structure is shown in figure 1. In summary, the specific objectives are derived from the main aim, and each one is addressed individually with its own methods, which are briefly described below and in more detail in the respective sections.

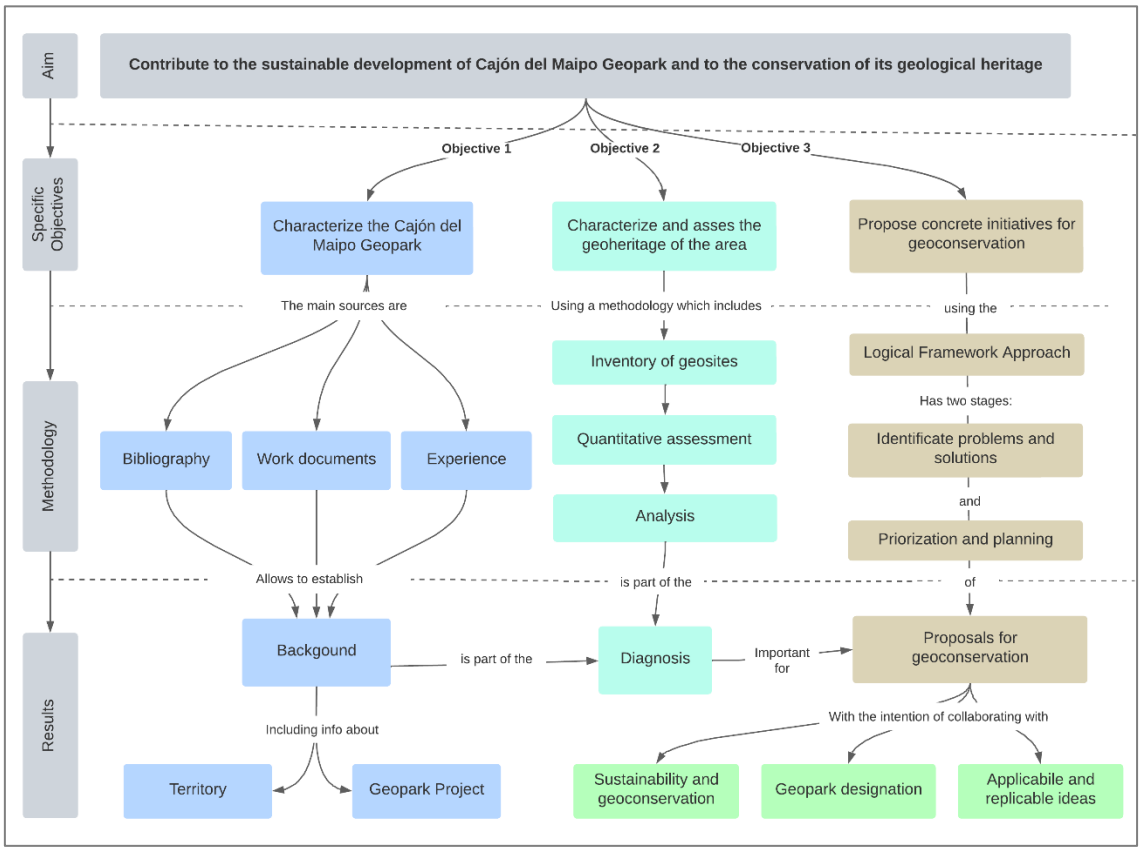

Figure 1: Conceptual map representing the methodological structure of this work. The specific objectives are derived from the aim, and each of them is addressed individually with its own methods. The results of specific objectives 1 and 2 contribute to the outcome of objective 3.

Specific objective 1 aims to synthesize existing information from three main sources:

- Bibliographic review: existing articles and publications on the area have been reviewed and compiled, including sources on its geography, geology, geomorphology, biodiversity, demography, cultural heritage, and economy.
- Technical documents: several internal working documents of the geopark management team, such as the Action Plan (2017), formulation of projects for

funding, FUNDESO reports, among others, which have not been published and present information of interest.

- Author's experience: The author, as scientific coordinator of the project, has participated in numerous meetings and activities continuously over the last 5 years related to the different aspects of the geopark, which has served to build an integral vision beyond the references previously described.

With this information, the background for the following sections was established, mainly including information on general aspects of the territory and on the history and strategy of the Cajón del Maipo geopark project.

Specific objective 2 is addressed by analysing the geoheritage inventory and geosites of the Cajón del Maipo geopark, which was developed with a methodology based on previous work and adapted to local conditions (mainly Brilha, 2016) and considering previous work on geoheritage in the area (Benado, 2013). According to Lima et al. (2010), four issues should be considered for the elaboration of a geoheritage inventory: theme, value, scale, and use. In this case, the theme is the entire geoheritage of the area, the values to be considered are scientific, touristic, and educational, the scale is the municipality of San José de Maipo (~5,000 km^2) and the use is to form the basis of a geoconservation strategy in the framework of the development of a UGGp. The methodology used for the geoheritage inventory is summarized in six main steps described in detail in section 5, which are: 0. Conceptualization, 1. Identification, 2. Selection, 3. Assessment, 4. Analysis, 5. Proposals, and 6. Updating.

Specific objective 3 is approached with the results obtained by objectives 1 and 2, considering the information on the territory, the geoheritage and the strategies governing the project (Fig. 1). The expected result of which is the presentation of a portfolio of projects that can be implemented in the defined context. The proposals, which are born from the combination of own ideas, inspiration from other projects and the needs identified for the Cajón del Maipo geopark project, must be concrete and viable ideas in the medium term. The conceptual basis for justification is the Logical Framework Approach, a tool to facilitate the process of project conceptualization,

design, implementation, and evaluation of initiatives, and is composed of two main stages (Ortegón et al., 2005):

- Identification of the problem and solution alternatives, in which the existing situation is analysed to select the strategies to be applied.
- The planning stage, in which the project idea is converted into a practical operational plan for its implementation.

The proposals should be framed within the pillars of action of the geopark, and their purpose is to contribute to sustainable local development and geoconservation. Each project is described including its objectives, a brief description, fundamental background, expected outcomes and stakeholders involved.

2. Concepts and background

2.1 Geoheritage and geoconservation

Numerous definitions of the concepts of geoheritage, geodiversity and geoconservation have been proposed in the last decades (e.g., Gray 2004; Wimbledon 2011; Brilha 2016). In this work, it has been decided not to deepen or discuss theoretical aspects of these definitions, but to use practical adaptations to the most used meanings. This decision is justified by the general aim of the work, which seeks to contribute to geoconservation in the context of the creation of a UGGp at Cajón del Maipo.

To define the conceptual framework, it has been decided to use two main references in terms of definitions and methodologies. Firstly, the guidelines established by the International Geoscience and Geoparks Programme of UNESCO (IGGP) for UGGp, understanding that geological heritage management should be developed with a holistic approach, based on protection, and education and oriented to sustainable development (UNESCO, 2016). On the other hand, it has been decided to use the IUCN's "Guidelines for geoconservation in protected and conserved areas", considering that it is an official and up-to-date document from the world's most recognized body on the state of the natural world and the measures needed to safeguard it (Crofts et al., 2020). Combining these two sources, below are the definitions adopted in this work, which will be used repeatedly in the following sections, following the IUCN's Best Practice Guideline No. 1 (Crofts et al., 2020).

- *Geodiversity* is the variety of rocks, minerals, fossils, landforms, sediments, and soils, together with the natural processes that form and alter them. It includes past and present geological and geomorphological features and processes that record the history of the Earth and the evolution of life forms as represented in the geological record.
- *Geoheritage* comprises those elements and features of the Earth’s geodiversity that are considered to have significant value for intrinsic, scientific, educational, cultural, spiritual, aesthetic, ecological, or ecosystem reasons and therefore deserve conservation. It is represented in special places (geosites) and objects (specimens in situ and museum collections).

- *Geosite* is used to refer to any site with geological or geomorphological features and processes that merit management and geoconservation efforts, together constituting the local in situ geoheritage. Its scientific, educational, and touristic values will be considered primary.
- *Geoconservation* is the practice of conserving, enhancing, and promoting awareness of geodiversity and geoheritage. The key steps in the development of a geoconservation strategy comprise site inventory, assessment, management, protection, interpretation, promotion, and monitoring.
- *Geotourism* is a type of sustainable tourism based on the geological and geomorphological features and processes of an area. It is an innovative and holistic territorial approach for sustainable economic development in which geoparks have a special and leading role.

2.2 UNESCO Global Geoparks

A UNESCO Global Geopark (UGGp) correspond to single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development. These territories use its geological heritage, in connection with all other aspects of the area's natural and cultural heritage, to enhance awareness and understanding of key issues facing society in the context of our dynamic Planet (UNESCO, 2019; Martini et al., 2021).

UNESCO Global Geoparks are established through a bottom-up process involving all relevant local and regional stakeholders and authorities in the area (e.g., majors, landowners, community groups, tourism providers, indigenous people, and local organizations). This process requires firm commitment by the local communities, a strong local multiple partnership with long-term public and political support, and the development of a comprehensive strategy that will meet the communities' goals while showcasing and protecting the area's geological heritage. Currently, UGGp focus the actions of their development strategy on the "Top 10 Focus Areas": Natural Resources, Geological Hazards, Climate Change, Education, Science, Women and gender responsibility, Sustainable Development, Local and Indigenous Knowledge, and Geoconservation (UNESCO, 2019).

The geopark concept was created in the 1990s, aiming to identify territories hosting significant geoheritage of international importance, which implement geoconservation and management of their natural and cultural resources, following a sustainable development strategy for the benefit and development of the local communities. In 2004, the Global Geoparks Network came to be under the auspices of UNESCO, to support collaboration, exchange, and sharing of good practices, through networking among these territories, and to establish new Geoparks in all continents (Martini et al., 2021 and references therein). On 17 November 2015, the 195 Member States of UNESCO ratified the creation of a new label, the UNESCO Global Geoparks, during the 38th General Conference of the Organization. This expresses governmental recognition of the importance of managing outstanding geological sites and landscapes in a holistic manner (UNESCO, 2019).

At present, there are 177 UNESCO Global Geoparks in 46 countries, in addition to dozens of projects in various stages of progress around the world. In addition, they have been organized into different regional networks, which are as of today the Asia Pacific Geoparks Network (APGN, 67 members), the European Geoparks Network (EGN, 94 members), the Latin American and Caribbean Geopark Network (GeoLAC, 10 members), and the African UNESCO Global Geoparks Network (AUGGN, 2 members) (Fig. 2).

Figure 2: Global and regional distribution of UGGp. In May 2022, there were 177 in 46 countries, organized into regional networks: the Asia Pacific Network (green), the European Network (blue), the Latin American Network (yellow), and the African Network (red). Canada's geoparks are shown in purple. Source: GGN website[2].

[2] https://www.visitgeoparks.org/geopark-visit-us

2.3 Geoheritage in UGGp

Geoparks are territories with a sustainable development strategy based on geological heritage and other natural and cultural assets. This means that geoparks play a very important role in the characterization, conservation, and interpretation of geoheritage, which are basic steps for any geoconservation strategy. A geopark must implement a series of stages that will allow it to develop an adequate geoconservation strategy, including the following elements as a basis (Brilha, 2016; 2018):

1. A general description of geodiversity with an explanation of the geological and geomorphological setting of the territory.
2. Inventory and quantitative assessment of geosites, including scientific value and degradation risk.
3. Quantitative assessment of educational and touristic potential uses of geosites.
4. An inventory of geodiversity sites.
5. Quantitative assessment of educational and touristic potential uses of geodiversity sites, together with the degradation risk evaluation.

The analysis of these results allows to define priorities for the management of the sites: which ones will be used as educational and/or touristic resources, what kind of infrastructures are needed, which trails can be implemented, etc.

It should be emphasized that for any UGGp, not only geosites with international relevance are the ones to be properly managed. All other sites are also important because they support most of the educational and touristic actions. The results of the above-mentioned tasks will also give all the necessary data required by UNESCO for new UGGp applications (UNESCO, 2017), namely general geological description; listing and description of geological sites; details about their international, national, regional, or local value; status in terms of site protection; and data on the management and maintenance of all sites (Brilha, 2018).

2.4 How to become a UGGp[3]

The UNESCO Global Geoparks Secretariat at UNESCO Headquarters coordinates the proposal submissions. Successful UGGp applications will have demonstrated that, already in the planning phase, they discussed and exchanged with UGGp as well as the Global Geoparks Network (this usually starts several years before the actual submission of a dossier).

Before any formal application, an aspiring UGGp must submit an expression of interest via the official channel as set out in the Statutes and Operational Guidelines for UNESCO Global Geoparks. A comprehensive and carefully formatted application dossier (including supporting material to demonstrate that the area has already been functioning as a *de facto* Global Geopark for at least one year) must be submitted in the same way.

The aspiring UGGp must have geological heritage of international value and to be managed by a body having legal existence recognized under national legislation that has a comprehensive management plan, covering governance, development, communication, protection, infrastructure, finance, and partnership issues.

The timelines for UGGp proposals and evaluation procedure are:

- Aspiring UGGp sends a letter of intent, by 1 July (year 1)
- Submission of applications between 1 October and 30 November
- Verification checks on completeness of documents after 1 December
- Desktop evaluations until 30 April (year 2)
- Field evaluation missions starting 1 May
- Recommendations on applications by the UNESCO Global Geoparks Council in September
- Decision by the Executive Board of UNESCO during its spring session (year 3)

[3] The information in this section is based on official UNESCO and IGGP documents (https://en.unesco.org/global-geoparks/)

2.5 Application dossier for UNESCO Global Geoparks

The application dossier required by UNESCO for the evaluation of aspiring geoparks includes five main sections (A to E), which are:

A. General information
B. Documents checklist
C. Location of the area
D. Main geological highlight and other elements
E. Verification of UGGp criteria

Section E is the most relevant, as it includes information on all aspects that must be fulfilled according to the Operational Guidelines for UGGp designation, including information on the territory and its delimitation, the geological heritage and its state of conservation, the management structure, and the development of activities, among other relevant aspects.

Additionally, mandatory annexes are required, including:

- Annex 1: Self-evaluation document.
- Annex 2: An additional copy of the section about geoheritage and geoconservation.
- Annex 3: An explicit endorsement of any relevant local and regional authorities and a letter of support from the National Commission for UNESCO
- Annex 4: A large scale map of the aUGGp showing a clearly defined boundary of the aUGGp and marking all the geosites and other relevant attributes.
- Annex 5: One-page geological and geographic summary.
- Annex 6: Complete bibliography of the area in Earth Sciences highlighting international publications.

Annex 2 is particularly interesting as it allows a quantitative estimation of the level of progress of a geopark nomination with respect to the situation of an "ideal geopark" in which all its requirements are fulfilled. The document consists of a self-assessment matrix that seeks to quantify the level of compliance with the specific requirements for the declaration of a geopark in the various relevant areas of action.

The matrix is divided into various criteria, which in turn are divided into items, where the final score is evaluated from 0 (minimum) to 1000 (maximum) (Table 1). When analysing the relative importance of the scores, the most relevant criterion in the evaluation is Geology and Landscapes, which reaches 35%. However, when broken down into its three items (Geoconservation, Territory, Natural and Cultural Heritage), the most important criterion is the Management Structure.

Table 1: Criteria and weightings applied in the quantitative evaluation of the candidacy of an UGGp according to the self-assessment matrix in Annex 2 of the application to UNESCO.

N°	Category	Ponderation (%)
I	Geology and Landscape	35
1.1	Territory	(5)
1.2	Geoconservation	(20)
1.3	Natural and Cultural Heritage	(10)
II	Management Structure	25
III	Interpretation and Environmental Education	15
IV	Geotourism	15
V	Sustainable Regional Economic Development	10

According to Canesin et al. (2020), who examined the geoconservation and management of two Spanish UGGp, there are six crucial components for the success of any geopark:

- First, is the establishment of a database with all actions and activities organized in the geopark, by management and partners.
- Second, the presence of geoconservation experts within the geopark's staff helps to raise the profile of geoheritage and to better inform other staff.
- Third, the creation and implementation of a geoconservation action plan provides a new base for management planning and action.
- Fourth, the existence of a multidisciplinary staff team creates a new dynamic.
- Fifth, management and strategic plans covering key activities of geoparks – education, tourism, sustainable development, etc. – are completed.
- Sixth, the promotion of participative management with stakeholders and the local population provides a tool for the development of the whole territory.

In 2019, a new tool was launched to guide the development of geopark applications: the Self-Assessment Checklist. It contains 101 questions in a quick self-assessment checklist format based on the quality criteria for UGGp aspirants set by the IGGP.

According to a recent survey answered by aspiring geoparks and UGGPs in South America, the most difficult areas to implement in geoparks in the region are governance (57%), infrastructure (21%) and geoconservation (14%)[4].

[4] Proyectos de Geoparques del Cono Sur, ¿cuáles son las ventajas y desafíos? (2022). https://es.unesco.org/news/proyectos-geoparques-del-cono-cuales-son-ventajas-y-desafios

3. Characterization of the territory

3.1 Regional setting

The Cajón del Maipo Aspiring Geopark is part of the Andes Cordillera, a mountain belt that stands as one of the highest topographic regions on Earth, being the only present-day active example of a subduction type orogen (Riesner et al. 2018). This outstanding chain is represented up to now by three Andean territories in the UNESCO Global Geoparks Network: Imbabura in Ecuador, Colca y Volcanes de Andagua in Peru, and Kütralkura in Chile (UNESCO 2019; Fig. 3A).

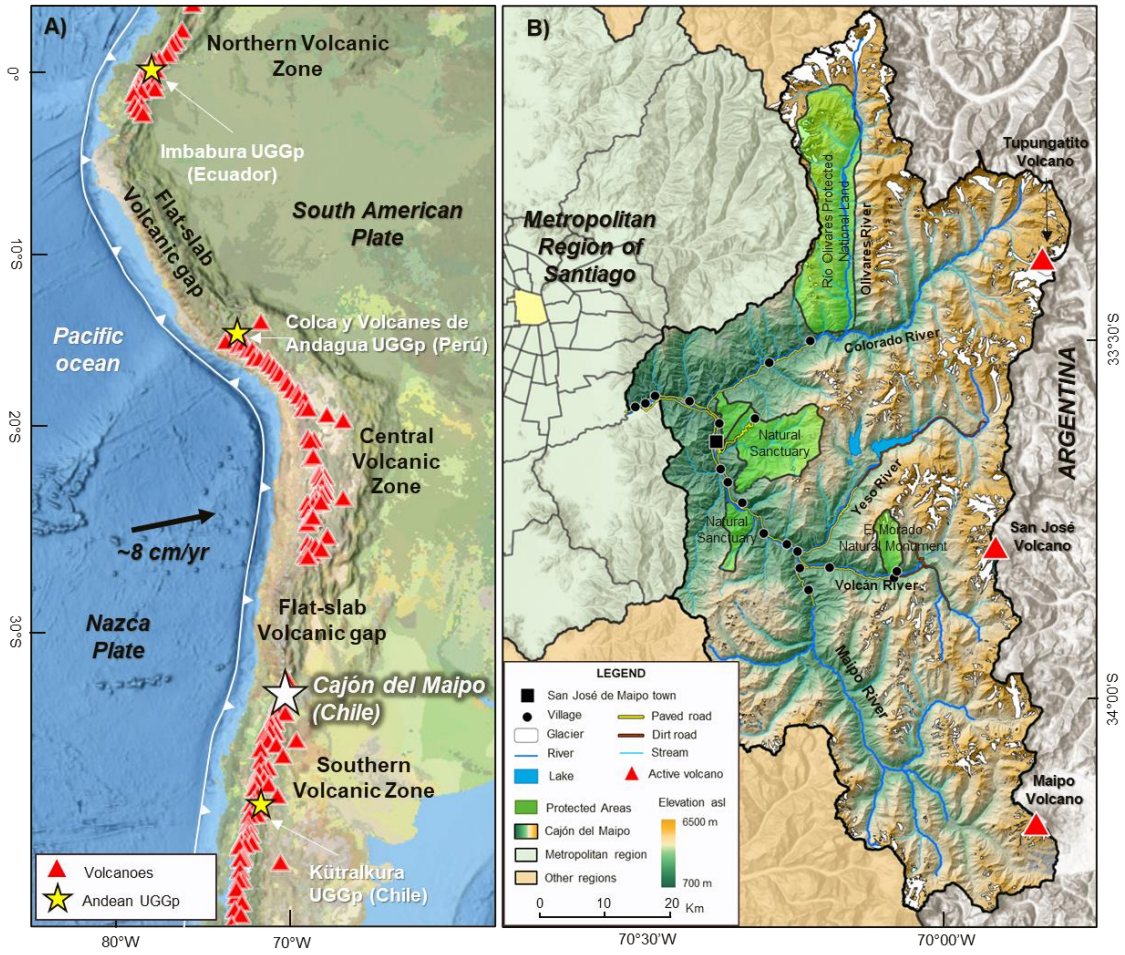

Figure 3: (A) Tectonic framework of the Andean margin. The white star indicates the location of Cajón del Maipo. (B) Geographic map of Cajón del Maipo.

More specifically, Cajón del Maipo is part of the Principal Cordillera in the Central Andes and is part of the Southern Volcanic Zone (Fig. 3A). This section of the mountain range is the result of tectonic shortening and magmatic activity due to almost uninterrupted subduction since Jurassic times of the oceanic Nazca Plate beneath the

South American continent (Charrier et al. 2015; Farías et al. 2008), with a current convergence rate of ~8 cm/year (Farías et al. 2010). Although the continuous subduction could suggest a continuous compressive regime along the active continental margin, the observed tectonic styles indicate that the stress regime underwent major changes during Andean evolution, alternating contractional and extensional episodes (Charrier et al., 2002).

This zone is in the transition where the Nazca plate changes from the flat-slab subduction (<10°E dip) in the north of ~33°S to the normal slab subduction in the south of that latitude (~30°E dip) (Nacif et al. 2015). This change in the subduction geometry would explain the presence of active volcanism to the south of 33°S and its absence to the north, where volcanism has ceased at ~10 Ma (Fig. 3A). Consequently, this is the northern section of the Southern Volcanic Zone (SVZ) of the active Andean Volcanic Belt, including the three highest volcanic complexes of the SVZ: Tupungato-Tupungatito (6570 m a.s.l.), San José-Marmolejo (6108 m a.s.l.) and Maipo-Diamante (5264 m a.s.l.) from north to south, all partially covered by glaciers (Stern 2004; Fig. 3B; Fig. 4).

Figure 4: The three active volcanoes of Cajón del Maipo, all over 5000 m above sea level, ordered from north to south. a) Tupungatito Volcano, with its hyperacid lake in one of its craters b) San José Volcano and c) Maipo Volcano, which is nested in the Diamante caldera. Location in Fig 3B.

3.2 Physical geography

Cajón del Maipo is the colloquial name of San José de Maipo municipality, which is part of the Metropolitan Region of Santiago, in central Chile (Fig. 3B). Its administrative centre, San José de Maipo town, is located 48 km from Santiago, the main economic and political centre at the national level. This municipality covers 4995 km^2 and has a population of 18,189, with a very low population density of 3.7 inhabitants/km^2 (Ministerio de Economía, 2017).

The geographical characteristics of Cajón del Maipo are determined by its location in the Principal Cordillera, a zone characterized by its active seismicity, volcanism, and a sharp gradient of altitudes, varying from 750 m a.s.l. to more than 6500 m a.s.l. The territory includes the upper part of the Maipo river basin and its main tributaries (Olivares, Colorado, Yeso, and Volcán rivers). Some of the main peaks that stand out in these valleys are Tupungato (6570 m a.s.l), Alto San Juan (6148 m a.s.l.), and Marmolejo (6108 m a.s.l.), the southernmost point on Earth to exceed 6000 m of altitude. In addition, more than 100 mountains over 4000 m a.s.l. have been documented within this municipality (Sociedad Geográfica de Documentación Andina, 2022).

The headwaters of the Maipo basin host 832 individual glaciers, which together cover about 378 km^2 (approximately 7.6% of the communal surface), including a wide variety of glacier types, deposits, and landforms (Barcaza et al., 2017; Ormeño 2007). The glaciers, together with the rivers, lakes, and wetlands are the primary source of water for drinking, agriculture, hydroelectricity, and industry in the Metropolitan region of Santiago, which concentrates about 40 % of the country's population (Ayala et al. 2020).

Since 2010, this region has experienced a persistent drought, observed by an increase of up to ~0.8 °C in mean annual air temperature and a reduction of up to 40% in annual precipitation (Fuentealba et al., 2021; Shaw et al., 2021). Recent studies show that glaciers are dramatically retreating (Farías-Barahona et al., 2019, 2020a), lake volumes are decreasing (Fuentealba et al., 2021), and river streams are descending (Vergara et al., 2022). These negative trends are driven by climate change but are accelerated by anthropogenic activities (e.g., over-extraction, mining, and city pollution)

and have serious implications for the region's water security (Shaw et al., 2021; Farías-Barahona et al., 2020b).

Despite the great value and vulnerability of the local natural heritage, only 4% of the total surface is designed under a category of protection, including El Morado Natural Monument, two Natural Sanctuaries, and the Río Olivares Protected National Land (Fig. 3B). This situation will improve considerably (up to 19% of the land protected) with the recent announcement of the creation of the Glaciares de Santiago National Park, which will protect a surface of 751 km^2 in the headwaters of the Olivares and Colorado river basins (CONAF 2022). However, there are criticisms from local communities and environmental groups, and they propose that this park should cover a larger area[5].

All these geographic characteristics have been the basis for accelerated tourism growth in recent decades, resulting in the consolidation of a wide range of tourism products and services that include lodging, food, commerce, handicrafts, and operators, making tourism one of the main sources of income for the local community. One of the greatest comparative advantages as a destination is its strategic location, near Santiago, its international airport, and its growing population.

3.3 Geology and geomorphology

All the geological record in Cajón del Maipo is part of the Andean Tectonic Cycle, determined by the beginning of the subduction-related volcanism in the late Early Jurassic after the Pangaea breakup, magmatism that has been active almost uninterruptedly right through to the present day (Charrier et al., 2007, 2015). In general terms, the main geological units can be grouped into two sectors, the Eastern and the Western Principal Cordillera (Fig. 3; Muñoz et al., 2013).

The Eastern Principal Cordillera (EPC) presents a series of mostly sedimentary Mesozoic highly deformed rocks composing the east-vergent, thin-skinned Aconcagua fold-and-thrust belt at the Chilean-Argentinean border. This is represented locally by Río Colina, Río Damas, Lo Valdés, and Colimapu Formations, which are overlain in angular

[5] Diario La Segunda: El Primer Parque Nacional de Santiago enfrenta a ambientalistas con el Gobierno. https://queremosparque.cl/prensa/

unconformity by Pliocene-Quaternary volcanism of the current volcanic arc (Thiele 1980; Charrier et al., 2002; Figs. 5 and 6).

The Western Principal Cordillera (WPC) is an Oligocene–Miocene series composed of ~5000m-thick dominantly volcanic and minor sedimentary rocks of continental origin intruded by Miocene plutons. The main units are Abanico and Farellones Formations, which together make up the pre-Pliocene Cenozoic deposits in the Principal Cordillera of Central Chile (Thiele 1980; Charrier et al., 2002; Figs. 5 and 6).

Figure 5: Geosites representing the main geological domains of Cajón del Maipo. (a) Folded Mesozoic units near Nieves Negras glacier. (b) Vertical strata of Río Damas Formation in Punta Zanzi geosite. (c) Dramatic landscape related with the vertical marine strata of Lo Valdés geosite. (d) Tilted and folded volcanic and sedimentary Cenozoic successions in Maipo Anticlinal geosite. (e) Outcrop of Cenozoic strata intruded by dykes in Likán Mountain geosite.

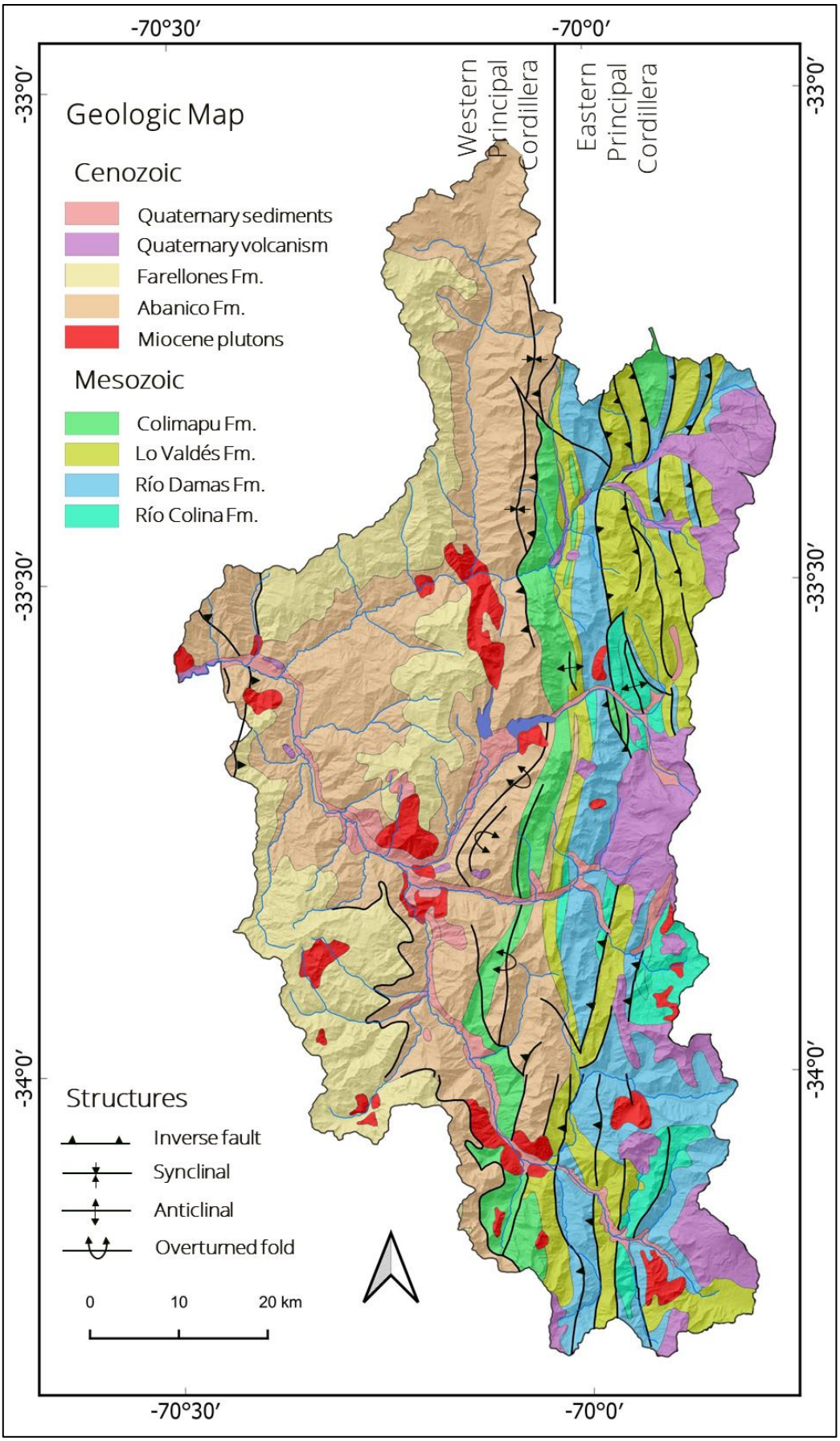

Figure 6: Geological map of Cajón del Maipo. Based on SERNAGEOMIN (2003).

All over the geopark, the main structures have an N-S direction and correspond to asymmetric folds and reverse faults with eastward and westward vergence (Thiele 1980; Charrier et al., 2002; Fig. 6), including potentially active faults. Furthermore, the Central Andes in general is a tectonically active region, with abundant shallow and deep seismic activity (Alvarado et al., 2009).

The Quaternary deposits and landforms are diverse and widely distributed in the area and can be divided into two main geomorphological domains: the *High Cordillera Domain* (HCD) and the *Low Cordillera Domain* (LCD). In the HCD, glacial, colluvial, and mega-landslides deposits predominate, with a steep gradient and U-shaped valleys (Fig 7a, b). The LCD is characterized by lower gradients and V-shaped valleys, where the erosion is mostly related to the fluvial incision. The dominant deposits are aggradational fluvial terraces, alluvial fans, debris flows, and landslides (Ormeño, 2007; Fig 7b). The vast majority of villages and settlements are located in the LCD area, occupying the lower reaches of the river valleys, although there are also smaller settlements in the high cordillera.

Figure 7: Representative images of the local geomorphology. (a) El Morado Natural Monument, characteristic of the HCD and its glacial morphologies, as a horn and a moraine. (b) La Engorda Complex geosite, showing the steep relief and a planar landslide slip. (c) A representation of the LCD, with the V-shaped valley and the settlements in the aggradational fluvial terraces. Photos: FUNDESO

3.4 Geological evolution

The Andean tectonic cycle began in the Early Jurassic with the activation of the subduction in the western margin of Gondwana. The general configuration of the Chilean continental margin in this period is characterized by the presence of a volcanic arc in the coastal area, and a wide extensional back-arc basin called Neuquén, in a dominating extensional tectonic regime. The Mesozoic units of the Eastern Principal Cordillera in the geopark were deposited into the northern sector of this backarc basin, recording two marine transgression–regression cycles (Charrier et al. 2015; Muñoz, 2011).

The first transgression is represented by the marine deposits of the Rio Colina Formation (Callovian-Oxfordian). That unit is overlain by subaerial deposits of the Río Damas Formation (Kimmeridgian), marking the end of the first transgression–regression cycle. The Río Damas Formation is conformably overlain by marine fossiliferous sediments that form the second transgression-regression cycle, which is represented by the Lo Valdés Formation (Tithonian-Hauterivian). Over that sequence is the reddish detrital Colimapu Formation (Aptian–Albian), which corresponds to the continental deposits that followed the regression (Thiele 1980; Charrier et al., 2015). At the end of the first Andean stage, a major plate reorganization was associated with an increase in the generation of oceanic crust in the proto-Pacific. This is called the Peruvian orogeny, which caused uplift of the continental margin, the marine regression in the backarc basin, and compressive deformation of the existing units (Charrier et al., 2007, 2015).

The second stage of the Tectonic Andean Cycle in Cajón del Maipo is represented by the Abanico Formation (middle-late Eocene to Oligocene), and the Farellones Formation (Miocene), which dominate the Western Principal Cordillera. The Abanico Formation consists of a succession of volcanic, volcaniclastic, and sedimentary rocks deposited in an extensional intraarc basin bounded by normal faults. The Abanico basin underwent a tectonic inversion in late Oligocene to early Miocene time (21 to 16 Ma), a contractional event that is considered the starting point of the modern Andean orogeny. This process led to the formation of a new basin that was filled by the younger volcanic Farellones Formation (Charrier et al., 2002, 2015).

The posterior uplift and exhumation events of the Andean orogen are the result of progressive cortical thickening, attributed to cortical shortening processes (Farías et al., 2010; Muñoz, 2011). Currently, the western basin-bounding fault system of the Abanico basin is still active (San Ramón fault), which is critical for the seismic hazard in the city of Santiago, and other faults inside the geopark are potentially seismogenic (Farías et al., 2008; Alvarado et al., 2009).

Coeval to the beginning of contractive tectonics in the early Miocene, many granitic intrusions were emplaced in the westernmost Principal Cordillera, next to the main faults that controlled the development of the pre-existing basins (Charrier et al., 2007; Mardones et al., 2021). The modern volcanoes in this area, located in the Chile-Argentina drainage divide, represent the Holocene configuration of the continued Cenozoic arc, a magmatic activity that has progressively migrated ∼80 km eastwards since the Oligocene (Muñoz-Gómez et al., 2020; Stern, 2004).

3.5 Geodiversity

The description of geodiversity in Cajón del Maipo, including the variety of rocks, minerals, fossils, landforms, and deposits, together with the natural processes that form and alter them, was done by Benado (2013) having defined a set of 10 local geodiversity thematic areas, which are briefly described below, after adaptations and updates:

- Mesozoic sedimentary record: Includes the four Mesozoic geological formations of mostly sedimentary origin which together reflect the Neuquén backarc basin development. The most common rocks are sandstones, limestones, shales, calcilutites, conglomerates, travertines, gypsum, and andesitic intercalations (Thiele, 1980; Charrier et al., 2015).
- Cenozoic volcanic record: Represents the extensive volcanism record of the Cenozoic and its progressive migration. There are at least 11 volcanoes of the Pleistocene-Holocene, of which three are active. There are stratovolcanoes, lava flows, tuffs, ignimbrites, ash deposits, domes, fumaroles, and the Diamante caldera (Stern, 2004; Muñoz-Gómez et al., 2020; Fig 8c).
- Plutonic record: There are more than 15 important intrusive bodies, including granodiorite and monzonite plutons, as well as other minor units, like stocks, dykes, and sills. The ages of the magmatism decrease eastwards, varying from

19-20 Ma in the west to 10-13 Ma in the central area, to ~1 Ma closer to the current arc in the east (Thiele, 1980; Muñoz, 2011; Fig 8a).

- Andean tectonics: There is a wide range of structures related to the Andean orogeny. In the Western Principal Cordillera, the deformation is characteristic of a thin-skinned fold-and-thrust belt, and the Eastern Principal Cordillera includes asymmetric folds and west verging faults, some showing recent activity (Mardones et al., 2021; Alvarado et al., 2009).

Figure 8: Geosites of the geopark that represents some local geodiversity thematic areas. (a) Los Lunes Pluton, part of the plutonic record area. (b) El Morado hanging glacier, part of the glaciers and glacial landforms area. (c) Casimiro volcano columnar basalts, part of the Cenozoic volcanic record. Photos: FUNDESO.

- Glaciers and glacial landforms: These are the dominant features in the High Cordillera Domain, including more than 800 glaciers (mountain, valley, and rocky glaciers) and a record of the last glacial-interglacial cycle of the Andes. Some elements of interest are horns, moraines, striations, and cirques (Herrera, 2016; Barcaza et al., 2017; Fig. 8b).
- Mass wasting movements: The area favours mass wasting movements, for a combination of factors such as steep relief, intense deformation, seismicity, volcanism, and variable climatic conditions. The most characteristic processes are debris flows, landslides, and block falls (Deckart et al., 2014; Moreiras & Sepúlveda, 2015; Fig. 9a).
- Fluvial-alluvial deposits and landforms: These are the features dominant in the Lower Cordillera Domain, related to the action of the Maipo River and its tributaries, in a drainage network fed by a pluvial, nival, and glacial mixed regime. Some elements of interest are waterfalls, aggradational fluvial terraces, and alluvial fans (Ormeño, 2007; Fig. 9b).
- Geothermal springs: There are seven thermal springs documented, most of which are of the sodium chloride type. These springs are related to regional fault systems and would be connected at depth through structures and fractures, showing temperatures from 17 to more than 50°C. Some of them show travertine deposits (Benado, 2013; Pincetti, 2016; Fig 9c).
- Paleontological record: There are marine fossils in the Río Colina and Lo Valdés Fm, vertebrate ichnites in Río Damas Fm, charophytes in the Colimapu Fm, and continental fossils in the Abanico Fm. The most studied remains are the ammonites of Lo Valdés, which record the Jurassic/Cretaceous boundary (Charrier et al., 2015; Salazar et al., 2020).
- Ore deposits and geomining heritage: There are several metallic (copper and silver) and non-metallic (limestone and gypsum) deposits, whose exploitation was important for the development of the country in the 19th and 20th centuries. These sites combine geoheritage with industrial heritage, having a relevant potential for geotourism and education (Benado, 2013; Bunster, 2017; Sánchez et al., 2018).

Figure 9: Geosites of the geopark that represents some local geodiversity thematic areas. (a) Las Amarillas, part of the mass wasting movements area. (b) El Cristo bridge, part of the Fluvial-alluvial deposits and landforms. (c) El Plomo springs, part of Geothermal springs area. Photos: FUNDESO.

3.6 Biodiversity

The flora of the study area is composed by 443 species of vascular plants, with 71% native species, 17% endemic species, and the remaining percentage of feral exotic species. Comparison with other Mediterranean areas of Chile indicates a high richness of native species. There are also sectors of vegas, which are a type of Andean wetland characterized by the presence of water during most of the year, where about 85 species of native vascular plants grow (Santiago Andino Action Plan, 2011).

Related to the altitudinal variations, there are important changes in climate and soil conditions, which determines the existence of different plant communities or vegetation floors. Although there is some heterogeneity within each vegetation floor, it is possible to establish a general classification of its dominant species. According to the

Santiago Andino Action Plan (2011), is possible to find five vegetation floors: the Sclerophyllous Forest floor (750 to 1700 m asl), the Andean Sclerophyllous Forest floor (1650 to 2000 m asl), the Lower Andean floor (1950 to 2800 m asl), the Upper Andean floor (2500 to 3250 m asl), and the High Andean floor (over 3250 m asl) (Fig. 10).

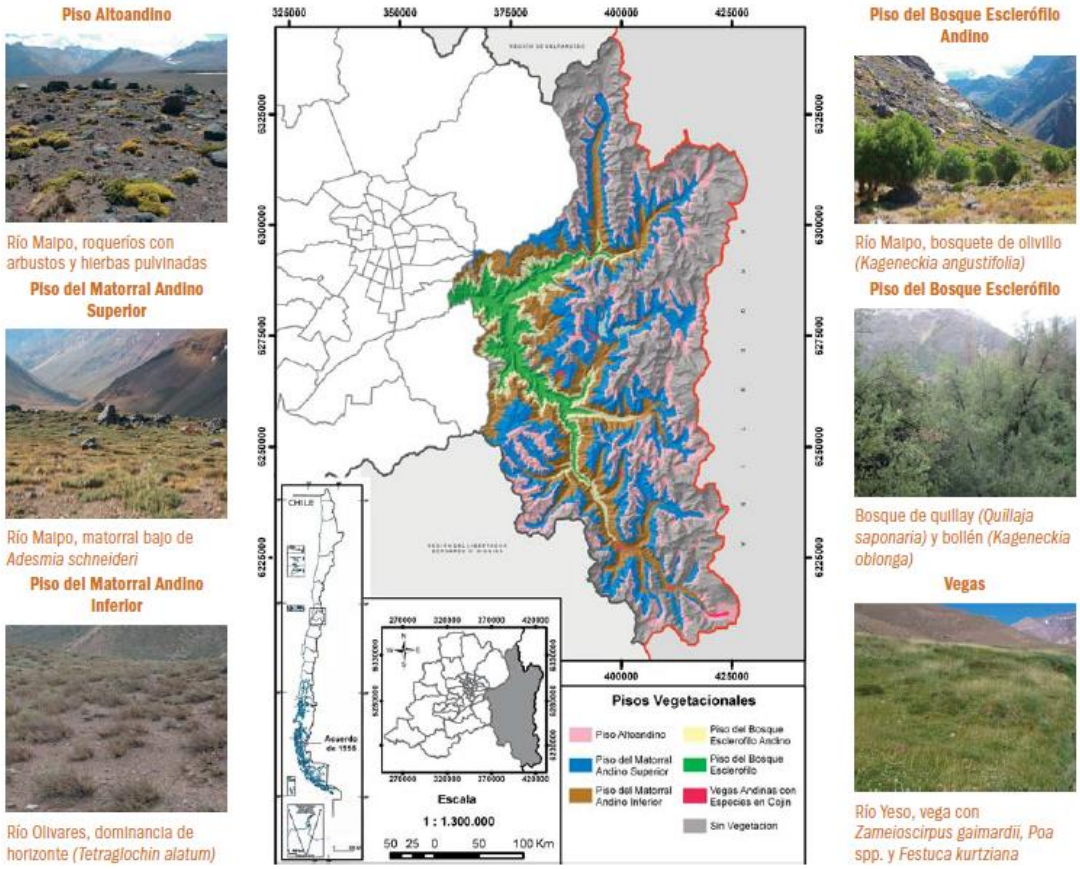

Figure 10: Vegetation floors and dominant species of the San José de Maipo Commune, Santiago Metropolitan Region (Santiago Andino Action Plan, 2011).

The most characteristic ecosystem is the sclerophyllous forest, which is a scarce type of forest of Mediterranean climates. Is characterized by very dry summers and long periods of drought; by having hard, evergreen leaves; and by having a high level of endemism, with many species found only in Chile, such as the quillay (*Quillaja saponaria*) and the litre (*Lithraea caustica*). The sclerophyllous forest is an important part of the biodiversity *hotspot* of Chile, which indicates an international conservation priority given its high levels of endemism and strong anthropogenic impact on its original habitats (Arroyo et. al., 2006, in CONAMA, 2008). Within the study area, this forest is concentrated in the lower altitude zones, covering about 500 km^2 of surface and

coinciding with the sectors with the highest population (Santiago Andino Action Plan, 2011).

About the fauna, at least 140 species of non-aquatic vertebrates have been identified in the study area, including endemic, native, and exotic species. Of these, the richest group corresponds to birds with 58% of the species, followed by mammals with 25%. Of the total number of species identified, almost 20% are endemic to the country, and some are locally endemic, such as the El Morado brown lizard *(Liolaemus moradoensis)*, the Lo Valdés lizard *(Liolaemus valdesianus)*, and El Volcán grunt (*Pristidactylus volcanensis*). In terms of conservation categories, 55 species have been catalogued in the area, 48 of which belong to the categories of threatened and/or rare, and 7 to endangered (Santiago Andino Action Plan, 2011).

3.7 Demography

The commune of San José de Maipo is a territory of semi-rural characteristics that is part of the Cordillera province, located in the southeastern sector of the Metropolitan Region. This municipality covers 4995 km^2, representing 90.7% of the provincial extension and 32.4% of the regional extension, being by far the commune with the largest surface in the Metropolitan Region of Santiago. According to information presented by the National Institute of Statistics[6] (2021), in 2017 the communal population was 18,189 inhabitants, with a projection to 2021 of 18,917 people.

The urban population is predominant with 61.6%, exceeding the 38.4% rural population. These data could indicate that this is an urban commune, but in practice they are explained by the location pattern of its inhabitants, which is based on the development of small urban settlements that are separated from each other by large tracts of rural land (Estay, 2022). The system of population centres of the commune is composed of 17 localities, of which 13 have an urban extension limit defined by the Santiago Metropolitan Regulatory Plan[7] (PRMS). Although these localities concentrate most of the population, at the same time they cover a reduced area of about 12.4 km^2, equivalent to 0.25% of the communal extension (Estay 2022 and references therein).

[6] https://www.bcn.cl/siit/reportescomunales/comunas_v.html?anno=2021&idcom=13203
[7] https://ide.minvu.cl/maps/600b759060a0488c87719dcd9047feb4

According to information provided by the Socioeconomic Characterization Survey (CASEN) 2017 and the Social Registry of Households (RSH); the commune of San José de Maipo has an income poverty rate of 6%, being higher than 5.4% of the Metropolitan Region and lower than 8.6% nationwide. However, the multidimensional poverty rate reaches 24%, which is above the regional 20% and national 20.7% rates. Finally, 43.7% of its population lives in households lacking basic services, far exceeding the regional 8.1% and national 13.8%. In relation to economic activities, in the commune of San José de Maipo there are productive sectors associated with the natural resources, the most common being tourism, mining, hydroelectric generation and livestock (Estay, 2022 and references therein).

3.8 Cultural heritage

The tangible cultural heritage of Cajón del Maipo includes sites and elements that show how determinant the geographic and geological environment has been historically in the development of the identity, culture, and economy of this commune.

In the case of archaeological heritage, excavations and studies have been carried out at sites of indigenous cultures that inhabited this territory prior to the Spanish Conquest. These investigations indicate the presence of groups and human settlements in which the “Alfarero Temprano” (200 BC to 1000 AD), “Alfarero Intermedio Tardío” (1000 to 1400 AD) and “Peíodo Inka” (1400 to 1550 AD) predominate. The most characteristic cultures associated with these periods are the Aconcagua culture (Fig. 11a), a group that was characterized by the development of agriculture, and by the most important pre-Hispanic civilization in South America, the Inka Empire, which in this area has left as evidence some high-altitude sanctuaries, roads, and simple constructions (e.g., Cornejo and Sanhueza, 2011).

The architectural heritage of Cajón del Maipo is associated with the last decades of the Spanish Colony and the first decades of the Republic period (17th and 19th centuries). The arrival of the Spaniards caused profound changes in the indigenous population of Chile and Cajón del Maipo, which in time caused the indigenous population of the area to decrease abruptly and lose the leading role in the cultural development of the area. The main motivation for the Spanish occupation of the area

was the search for mineral wealth. At the end of the 17th century, the search for silver mines in the Cordillera de Santiago was strongly promoted, one of the best known being the San Pedro Nolasco mine, discovered in 1692. The exploitation of this and other mines led to the founding of the Villa de San José de Maipo in 1792 (Cabeza et al., 2011).

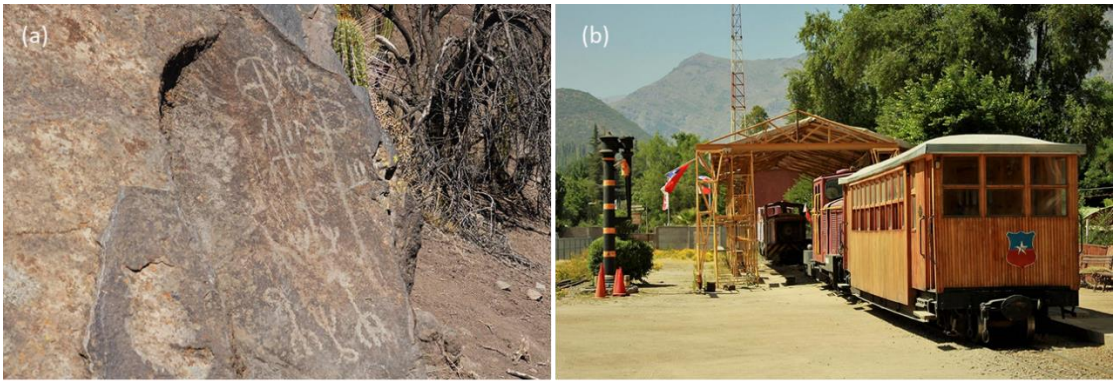

Figure 11: Cultural sites of Cajón del Maipo. (a) Archeological site related to the Aconcagua culture. (b) Old railway, used in the XX century for mining exploitation. Photos: FUNDESO

The industrial heritage of Cajón del Maipo comes from the development of the mining and hydroelectric industries (late 19th century and first half of the 20th century). In the beginning it was the silver mines that drove mining activity, but since the second half of the 19th century it has been the copper and gypsum mines that have allowed for mining development at an industrial level. Mining reached its peak between 1914 and 1958, to which the construction of an extensive railroad to transport mining production to the city of Santiago contributed significantly (Fig. 11b). At that time, the mining camp in the town of El Volcán had a population of more than 1000 people. Unfortunately, in 1958 there was a cortical earthquake that caused severe damage to the industrial facilities in the area and meant its decline in the following years (Alvarado et al., 2009). This is a very good example of the close relationship that can exist between the development of societies and the geological environment in which they are located (Benado, 2013).

Regarding protection, in the Cajón del Maipo aspirant geopark there are eight declarations of National Monument, seven of which correspond to the category of "Historic Monument" and one to "Typical Zone", all related with historic buildings and the railway. These declarations include more than 20 sites that are under the control

and oversight of the National Monuments Council, which means that all work associated with them will be subject to its prior review and authorization.

3.9 Touristic activity

In recent decades, Cajón del Maipo has shown a sustained increase in the number of visitors and tourists, both national and foreign. This has been accompanied by a growth in the supply of touristic services, including lodging, restaurants, tour operators, and tourism guides. Regarding the tourist offer of Cajón del Maipo, it has focused on adventure and nature tourism, being common recreational and sports practices of snow, mountaineering, climbing, rafting, cycling, camping, thermal baths, horseback riding, trekking, and hiking.

The Registered Tourist Services in the commune of San José de Maipo in May 2022 were 255, including 81 lodging services, 42 restaurants, 28 guides, 18 local tour operators, 61 adventure tourism services, and other services such as handicrafts, transport, and recreation (National Registry of Tourist Service Providers[8]).

The increasing trend in visitors and services has made tourism one of the main sources of income for the local community and for numerous tour operators in the Metropolitan Region, and it is currently classified as a "Consolidated Destination" and declared a “Zone of Tourist Interest” (ZOIT) in 2001 by the National Tourism Service[9] (SERNATUR).

The exponential growth of the destination in a context lacking planning and management tools has caused tourism activity to develop spontaneously, unregulated and with low added value, wasting and putting at risk the competitive advantages of the territory, a problem that will increase over time if the necessary measures are not taken. This leads to a series of negative externalities for the local community and its visitors. Two of the main ones are the vulnerability and risk of degradation of heritage sites and tourist attractions, and the risk for tourists associated with natural hazards.

The morphological characteristics of the terrain, coupled with the effects of climate change, are a constant source of potential disaster risk. Particularly dangerous are mass

[8] National Registry of Tourist Service Providers: https://registro.sernatur.cl/
[9] http://www.subturismo.gob.cl/zoit/zoit-declaradas-2/

landslide events, including debris flow, rockfalls and landslides. The lack of planning and management of the sites, added to the precarious training of tour operators and the community in general, has generated a score of tragedies in the last 50 years (JICA), some of which have strongly affected the development of tourism activity. Some recent examples: El Melocotón Flood (2016, 4 dead), San José Flood (2017, 7 tourists dead), Rock fall in Embalse El Yeso (2020, 2 with fatal consequences for tourists) and San Alfonso Flood (2021, more than 150 victims).

4. Geoheritage of the area

4.1 A school of geology

Cajón del Maipo is considered a school of geology in Chile, where dozens of undergraduate, master, and doctoral theses have been completed, and it is a classic place for field trips for university classes, congresses, and scientific symposiums on various topics of Earth sciences. Numerous papers have been published in national and international peer-reviewed journals in a variety of disciplines, such as volcanology, petrology, geothermal exploration, seismology, structural geology, tectonics, hydrogeology, palaeontology, sedimentology, stratigraphy, geomorphology, glaciology, geohazards, economic geology, and recently, geoheritage.

Some of the oldest geological observations about the study area come from Charles Darwin, who visited the area in 1835 and described with interest the fluvial terraces of the Maipo river ("*no one fact in the geology of South America, interested me more than these terraces of rudely-stratified shingle*"; Darwin 1845, p.313), the presence of marine fossils in Mesozoic units ("*shells which were once crawling on the bottom of the sea, now standing nearly 14,000 feet above its level*" (Darwin 1845, p. 320)), and other pioneering observations on the origin of the mountain range and its evolution (Giambiagi et al., 2009).

Other early observations are those of the British traveller Francis Bond Head in 1823 (visit to the San Pedro Nolasco silver mine); of the notable Polish mining engineer Ignacio Domeyko in 1841 (description of the copper mines of El Volcán); of the German geologist and explorer Paul Güssfeldt in 1883 (first ascension to Maipo volcano); and those of the politician Benjamín Vicuña Mackenna in 1873 (study of the freshwater reserves in Laguna Negra) (Cabeza et al., 2011).

Subsequently, its geology has been studied intensively in the last 60 years from a variety of perspectives, particularly since 1957 with the foundation of the School of Geology at the University of Chile and the creation of the Institute of Geological Research, the precursor of the current National Geology and Mining Service (Benado et al., 2013).

4.2 Previous work on geoheritage

The first important and systematic work addressing the study of the local geoheritage was the master dissertation of Benado (2013), which was intended to be the first stage for the future creation of a geopark. It finished with an inventory of 38 sites with scientific value divided into 10 geological thematic areas representing the local geodiversity. Five of those sites were after included in the inventory of geosites of national interest by the Geological Society of Chile (Benado *et al.* 2013, 2019).

A second stage of the study of the geoheritage of Cajón del Maipo is the research led by FUNDESO and which has been submitted to be included in the Special Publication of the Geological Society of London called "Visages of Geodiversity and Geoheritage", to be published during 2022. That work is summarized in this section and allowed the inclusion of 40 geosites in the National Inventory of Geosites of the Geological Service of Chile (SERNAGEOMIN).

Other noteworthy efforts are those developed by the University of Santiago de Chile, which laid the groundwork for the creation of an inventory of the geomining heritage of Cajón del Maipo under the philosophy of the geopark project (Bunster 2017; Sánchez et al. 2018).

4.3 Inventory of geosites

The methodology used to prepare the Cajón del Maipo geoheritage inventory was mainly based on the proposals of Brilha (2016) and Reynard (2016). The workflow is summarized in seven main steps that are described below and shown in figure 12.

Step 0 - Conceptualization: The first task to address when elaborating a geosite inventory is to define a clear objective to guarantee that the geosite selection occurs under rigorous and consistent criteria. To define the objective, four issues must be considered: the topic, the value, the scale, and the use (Lima et al., 2010). In the case of Cajón del Maipo geosite inventory, the topic is the whole geoheritage of the area, the values to be considered are the scientific, touristic, and educative, the scale is the San José de Maipo municipality (~5000 km^2), and the use is to constitute the basis for a geoconservation strategy in the framework of the development of a UGGp.

Step 1 - Identification: Once the objective was defined, an exhaustive compilation and analysis of bibliographic material associated with the geology of the study area (Brilha 2016) was performed, including papers from national and international journals, undergraduate and postgraduate thesis, technical reports, and geological maps, highlighting the work carried out by Benado (2013). Then, experts on the local geology were contacted to inquire about their knowledge of geological sites of interest in the territory. Finally, all the information obtained was enriched by consulting local inhabitants with knowledge of the territory and through proposals from the work team that developed the inventory. With this compilation, a list of 54 potential geosites was proposed.

Step 2 – Selection: Once the preliminary list of geosites has been established, it is necessary to carry out a qualitative characterization of each one of them, including extensive fieldwork. For this step, a descriptive data sheet was used. This file includes elements such as name, geographical location, land ownership, access conditions, state of conservation, and geological description, among other data of interest. For each of the selected sites, a qualitative evaluation of their three main types of use was applied (scientific, educational, and touristic), each of which is composed respectively of four criteria (Brilha 2016, 2018; Table 2). The information obtained in the field was complemented with petrological descriptions of rock samples, and interpretation of satellite images and pictures. The qualitative assessment culminated in the selection of 40 geosites.

Step 3 – Assessment: One of the main objectives of studying geological heritage through inventories is to know the general state in which these elements are found, and to identify those that require management that ensures their conservation and sustainable use. One way to reduce subjectivity in this process is through the quantitative assessment using parameters that numerically reflect their values, potentials, and vulnerabilities. In this case, four parameters were assessed, corresponding to Scientific Value (SV), Educational Potential (EP), Touristic Potential (TP), and Degradation Risk (DR), using a local adaptation of the method of Brilha (2016) (Table 3). Each geosite is ranked with 0-, 1-, 2-, or 4-points following indicators for each criterion. The final SV, DR, EP, and TP is a weighted sum of the criteria, going from 0

(minimum) to 400 (maximum). The quantitative assessment was applied to the 40 geosites selected in step 2.

Step 4 – Analysis: The results obtained were synthesized and analysed, as a basis to prepare general management proposals. To display the quantitative results and their spatial distribution, a synthesis map has been developed combining the multivariate and univariate modes of cartographic representation, as defined by Reynard (2016).

Step 5 – Proposals: Combining numerical, geographical, and qualitative analysis of the previous parameters; management priorities and opportunities were identified, including research, protection, promotion, infrastructure, and monitoring.

Step 6 – Updating: After the first version of the inventory, sporadic fieldwork and new research publications allowed to include new geosites to the previous lists, monitor changes in the assessment parameters, and adapt and continuously improve the methodology. As Brilha (2016) mentions, an inventory is always dynamic and needs to be regularly updated (Fig. 12).

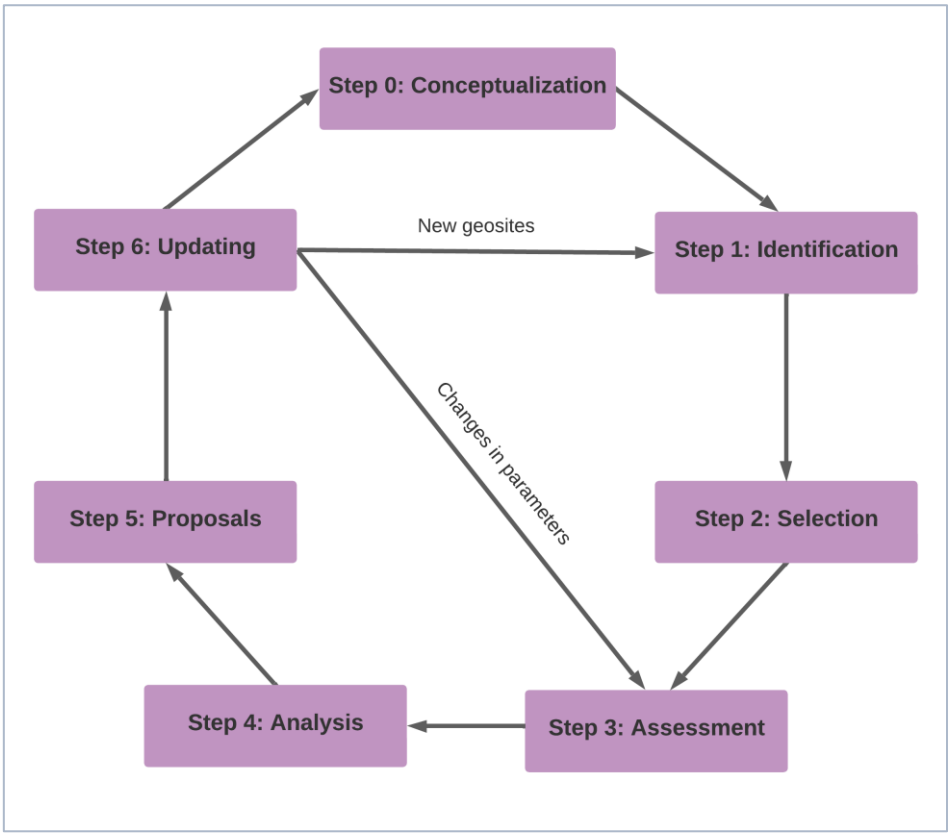

Figure 12: Workflow of the methodology used for the inventory of geosites.

Table 2: Criteria used for the qualitative characterization of geosites, after Brilha (2016, 2018).

Field characterization of Scientific Value
1. Representativeness: appropriateness to illustrate a geological process or feature that brings a meaningful contribution to the understanding of the geological topic, process, or feature. **2. Integrity:** current conservation status of the site, considering both natural processes and human actions. **3. Rarity:** number of sites in the study area presenting similar geological features. **4. Scientific knowledge:** based on the existence of scientific data already published about the site.
Field characterization of Touristic Potential
1. Scenery: associated with the visual beauty of the geological occurrence (landscape or outcrop). **2. Interpretative potential:** related to the capacity of a geological feature to be easily understood by laypeople. **3. Accessibility:** conditions of access to the site in terms of difficulty and time of the walk for the general public. **4. Safety:** related to the visiting conditions, taking into consideration minimum risk for visitors.
Field characterization of Educational Potential
1. Didactic potential: capacity of a geological feature to be easily understood by students of different educational levels. **2. Variety of geological elements:** different types of geodiversity elements present in the same site. **3. Accessibility:** conditions of access to the site in terms of difficulty and time spent on foot for ordinary students. **4. Safety:** related to the visiting conditions, taking into consideration minimum risk for students.

Table 3: Criteria used for the quantitative assessment of geosites (adapted from Brilha, 2016).

Scientific Value (SV)	**Educational Potential (EP)**	**Touristic Potential (TP)**
Representativeness (30%) Key locality (20%) Scientific knowledge (5%) Integrity (15%) Variety of geological elements (5%) Rarity (15%) Use limitations (10%)	Vulnerability (10%) Accessibility (10%) Use limitations (5%) Safety (10%) Logistics (5%) Seasonality for use (5%) Association with other values (5%) Scenery (5%) Singularity (5%) Conditions of observation (10%) Didactic potential (20%) Variety of geological elements (10%)	Vulnerability (10%) Accessibility (10%) Use limitations (5%) Safety (10%) Logistics (10%) Seasonality for use (5%) Association with other values (5%) Scenery (15%) Singularity (10%) Conditions of observation (5%) Outreach potential (10%) Proximity of recreational areas (5%)
Degradation Risk (DR)		
Deterioration of geological elements (35%) Proximity to areas with potential to cause degradation (10%) Legal protection (20%) Accessibility (15%) Density of population (10%) Interest for extraction (10%)		

4.4 Results

The result of the described method is a geoheritage inventory thought to be the basis of the creation of a UGGp, which includes 40 geological sites (not differentiated by geosites and geodiversity sites) classified into 10 local geodiversity categories, located in different geographical areas, and representing different geological units (Table 4).

All sites were quantitatively assessed in four parameters, corresponding to Scientific Value, Educational Potential, Touristic Potential and Degradation Risk. The scores for each category range from 0 (min) to 400 (max) points. In the case of DR, low scores represent a positive situation. Table 5 compiles all the scores obtained by each site, as well as the overall average for each parameter.

To display the quantitative results and their spatial distribution, an innovative synthesis map has been developed combining two modes of cartographic representation, as defined by Reynard 2016 (Fig. 13). For each of the geosites, a triangular diagram is shown, which graphically displays the values obtained for the SV, TP, and EP parameters. In simple terms, it can be considered that a triangle of greater area implies a greater potential of the geosite for the development of research, education and geotourism activities. In addition, the colour of each triangle represents the DR level, with the coding indicated in the interpretation key of Fig. 13.

Table 4: Listing and short description of geosites of Cajón del Maipo.

N°	Name	Geological features
1	La Obra Pluton	Early Miocene granodioritic pluton (19-20 Ma). It is the oldest intrusive of the Geopark, historically exploited for stonemasonry.
2	Las Vertientes Fluvial Terraces	Three nested systems of fluvial terraces of the Maipo river, related with uplifting. Described by Charles Darwin in 1835.
3	Cerro Divisadero Landslide	Rotational slip associated with a fault system. Implies geohazard for the local population.
4	Likán Mountain	Cliffy slope of 700 m high exposed by fluvial action, showing excellent examples of stratification and folding.
5	Maipo Anticlinal Fold	An anticlinal fold of kilometric dimensions that controls the Maipo river orientation.
6	Las Ánimas Waterfall	Private protected area with important biodiversity and a variety of fluvial and alluvial landforms.
7	La Vuelta del Padre	A curved, high-angle rocky slope shaped by fluvial action, showing a sequence of more than 50 m of folded and tilted stratification.
8	Los Cóndores Viewpoint	A viewpoint located on a cliff, with a great view of fluvial and glacial landforms. Is a sighting place for the Andean condor (*Vultur gryphus*).
9	La Gloria Pluton	Miocene Granodioritic Pluton (11-12 Ma). Is the largest intrusive unit of the geopark. Shows ∼3,000 meters of vertical exposure.
10	Río Olivares Park	U-shaped valley of glacial origin aligned to regional structures. Includes the largest glaciers of the geopark.
11	Tupungatito Volcanic Complex	Comprises the active stratovolcano Tupungatito (80 ka years, 5600 m a.s.l.), and the Pleistocene stratovolcano Tupungato (6570 m a.s.l.).
12	Los Piches Ignimbrite	Ignimbrite rhyolitic deposit with 40 m thickness. It has excellent preservation and the normal ignimbrite zonation.
13	El Yeso Waterfall	Knickpoint of 7 m height forming a waterfall. Its waters are always crystal clear because it is downstream of El Yeso Dam.
14	El Yeso Dam	Artificial dam that together with Laguna Negra Lake makes up the main freshwater reserve for Santiago city.
15	Laguna Negra Lake	Glacial lake with elongated shape (280 m deep). It is the main natural freshwater reservoir in the area. Studied by NASA as a terrestrial analogue.
16	Echaurren Norte Glacier	Retreating mountain glacier. It is one of the most studied ice bodies in South America, with continuous monitoring since 1975.
17	Aparejo valley	U-shaped valley of glacial origin, which registers a historic catastrophic landslide related to a sudden detachment of the Aparejo glacier.
18	El Plomo springs	Geothermal springs that emerge from a permeable sedimentary sequence. Associated with deep faults and fractures.
19	Contact Abanico - San Gabriel	Contact between intrusive and volcanic rocks. The latter are folded and affected by contact metamorphism.
20	El Volcán Mining District	Abandoned village and old copper mines that enter hundreds of meters on the mountain. Damaged by an earthquake in 1958.
21	El Volcán anticlinal fold	Overturned anticlinal fold affecting volcanic strata with excellent exposure. Its origin has been associated with a blind fault.

22	Los Lunes Pluton	Pleistocene diorite pluton (1.1 Ma). It is the youngest intrusive body of the geopark and shows columnar jointing structures.
23	Las Amarillas	Debris flows area mobilizing yellow clays, originated by hydrothermal alteration. Is related to a possibly active fault.
24	El Morado Moraine	Moraine deposits with terminal characteristics that invade the Volcano River. Part of a Natural Monument.
25	Morales Glacial Lake	Glacier lake fed by runoff of El Morado-San Francisco glaciers. Part of a Natural Monument.
26	El Morado-San Francisco Glaciers	Glacial system formed by two retreating glaciers and related landforms, such as cirques, horns, and moraines. Part of Natural Monument.
27	Lo Valdés Marine Strata	Vertical sequence of fossiliferous marine sedimentary rocks. Includes 39 species of ammonites, and marine reptiles' bones of the J/K boundary.
28	Punta Zanzi	Outcrop of vertical strata of the Mesozoic continental Rio Damas Formation reaching 3250 m a.s.l. It is a classical site for climbing.
29	La Engorda Complex	Corresponds to the Late Pleistocene–Holocene deposits of rock avalanches coming from a source with stepped planar morphology.
30	La Engorda Structures	Fallen blocks related to the La Engorda complex. Display sedimentary structures such as ripple marks, mud cracks, and vertebrated ichnites.
31	El Morado Hanging Glacier	Hanging glacier affected by climate change, with clear lateral moraines. It has a proglacial lake that originated from ice melting.
32	Colina Springs	Hot spring that surges in gypsum deposits, with temperatures over 50°C. Related to deep structures.
33	Colina Gullies Viewpoint	Gullies formed on the banks of the Colina River, where is possible to observe neotectonic structures.
34	Nieves Negras Glacier	Valley glacier partially covered by detritus, on the slope of the San Jose volcano. It extends for 6.5 km.
35	San Jose Volcano	Active stratovolcano (5856 m a.s.l.), with two main volcanic buildings and fumarolic craters. Record of 21 eruptions since 1822.
36	Gorge in El Cristo Bridge	Narrow gorge of 15 m height formed by the fluvial incision of the Maipo River on granitic rocks of the San Gabriel pluton.
37	Puente de Tierra Springs	Thermal springs that surge at more than 50°C. The precipitation has formed a natural bridge of travertine over the Maipo River.
38	Casimiro Basaltic Columns	Basaltic lava flows with spectacular columnar jointing, corresponding to sequences of the Don Casimiro extinct.
39	Maipo Pinnacles	Subvertical structures in the form of pillars and arches up to 20 m high, a product of eroded debris flow deposits.
40	Maipo Volcanic Complex	Stratovolcano (5664 m a.s.l.) nested within a huge caldera, a collapse structure of 15 km in diameter formed by a cataclysmic eruption.

Table 5: Quantitative assessment of the four parameters for the geosites inventory.

N°	Name	Scientific Value	Educational Potential	Touristic Potential	Degradation Risk	Geosite Categories
1	La Obra Pluton	130	205	245	290	Plutonic
2	Las Vertientes Fl. Terraces	235	270	275	290	Fluvial
3	Cerro Divisadero Landslide	285	235	270	205	Mass wasting
4	Likán Mountain	190	315	280	155	Volcanic
5	Maipo Anticlinal Fold	195	235	250	120	Tectonic
6	Las Ánimas Waterfall	160	305	320	115	Fluvial
7	La Vuelta del Padre	205	275	300	175	Tectonic
8	Los Cóndores Viewpoint	180	210	300	175	Fluvial
9	La Gloria Pluton	295	185	220	140	Plutonic
10	Río Olivares Park	270	160	165	120	Glacial
11	Tupungatito Volcanic C.	330	200	155	85	Volcanic
12	Los Piches Ignimbrite	285	190	250	145	Volcanic
13	El Yeso Waterfall	220	295	280	195	Fluvial
14	El Yeso Dam	270	285	320	230	Fluvial
15	Laguna Negra Lake	320	185	235	160	Glacial
16	Echaurren Norte Glacier	200	215	160	215	Glacial
17	Aparejo valley	240	165	195	125	Glacial
18	El Plomo springs	310	225	210	130	Geothermal
19	Contact Abanico – S. Gabriel	325	315	290	300	Plutonic
20	El Volcán Mining District	270	330	330	240	Mining
21	El Volcán anticlinal fold	345	210	255	150	Tectonic
22	Los Lunes Pluton	190	220	255	130	Plutonic
23	Las Amarillas	385	310	310	205	Mass wasting
24	El Morado Moraine	295	230	275	90	Glacial
25	Morales Glacial Lake	200	240	290	140	Glacial
26	Morado-San Francisco Gl.	280	225	265	140	Glacial
27	Lo Valdés Marine Strata	340	270	310	280	Paleontological
28	Punta Zanzi	280	230	270	160	Sedimentary
29	La Engorda Complex	275	215	265	160	Mass wasting
30	La Engorda Structures	275	175	200	340	Paleontological
31	El Morado Hanging Glacier	295	185	220	220	Glacial
32	Colina Springs	190	235	260	195	Geothermal
33	Colina Gullies Viewpoint	180	185	215	200	Fluvial
34	Nieves Negras Glacier	300	210	230	140	Glacial
35	San Jose Volcano	290	305	330	125	Volcanic
36	Gorge in El Cristo Bridge	285	330	350	190	Fluvial
37	Puente de Tierra Springs	265	200	155	135	Geothermal
38	Casimiro Basaltic Columns	255	165	205	55	Volcanic
39	Maipo Pinnacles	165	145	145	90	Mass wasting
40	Maipo Volcanic Complex	360	230	210	100	Volcanic
	Overall Mean	259	233	252	171	

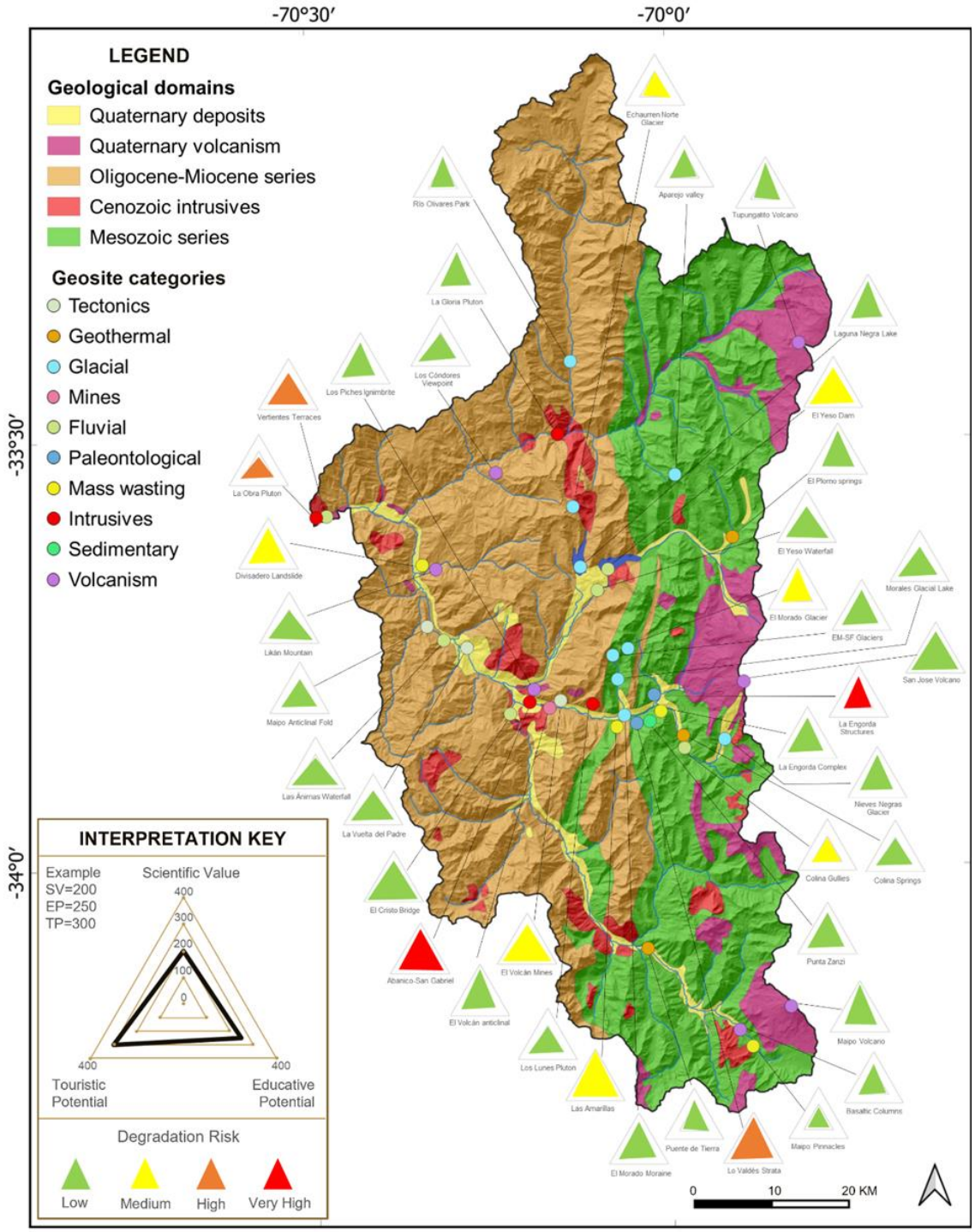

Figure 13: Synthesis map of the quantitative assessment of geosites shown in Table 5. For each of the geosites, a triangle diagram is shown that graphically displays the values obtained for the parameters SV, TP, and EP. In addition, the colour of each triangle represents the DR level, with the coding indicated in the interpretation key. In addition, there is displayed a simplification of the geological map of the Fig. 6, and the colours of the circles of the geosites indicate the local geodiversity category to which they belong.

4.5 Analysis

With respect to the spatial distribution of geosites, two main aspects stand out: first, the sub-basin with the largest surface area, the Colorado River, has the least number of geosites, despite its geology of great interest. This is due to the existence of strict restrictions on access to the site, which hinder and discourage scientific research and the tourist and/or educational use of geoheritage. On the other hand, the Volcán River sub-basin has the smallest surface area and the largest number of geosites, concentrating almost half of the total. This is explained, beyond its significant geological conditions, by its historically good access conditions, which have allowed this sector to be intensively studied for decades. Finally, with respect to the thematic areas, there is a predominance of geosites related to fluvial morphology, glaciers, and volcanism, which is associated with recent geomorphological features and active geological processes. Regarding the quantitative assessments, the main findings in each category are shown below and can also be seen graphically in figure 14.

Scientific Value (SV): This parameter was evaluated through seven criteria, averaging 259 points out of 400, being the one with the highest scores in the study area (Fig. 14). This is explained because most of the geosites were initially proposed based on a literature review and interviews with earth science experts, and their representativeness and uniqueness were considered in their selection. In addition, this parameter aims to estimate an intrinsic value of geosites, giving little relevance to their management status. Of the evaluated criteria, only two have an average of more than 3 points, with Representativeness (3.3) and Integrity (3.6) being the best evaluated, while the less evaluated is Key Location with an average of 1.4 points (Fig. 14). Thus, in this category, there are 9 geosites with SV in the Very High range, and 16 in the High range, while 9 are part of the Low range (Fig. 14a).

Educational Potential (EP): This category was assessed using twelve criteria, averaging 233 points out of 400, with an average lower than that of the SV. This occurs due to the incorporation of criteria that evaluate accessibility and safety conditions, which is a weakness observed in the study area. Of the criteria evaluated, only two present an average higher than 3 points: Observation Conditions (3.8) and Vulnerability (3.5). The less evaluated criterion is Safety with an average of 1.1, which indicates a

significant gap in management issues since this criterion evaluates the existence of infrastructures such as fences, stairs, and handrails, which are infrequent in the area. In this category, the medium range predominates with 18 geosites, while 12 of them are concentrated between the High and Very High ranges (Fig. 14b).

Touristic Potential (TP): This category was also assessed using twelve criteria, averaging 252 points out of 400, surpassing the scores of the Educational Potential. Although both parameters share most of their criteria, in this case less strict indicators have been applied with respect to Accessibility and Logistics. This difference arises because EP considers activities with large groups of students of different levels, while Tourist Potential of Use targets smaller groups with less presence of youngsters. The best evaluated criteria continue to be Observation Conditions (3.7) and Vulnerability (3.5), while the less evaluated criterion is Safety. Thus, in this category 15 geosites are in the High score range and 9 in the Very High range, while only 6 are in the Low range (Fig. 14c).

Degradation Risk (DR): To analyse this parameter, it should be considered that low values of DR represent a positive situation. Among the 40 geosites there is an average of 171 points, indicating a positive overall situation. Of the criteria evaluated, Population Density (1.0) stands out, since the study area has a low population, which is in small towns in the low mountain range, with many geosites far from any settlement. On the other hand, the scores for Accessibility (2.6) and Legal Protection (2.6) stand out negatively, reflecting the low coverage of protected areas and the absence of management plans. It has been identified that several geosites are located on private land with restricted access, which tends to keep them in a good state of integrity, but at the same time restricts their use by inhabitants and visitors. The predominant values are those of Low score with 28 geosites, while only 5 have been evaluated with High or Very High DR (Fig. 14d). About threats, there are four main sources of vulnerability, in decreasing importance: i) Mining, quarries, and hydraulic infrastructures. ii) Massive and non-planned tourism. iii) Lack of statutory protection for geological sites; and iv) General illiteracy about geodiversity and geoheritage values.

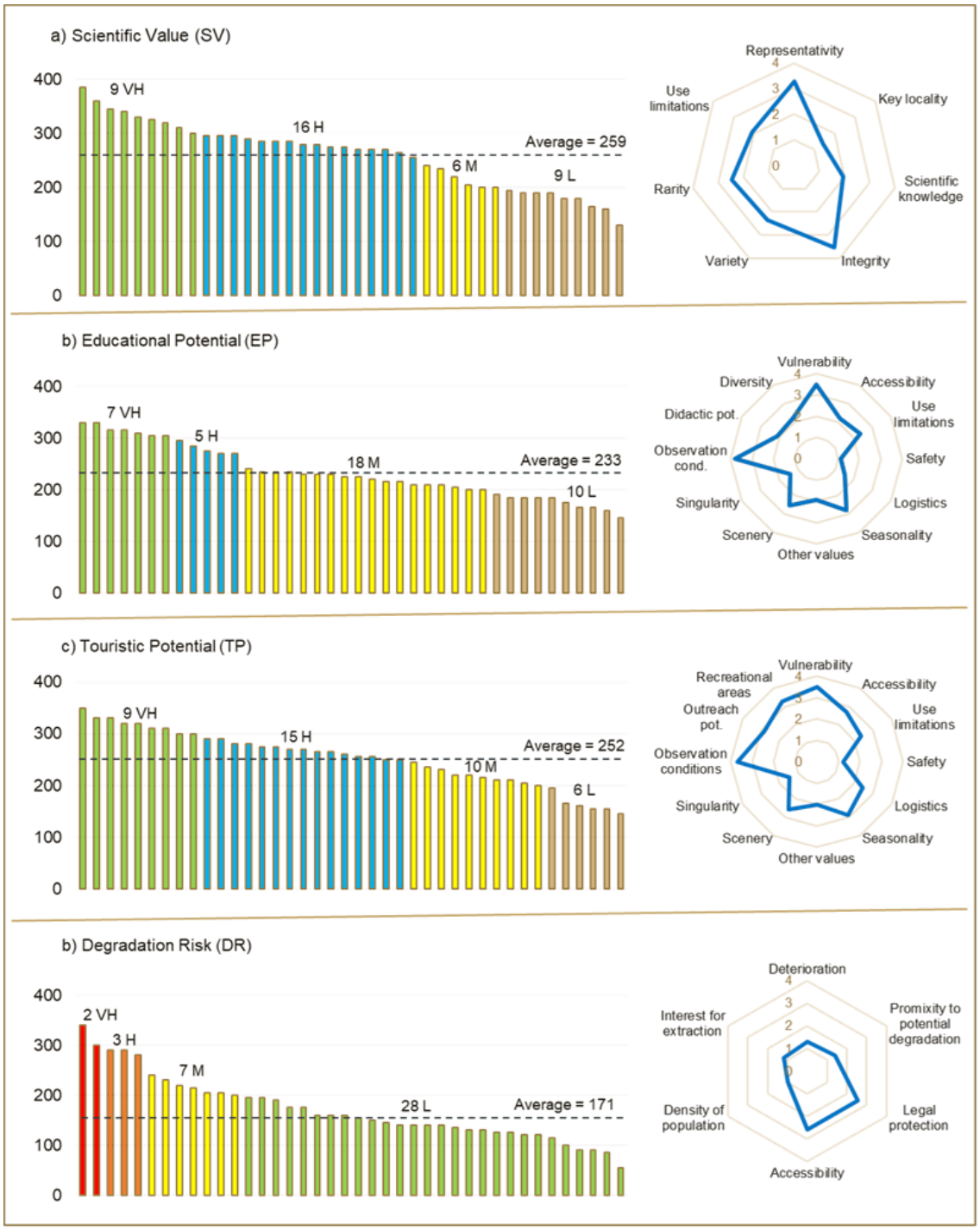

Figure 14: Graphical synthesis of the quantitative assessment shown in Table 5 and Fig. 13. For each parameter assessed (SV, EP, TP, and DR) is displayed the statistical classification of geosites in four classes: Low (L, < 200), Moderate (M, 200–250), High (H, 250–300) and Very High (VH, >300 points). For each parameter, a radial diagram is shown on the right, plotting the averages obtained for each evaluation criterion, with values ranging from 0 (min) to 4 (max).

4.6 Discussion

As established in the literature, the first stage in the development and implementation of a geoconservation strategy is the elaboration of geosite inventories (e.g., Reynard et al., 2016), which constitute the main source of information on the characteristics, potential and spatial configuration of these elements in a territory (Poiraud et al., 2016). It is desirable that these inventories are systematic and rigorous, and that they include qualitative and quantitative evaluations, thus reducing subjectivity in the process of analysis and identification of values. It is also important that the numerical results obtained are duly analysed and processed, on the one hand to assess their quality and relevance, and on the other to make the best use of them, as their elaboration is demanding in terms of time and resources (Brilha 2016; Poiraud et al. 2016). Throughout this process there will always be a level of subjectivity associated with the vision and experience of who coordinates the inventory; but it can be reasonably reduced by using a sound methodological framework, having a good knowledge of the study area, and applying rigor in developing the different stages (Brilha 2016; Poiraud et al. 2016).

The geosite inventory in Cajón del Maipo was carried out based on the method proposed by Brilha (2016), which arose from a review and compilation of the best work published to date. However, although this methodology is now recognized and used extensively, it was necessary to adapt the evaluation criteria and indicators to the local conditions. Therefore, the method was enriched with elements from other proposals such Reynard et al. (2016).

In the case of this inventory, the application of this methodology has provided results that are consistent with the reality of the territory in most cases. The 40 geosites represent well the geodiversity and geological heritage of the area, they are distributed in all the sub-basins, and their quantitative assessment responded reasonably to the observations made in the field. However, there were also several limitations in its development. One limiting factor is the large size of the commune and its remote nature, covering an area of 4995 km^2 and located in a mountainous context, with areas that require complex expeditions to reach, which has led to difficulties in terms of accessibility. Furthermore, large portions of the study area are private land, which

complicated its consideration in this study. These limitations, which are a challenge to overcome for future updates, translates into the existence of areas that were not satisfactorily explored. Thus, it is concluded that the inventory of geosites and their quantitative evaluations are a very good tool to diagnose the geological heritage of a territory, but it is essential that their analysis considers their limitations for a correct interpretation.

The work presented here is a direct contribution to the scientific knowledge and valuing of the local geological heritage with a systematic, practical, and rigorous approach. On the other hand, and as mentioned above, the goal of this inventory is to serve as a tool for territorial management and to promote regional sustainable development in the context of the creation of a UGGp. This work undoubtedly contributes to that objective by addressing the main questions to be answered in the initial stages of a geoconservation strategy, such as identifying the most relevant geological attributes, knowing their intrinsic value, determining their potential for use, and detecting the most vulnerable features.

Therefore, the first challenge is to take advantage of these results to promptly establish management plans and measures for the geological heritage of the commune. Likewise, there is a need to carry out this type of study in other sectors of the country, since, as in Cajón del Maipo, there are many areas with a remarkable geological heritage that, if left unmanaged, are vulnerable to other activities that can irreversibly degrade them.

This inventory has provided an understanding of the value, potential and vulnerability of the geological heritage of Cajón del Maipo, both in general and at the scale of geosites, indicating that the area includes relevant geosites from the scientific, educational and tourist point of view. In addition, and more importantly, the analysis and use of its results has allowed progress to be made in various components of sustainable territorial development, through institutional recognition, educational activities, new economic niches, and nascent conservation initiatives. The challenges posed propose a complex context that must be addressed in a holistic, integrated, and participatory manner, understanding that geological heritage is an indissoluble part of natural heritage, and highlighting its importance for the future of our communities.

5. Cajón del Maipo Geopark Project

5.1 General description

As shown in the previous sections, Cajón del Maipo has the potential to become a national reference in the study and teaching of Earth sciences, not only because of its significant geoheritage but also because of its strategic location. On the other hand, it is an area that faces great challenges, such as environmental degradation, unsustainable exploitation of its natural resources, massive tourism, the effects of climate change and the growing risk of disasters. It is in this complex context that the Cajón del Maipo geopark project is being implemented, which seeks to propose a new vision of local development, promoting the sustainable development of the territory of the commune of San José de Maipo through the creation of a UGGp.

The main elements that make up the Cajón del Maipo geopark project are graphically represented in Fig. 15. As indicated, this is a territory with geological heritage of international relevance, in addition to sites of natural and cultural values, with tourist attributes and activities, and a community involved in the process.

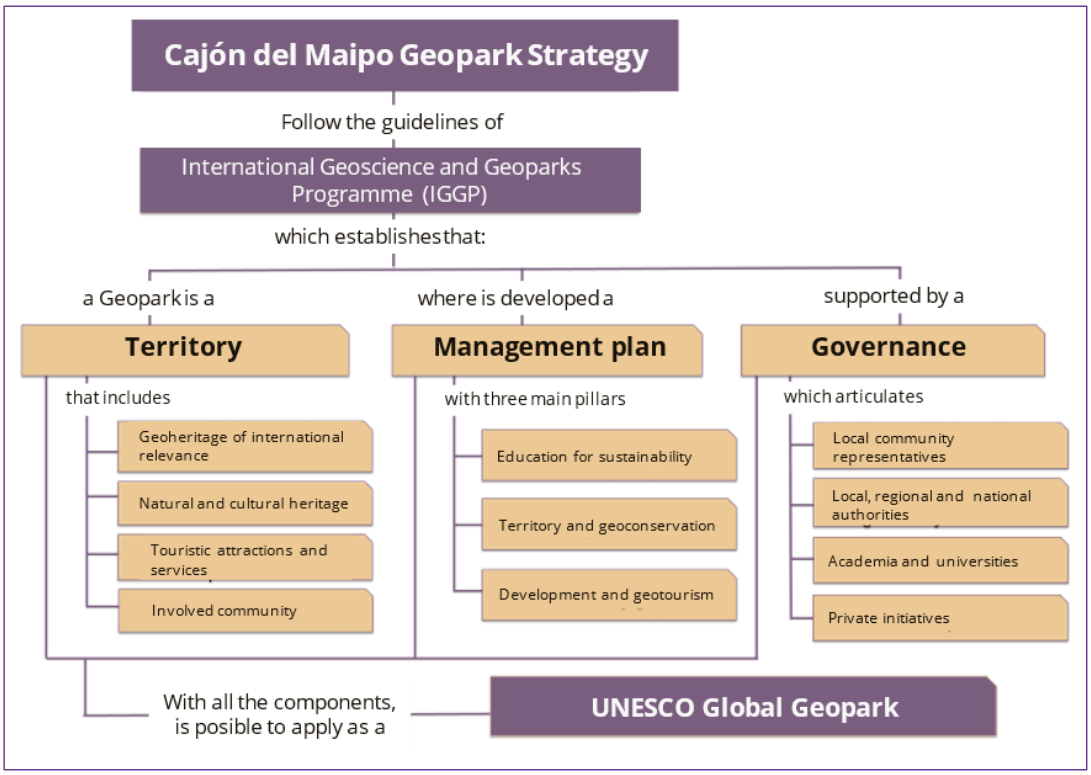

Figure 15: Conceptual model of the Cajón del Maipo geopark strategy.

The project management, framed within the UGGp pillars, should be supported by an articulated, participatory, and bottom-up governance, which includes actors from the local community; local, regional, and national authorities; universities and academia; as well as private initiatives (Fig. 15).

This initiative is driven collaboratively by various institutions of the territory in the "Cajon del Maipo Geopark Promotion Committee" (hereinafter, the Geopark Committee). At the beginning of 2022, the institutions that make up this body are FUNDESO Cajón del Maipo, the Municipality of San José de Maipo, the Cajón del Maipo Chamber of Tourism, the Metropolitan Technological University (UTEM), and Meri Foundation. A brief description of each is provided in table 6.

Table 6: List and description of the entities of the Cajón del Maipo Geopark Committee.

Institution	Description
FUNDESO Cajón del Maipo	Local non-profit foundation aiming the promotion of sustainable development. Created in 2017 and formalized in 2019, it works in conservation, research, and education. It is the main organisation promoting the geopark.
Municipality of San José de Maipo	Main body of the local administration, in charge of satisfying the needs of the local community and its economic, social, and cultural progress. It is involved in aspects relevant to the geopark such as education, tourism, and environmental protection.
Chamber of Tourism Cajón del Maipo	Non-profit trade association, which brings together small, medium, and large tourism entrepreneurs in the commune of San José de Maipo. Its objectives are to promote the destination, create alliances between tourism entrepreneurs, and work for a sustainable tourism destination.
Meri Foundation	Non-profit foundation that develops scientific research and environmental education in the service of ecosystem conservation. It has collaborated in the technical and financial aspects of the project.
Metropolitan Technological University	Chilean state institution of higher education founded in 1993. It has three campuses in Santiago and more than 8000 students. It has participated in the geopark from its Tourism Competitiveness Programme.

It is worth highlighting the leading role played by FUNDESO, a NGO created by a team of young local professionals in 2017, of which the author of this dissertation is one of its creators, aiming to be a platform to promote the Cajón del Maipo geopark project.

To date, the Geopark Committee has an Executive Secretary and a Scientific Coordinator, both representatives of FUNDESO, and area managers who are representatives of the Geopark Committee members. According to the statutes of the

organization, the Geopark Committee is a coordinating body made up of representatives of all the above-mentioned entities, who meet periodically. Its main objectives are:

- To coordinate inter-institutionally the management, progress, and development of the geopark project for its successful application to UNESCO.
- To join efforts in a public-private alliance for raising national and international funds.
- To develop territorial activities within the framework of a unique annual calendar in matters of sustainable economic development, environmental education, and conservation of local heritage.

Since its foundation, 15 official coordination meetings of the Geopark Committee have been held, the last one in December 2021. The Geopark Committee does not have a legal personality and operates based on informal engagement and bilateral working agreements, so it does not have its own budget or contracted work team, which is an obvious weakness that must be remedied to meet the requirements of the UGGp designation.

5.2 History and milestones

Despite the geopark's lack of legality and solid funding, great progress has been made in its development process, with a strong base of community support and collaborative work, which is described in the following pages.

The Cajón del Maipo Geopark has been promoted collaboratively by the Geopark Committee since 2017. However, its inception dates to 2012, when José Benado, with the support of the Geological Society of Chile, developed the first geoheritage inventory of Cajón del Maipo under the scope of his master's dissertation (Benado, 2013). A database of this inventory was also produced, and his results were presented at international conferences, in a television documentary[10] and in a scientific tourism book (Benado, 2013; Benado et al. 2019; Obaid 2016).

After a period of stagnation, in 2017 this initiative was taken up again in a collaborative manner, joining efforts of institutions such as FUNDESO, the Municipality

[10] Tecnociencia: Cajón del Maipo Geopark: https://youtu.be/bu8YcOyz1uM

of San José de Maipo, the Meri Foundation, the Metropolitan Technological University, the Geological Society of Chile, the Cajón del Maipo Chamber of Tourism, among others.

One of the first achievements of this new stage of the project took place in December 2017 when, after receiving an invitation from the project team and after 3-day visit to San José de Maipo, the Regional Coordinator of the International Geosciences and Geoparks Programme of UNESCO for Latin America and the Caribbean, Denise Gorfinkiel, acknowledged through a letter, the quality of "Aspiring Geopark" for the commune.

On July 16, 2018, the Mayor Luis Pezoa Álvarez signed the Municipal Decree declaring San José de Maipo as "Geological Capital of Chile" and "Aspiring Global Geopark". Through this decree the communal authority formalizes the communal intention to obtain the UGGp designation and instructs the Education Corporation to develop educational programmes in local schools related to the geopark.

In October 2018, the scientific coordinator of the geopark participated in the "Workshop for Latin American Geopark Projects", held in the UNESCO Global Geopark Grutas del Palacio, Uruguay and in May 2019, participated in the "International Intensive Course on UNESCO Global Geoparks", held at the Island of Lesvos UGGp, with a grant awarded by the Global Geoparks Network.

In June 2019, the Chilean National Commission for Cooperation with UNESCO, based at the Ministry of Education, communicated to UNESCO that Chile has the formal intention to apply to the UNESCO Global Geopark Cajón del Maipo, granting formal sponsorship to the aspiring geopark and expressing national interest to the project.

In August 2019, the book "Geodiversity, Geological Heritage and Geosites of the Cajón del Maipo" was published at the Likandes Elementary Reserve (San José de Maipo), which is a very important tool for the enhancement and scientific dissemination of the geological and natural heritage of the Cajón del Maipo Geopark (Vergara et al., 2019).

During the second half of 2019, the first draft of the application dossier for the application of San José de Maipo for the UGGp designation was concluded by the FUNDESO team – thanks to the support of a municipal grant – and subsequently reviewed by the Geological Society of Chile. Due to the social crisis that erupted in Chile

at the end of 2019 and to internal gaps related with the management structure, the submission of the nomination was postponed.

Between August and October 2020, the Online Course "Introduction to Geotourism and Heritage of Cajón del Maipo Geopark" was developed. More than 550 registrations were received, for a quota of 200. This course with the participation of 16 local, national, and international expert professors, was a resounding success, with more than 180 accredited students.

Since 2021, efforts are being made near the Regional Government and the Regional Development Corporation in order to obtain long-term financing through the Regional Development Fund.

The year 2022 is marked by a restructuring process, associated with changes in municipal, regional, and national administrations. In the meantime, progress has been made in the promotion and development of protected areas in the territory associated with geological heritage, such as the Baños Morales Wetland and Mirador de Cóndores Municipal Reserves.

One of the strengths of the project is the support and participation of various local organizations associated with social and productive development, such as the Cajón del Maipo Chamber of Tourism, the Cajón del Maipo Local Guides Association (whose creation and formalization was triggered by the project), the Cajón del Maipo Network of Women Entrepreneurs, the Mining Tourism Society, the Women Heads of Household Programme, the San Pedro Nolasco Artisans Association, among others.

5.3 Thematic activities

In addition to the main milestones described above, numerous activities and specific actions have been carried out in each of the work areas. The following are just a few of them, grouped by theme.

Protection and geoconservation: As indicated, the area has enormous potential for research development, while at the same time it is lacking in the protection and management of its geosites. In this sense, efforts have been made for the recognition of the geological heritage by the competent governmental institutions for its future

incorporation in local and regional development plans. For example, the 40 geopark's geosites are already included in the National Inventory of Geosites of the National Geological Survey (SERNAGEOMIN)[11], some of the highest TP sites are recognized in the cadastre of tourist attractions of the National Survey of Tourism (SERNATUR) and have begun to be systematically considered in the related Municipal Ordinances, such as those of Environment and Tourism.

On the other hand, the municipality has made progress in the creation of a Municipal Nature Reserve in the Los Cóndores Viewpoint Geosite[12], the regional government is promoting the creation of a Tourist Park in the Laguna Negra Geosite[13], and the central government has announced the creation of a National Park that will eventually include the Tupungato-Tupungatito Volcanic Complex and Olivares River Park Geosites[14]. In each of these new protected areas, collaborative work has begun to include geoconservation practices in their management.

An interesting line of work, due to the high proportion of private ownership of land where there are geosites, is the use of the conservation easement for their protection. This is a novel legal tool whose objective is to conserve the environmental heritage of a private property through a long-term contract between a specialized conservation entity and the property owner. A model is beginning to be developed for its application in the geosites of the Cajón del Maipo, which is expected to have real results in two years, as part of the "Boldo Cantillana" project of the Tierra Austral Foundation.

Regarding monitoring, the Communal Environmental Committee and other actors are developing the citizen science project "Volunteers for Water", which seeks to monitor the vital signs of the Maipo River basin and its tributaries using low-cost sensors. This initiative is described in more detail in section 6.

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[11] SERNAGEOMIN: National Inventory of Geosites https://portalgeominbeta.sernageomin.cl/

[12] Ladera Sur: Mirador de Cóndores se transformará en la segunda Reserva Natural Municipal del Cajón del Maipo. https://laderasur.com/articulo/mirador-de-condores-se-transformara-en-la-segunda-reserva-natural-municipal-del-cajon-del-maipo/

[13] País Circular: Corfo y Gore Metropolitano firman acuerdo para la conservación ambiental en el Cajón del Maipo. https://www.paiscircular.cl/biodiversidad/corfo-y-gore-metropolitano-firman-acuerdo-para-la-conservacion-ambiental-en-el-cajon-del-maipo/

[14] CONAF: Parque Nacional Glaciares de Santiago: Polo de investigación y de turismo de interés especial. https://www.conaf.cl/parque-nacional-glaciares-de-santiago-polo-de-investigacion-y-de-turismo-de-interes-especial/

Geotourism and development: The work done so far intends to promote the link between relevant actors and to offer training for entrepreneurs, workers, and tourist guides. For the development of these activities, some geosites with the highest TP, such as the El Volcán Mining District, Los Cóndores Viewpoint, or El Cristo Bridge, have been used as the setting.

This has resulted in the creation of a growing offer of tourism services that add a geological component to their activities. It is essential to strengthen this work, as the number of visitors to these sites has increased in an uncontrolled manner in recent years, which has not been accompanied by the necessary management measures, which undoubtedly increases the risk of degradation of these highly relevant attractions[15].

The development of this line of work was enhanced by being included as part of the governance of the Regional Strategic Programme "Santiago, World Capital of Mountain Tourism"[16], promoted by the Chilean Economic Development Agency (CORFO).

Education for sustainability and outreach: The work on this topic is oriented to the nine local educational institutions, most of them administered by the municipality, to the universities that teach geology and tourism, and also to offer informal dissemination activities aimed at the community and visitors.

With the schools, field trips have been developed to several of the geosites with highest EP, such as the marine strata of Lo Valdés, Likán Mountain, or Vuelta del Padre, and didactic materials have been developed such as the "Cajón de Tesoros" project, which includes geosites and their relationships with biodiversity and local culture. With respect to the universities, their visits are continuous and frequent, including in their itineraries several of the geosites depending on the type of interest of the programmed outing. For example, the La Gloria pluton is visited in igneous petrology courses, the La

[15] Revista Cajón del Maipo: Mirador de Cóndores: de una de las peores postales para el turismo de montaña a inédito modelo de gestión sostenible https://revistacajondelmaipo.cl/2022/05/01/mirador-de-condores-de-una-de-las-peores-postales-para-el-turismo-de-montana-a-inedito-modelo-de-gestion-sostenible/

[16] Andes Santiago Governance: https://g.andesstgo.cl/gobernanza/

Engorda complex in geomorphology, or the Volcan river area and several of its geosites are part of introductory geology courses.

On the other hand, a celebration that combines the educational spirit while promoting economic development is the celebration of the Latin American Geotourism Day, coordinated by the Latin American Geoparks Network. On this celebration, geosites such as El Morado Moraine and the Lo Valdés Marine Strata have been visited with numerous groups of visitors, mainly local inhabitants.

Finally, a mention should be made to endless materials and activities for the dissemination of geological heritage that have been carried out over the years, including the publication of a book, the production of documentary videos, itinerant exhibitions, the installation of information points, drawing and photography contests, creation of a website, and successful management of social networks, in which a large community of followers and promoters of the Cajón del Maipo Geopark has been generated.

5.4 Management and strategy

In 2017, the first action plan for the Cajón del Maipo Geopark Project was defined, which included a diagnosis, identification of gaps and proposals for management (Vergara et al., 2017). To build the action plan, a quantitative methodology based on the Self-Assessment Matrix in Annex 2 of the UGGp application was used. In order to identify the gaps that separate the current situation of Cajón del Maipo from the conditions required to achieve a successful candidacy as a UNESCO Global Geopark, the self-assessment matrix was applied in two situations: current situation vs. target situation (Fig. 16A, B and C).

The scores were assigned in a participatory manner, consulting with territorial stakeholders and the entire technical team, projecting the target situation on a realistic basis. Subtracting the target score from the current score reveals the gap that needs to be addressed to achieve the UGGp designation , which was used to identify the priority actions that make up the plan. The results of this exercise are shown in Fig. 16B and C, considering the unweighted and the weighted assessments respectively, according to Table 1. The result shows that the 2017 situation (334 points) was quite far from the desirable situation (851 points), where the gap to be closed exceeds 500 points.

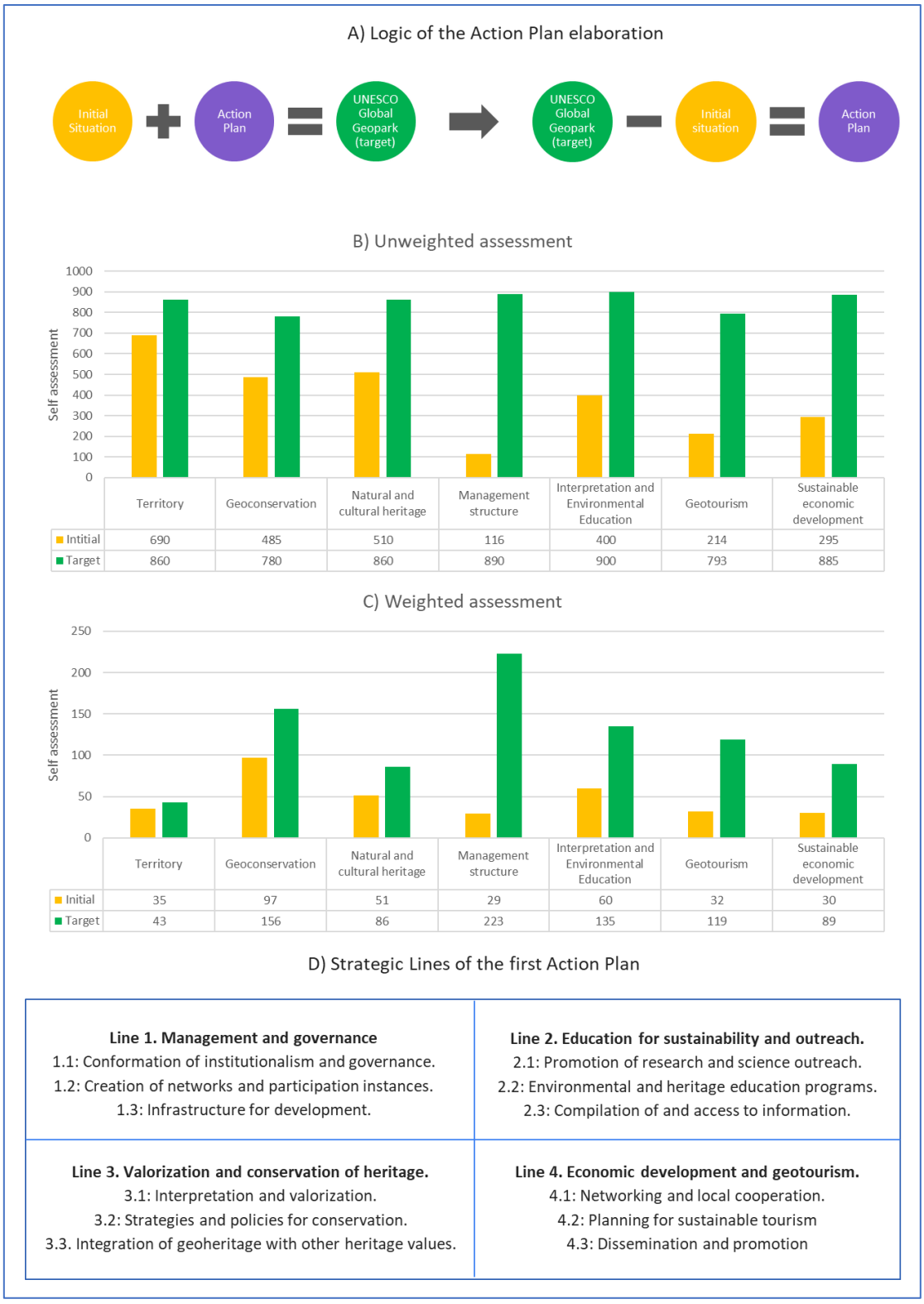


Figure 16: Results of the self-assessment applied in Cajón del Maipo for each of the criteria considered in the Annex 2. The results of the current situation are shown in blue and in orange the desirable results to be able to successfully apply for the geopark to UNESCO. In the upper graphic is displayed the punctuation from 0 to 100 for each criterion. In the lower graphic are weighted according to Table 1.

It is clearly observed that the Territory is the criterion with the best conditions, and the Management structure is the weakest, which is an obvious reflection of the absence of a legally recognized management body with the possibility of executing the actions of the geopark. Analysing each of the scores and criteria, an Action Plan was established consisting of strategic lines, each with components, which in turn include activities. Thus, the four strategic lines were the following:

Line 1. Management and governance

Line 2. Education for sustainability and outreach.

Line 3. Valuing and conservation of heritage.

Line 4. Economic development and geotourism.

As expressed in that document, the implementation of the geopark and its plan must be supported by a legally recognized management structure, with its own budget and equipment, which also allows for the articulation of intersectoral and multilevel governance.

6. Proposals for geopark management

The work carried out between 2017 and 2021 was framed by the guidelines established in the first Action Plan, although some of its most relevant expected results were not met, such as the formalization of the management structure.

In May 2022, led by the author of this dissertation, the geopark team developed a proposal of the Geopark Programme for 2023-2024, with the objective of implementing it with the support of the Regional Government of Santiago through the Regional Development Fund (FNDR). This is a public investment tool through which the Central Government transfers resources to regions for the development of actions in the different areas of social, economic, and cultural development of the Region to achieve harmonious and equitable territorial development[17].

To plan a project financed by the FNDR, it is necessary to follow the methodology known as the Logical Framework Approach, under the guidelines of the Economic Commission for Latin America and the Caribbean (ECLAC) as described in Ortegón et al. (2005). This methodology is a tool to facilitate the process of project conceptualization, design, implementation, and evaluation of projects of public interest.

The Logical Framework Approach includes two stages (Ortegón et al., 2005):

- *Stage 1: Identification of the problem and objectives,* in which the existing situation is analysed to create a vision of the desired situation and select the strategies to be applied to achieve it. There are four types of analysis to be carried out: stakeholder analysis, problem analysis, objective analysis, and strategy analysis.
- *Stage 2: The planning stage*, in which the project idea is converted into a practical operational plan for implementation. Includes the proposal of governance and management structure, and definition of strategic components, activities, indicators, means of verification, and assumptions.

[17] Fondo Nacional de Desarrollo Regional (FNDR): https://www.gobiernosantiago.cl/fndr/

6.1 Identification of the problem and objectives

After reviewing documentation, interviewing stakeholders and holding several working meetings, the technical team identified that the central problem to be addressed by the geopark at the territorial scale is the lack of sustainable management tools and instances of articulation relevant to the singularities of Cajón del Maipo and the challenges faced by its community, which is vulnerable to environmental degradation, climate change, disaster risk and overexploitation of its natural resources. It has been identified that the geological, natural, and cultural heritage of the destination is one of its most relevant attributes, given its high scientific, touristic, educational, and ecological value, a potential that has not been adequately studied, valued, disseminated, and managed. In short, the problem is the *"unsustainable management of Cajón del Maipo and the wasteful use of its heritage"*.

Some of the causes of the problem are the following:

- The territorial governance presents problems of articulation and little focus of intersectoral efforts towards objectives shared by the different actors. On the other hand, management and planning tools are either non-existent, outdated or have little territorial relevance.
- There are insufficient conservation measures and practices for heritage sites, which is associated with a low valuation by society, insufficient and inaccessible information, and a lack of enabling infrastructure for safe tourism and pedagogical use.
- Poor sustainability of the tourism activity, which is associated with low tourism heritage awareness, deficient use of the most relevant attributes, few instances of training and low linkage of the tourism value chain.

The identified problem has as a major effect the degradation of the natural and cultural heritage attributes of the territory, and consequently, losses in the quality of life of its inhabitants and in the territorial competitiveness. This is associated, on the one hand, with the negative externalities of massive and poorly planned tourism, which jeopardizes the most visited sites.

The tourist offer shows a low diversification and little market intelligence, which has repercussions on the economic loss and the waste of competitive advantages. On

the other hand, and this already implies effects on a regional scale, there is little sustainable use of natural resources, which increases their vulnerability and risk of degradation. In addition, the lack of resilience to face the challenges of the immediate future, such as climate change and disaster risk, implies a growing risk for the hydric security of the city of Santiago, since this territory is its main source and reserve of water.

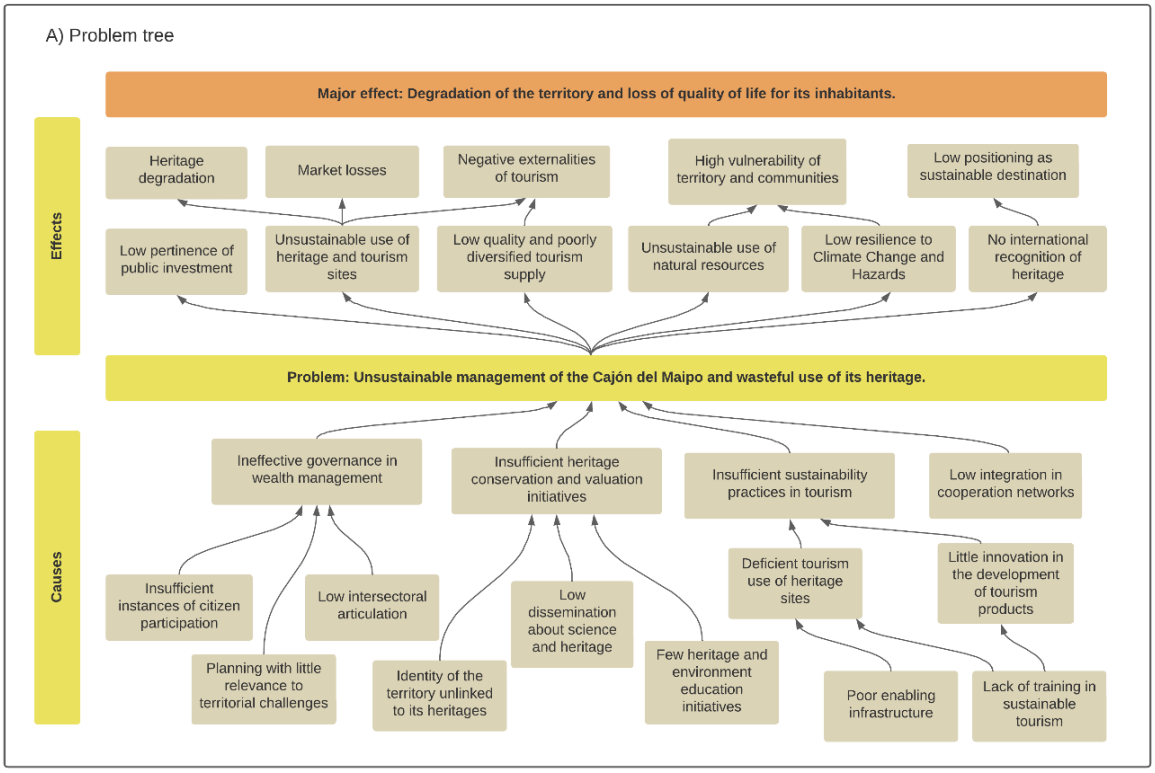
Figure 17A shows graphically the causes and effects of the identified problem, following the Logical Framework Approach in a Problem Tree representation (according to Ortegón et al., 2005).

The analysis of objectives makes it possible to describe the future situation to be reached once the problems identified have been solved. It consists of converting the negative states of the problem tree into solutions, expressed in the form of positive states. In fact, all these positive states are objectives and are presented in an objectives tree showing the hierarchy of means and ends.

Figure 17B shows the results of the Objectives Tree for this case. With the results of the process described above, the general objective of the project, called purpose, and its specific objectives are established, which will later give rise to the components. In this case, the purpose is to contribute to the sustainable development of the Cajón del Maipo area and the use of its heritage with a holistic, articulated, and participatory management model.

The *specific objectives* for the *Geopark Programme 2023-2024* are:

- To improve the effectiveness of local governance in heritage management.
- To promote knowledge and conservation of heritage, with emphasis on sites of scientific, touristic, and educational relevance.
- To promote sustainability, quality and innovation in the tourism offer.
- To increase visibility, promotion, and integration into national and international cooperation networks.



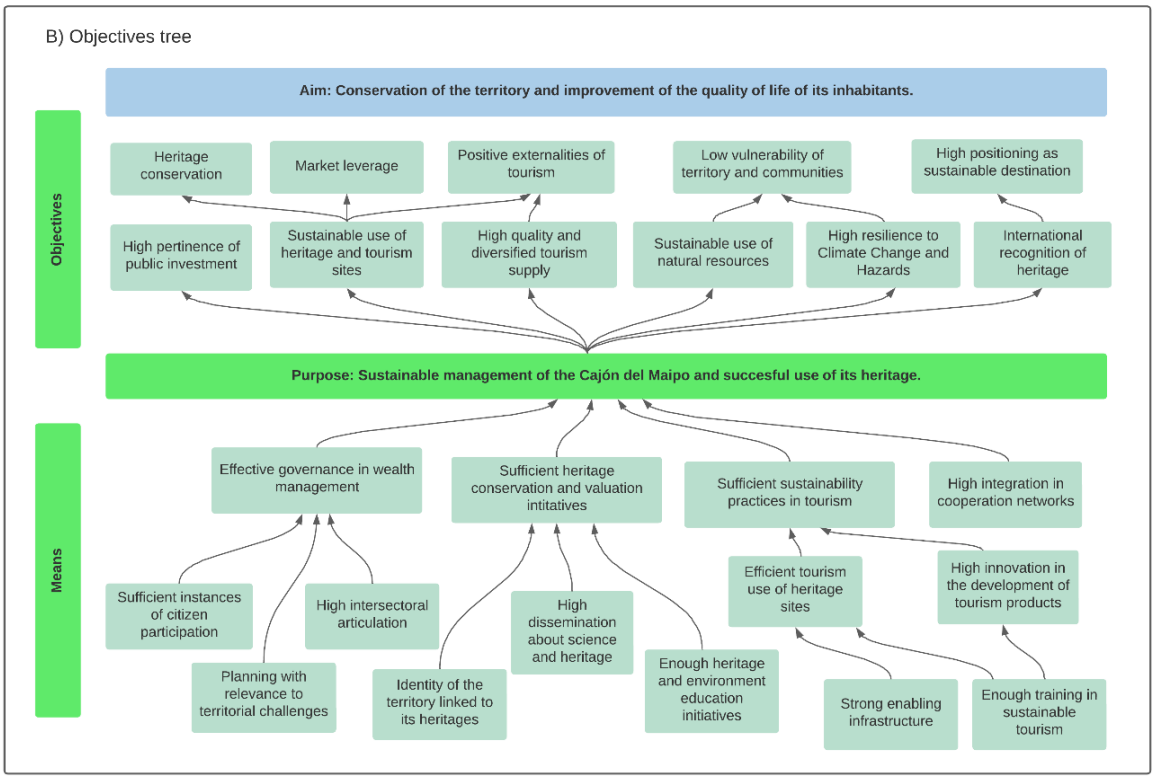


Figure 17: Results of the planning phase of the Framework Approach applicated in Cajón del Maipo Geopark. Problem Tree, showing graphically the causes and effects of the identified problem (A) and Objectives Tree, which transforms the problem into a purpose, generating the desired image (B).

6.2 Stakeholders' analysis

One of the key components when planning development strategies such as geoparks is stakeholder analysis, which is also indicated in the Logical Framework Approach (Ortegón et al., 2005). In this case, it has been identified that stakeholders can be classified by level of action (local, regional, national, and international) and by nature (public administration, civil society associations, academia and private).

Each of them can be analysed in terms of their degree of power and their degree of interest in the project. This process allowed mapping and prioritizing the stakeholders to be involved in the planning and development of the geopark in the future. The results of the stakeholder's analysis can be separated in three levels of action:

Local level: The entities directly involved in planning include the Municipality of San José de Maipo, the Cajón del Maipo Chamber of Tourism AG, the Association of Local Tourist Guides AG, the San José de Maipo Polyvalent High School, the Municipal Corporation of Education, the 7 local schools, the administration of Protected Areas, local media, the Community Environmental Committee, NGOs, and the Community Union of Neighbourhood Councils. Direct beneficiaries are tourism entrepreneurs, students, landowners, and the community in general.

Regional and national level: In the public sector, is needed a strong involvement of the Metropolitan Regional Government through the Regional Corporation for Territorial Development and Tourism, the central administration of protected areas (CONAF), the National Tourism Service (SERNATUR), the National Geology and Mining Service (SERNAGEOMIN), the Ministry of National Goods, the Ministry of the Environment, the Ministry of Science, and the Institute for Agricultural Development.

It will have a direct impact on the activity of the region's tour operators working in the Cajón del Maipo. A better and more diverse offer will be provided to thousands of visitors and tourists. There will be more opportunities for educational fieldtrips for schools and high schools in the region on topics related to natural sciences, history, and geography. Scientific work will be articulated with universities and research centres. Indirectly, the initiative will impact all the inhabitants of the metropolitan region that

benefit from the ecosystem services of the Cajón del Maipo, such as water supply, temperature regulation, carbon dioxide capture, and the existence of natural spaces for recreation and nature tourism.

International Level: To achieve and maintain the UGGp designation, a relationship must be maintained with the Global Geoparks Network, the Latin American and Caribbean Geoparks Network, and the International Geoscience and Geoparks Programme of UNESCO, particularly with the Montevideo Office. In addition, networking with other UGGPs in the region and the world should be pursued. Collaboration has already taken place with Kütralkura (Chile) and Grutas del Palacio (Uruguay), which should be strengthened and expanded.

6.3 Planning stage

As a result of the planning process, it was proposed to develop the programme for sustainable management and use of the heritage of the commune of San José de Maipo, called "Cajón del Maipo Geopark", which aims to promote sustainable development in this territory with a holistic management model of conservation, education and geotourism, which will be implemented with a "bottom-up" approach. This programme is articulated in four strategic axes (so-called components), which include 25 activities deployed in a Logical Framework Matrix, including indicators, means of verification and assumptions in each one. The four strategic axes are defined below and shown synthetically in figure 18.

Component 1: Governance and territorial management: This component will be addressed through a strategic planning process, which will include local and regional participation, and will seek to articulate national and international support. Expected results include the generation of a stakeholder map, the design of a governance and management model, the implementation of governance, and the preparation of a participatory and consensual master plan with a 5-year horizon.

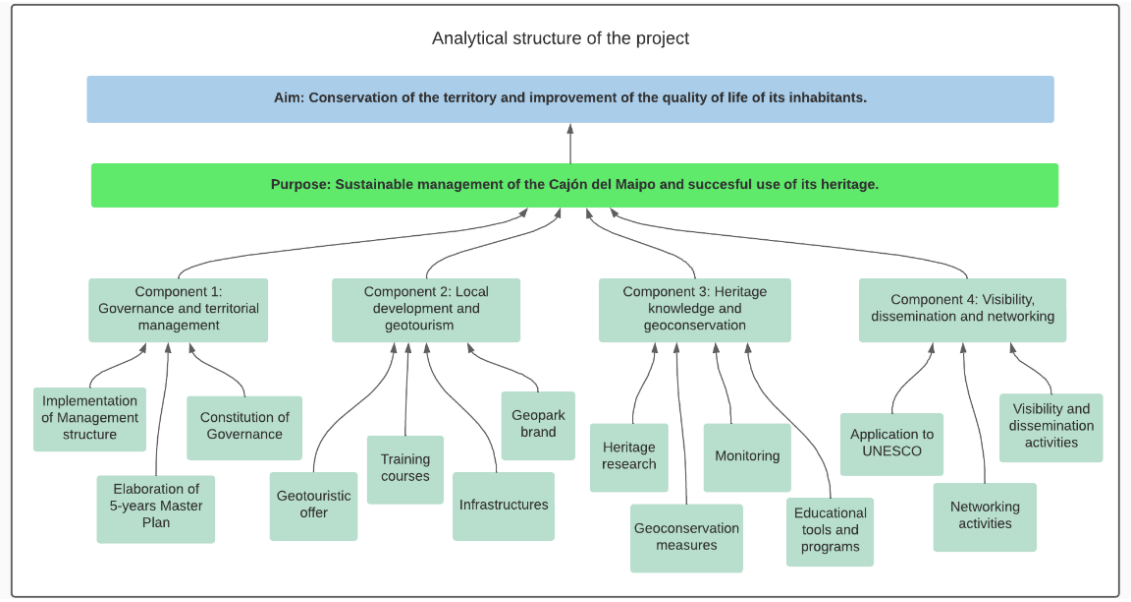


Figure 18: Analytical structure of the project, based on the Logical Framework Approach. The aim, the purpose, the components, and some of the activities are indicated.

Component 2: Local development and geotourism: This component seeks to improve the sustainability of tourism activities through innovation, human capital formation, co-design of tourism experiences and products, the creation of a brand of identity, the design of a marketing strategy and the articulation of the geotourism value chain. This will help to diversify and complement the tourism offer in the destination and to develop an identity as a sustainable tourism destination.

Component 3: Heritage knowledge and geoconservation: This component seeks to promote knowledge, appreciation, and conservation of local natural and cultural heritage, with emphasis on its most relevant and vulnerable attributes. This includes studies on local natural and cultural heritage, a plan for its conservation and sustainable use, a GIS database, developing citizen science for monitoring local heritage, and developing educational tools for different audiences. It is also necessary to implement a venue for heritage interpretation.

Component 4: Visibility, dissemination, and networking: This component seeks to increase visibility, promotion, and integration with national and international cooperation networks. To this end, efforts must be articulated for national and international recognition of the territory and its heritage, organize activities such as

seminars and a national symposium, and develop initiatives such as the development of a website, a guidebook and maps, identification signage, information points, press releases and related activities.

6.4 Proposed governance and management structure

The Geopark Management Plan 2021-2023, which for now is only a technical proposal that must be approved and financed by the Regional Government must have a management and governance structure that allows its correct implementation. As part of the planning process and because of the stakeholder analysis, a management structure for the geopark is proposed, composed of the following management and decision-making bodies: the Geopark Association, the Geopark Council, the Local Board, the Scientific Committee, and the Partners (Fig. 19). This structure should be formalized through a framework partnership agreement.

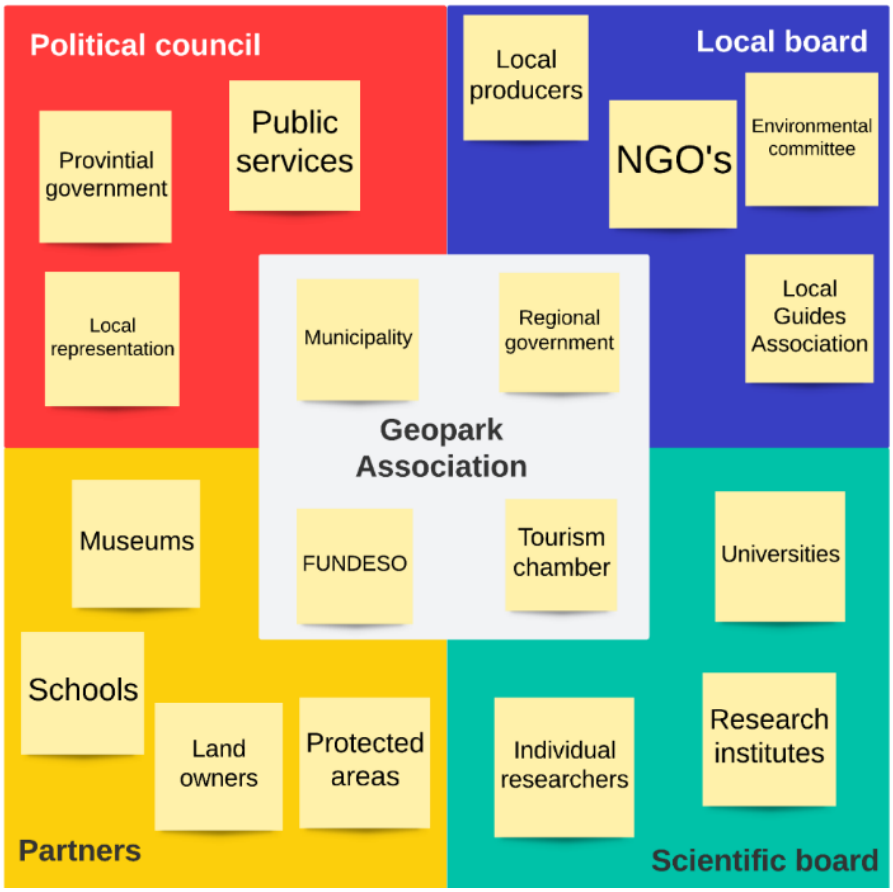


Figure 19: Generalized governance model proposed for the Cajón del Maipo Geopark project as part of the strategic planning process.

Geopark Association: It is recommended that a municipal association to be constituted can manage the geopark in the long term, legalizing the informal working structure that constitutes the Geopark Committee. This is a good option because is an adaptable public-private collaboration model capable of integrating more actors in the future. Initially, it is proposed that it be composed of the Metropolitan Regional Government and its Development Corporation, the Municipality of San José de Maipo, the Cajón del Maipo Chamber of Tourism and FUNDESO. This figure should include a professional team composed of at least two full-time staff who are responsible for coordinating and leading the project. The thematic work in each component should be supported by professionals from the entities that make up the Association. For example, the Municipality can make available a fraction of the workload of professionals from its Tourism, Environment and Education departments for specific activities coordinated by the Association. It should have an annual planning, and at least one board meeting per semester. It is recommended to study the example of the Arouca UGGp and its Association, which fulfils the same function with proven success.

Political Council: This is a coordinating body that incorporates actors from public services and representative entities at the local, regional, and national levels. It is expected to coordinate the efforts of these entities, as well as validate and enhance the progress of planning and implementation. It should have a president, who may be the Regional Governor, and at least one annual session. It is recommended to study the Villuercas-Ibores-Jara UGGp and its Geopark Council, which fulfils the same function with proven success.

Local Board: To ensure that the geopark is managed as closely as possible to its territory and its most representative entities, a Local Board, without legal entity, is proposed. It is a coordinating body that incorporates actors that can contribute to the geopark in its various components, including NGOs, local producers' associations, the Association of Tourist Guides, the Communal Environmental Committee, and individuals. Led by the Territorial Coordinator, its main functions are the proposal of activities in the geopark, as well as their follow-up.

Scientific Committee: The Scientific Committee is an advisory body in the scientific and educational areas of the geopark, and its members can inform or actively participate in activities such as: promotion of scientific research for the improvement or protection of the geological, natural, or cultural values of the geopark; provide scientific visibility with publications, seminars, and events of scientific nature; as well as advising educational projects of the geopark. It is composed of representatives from universities, research centres and individual researcher members, led by the Scientific Coordinator.

Associate Partners: Agreements must be formalized between the Geopark Association and the territory's partners whose actions are framed and aligned with the Cajón del Maipo Geopark vision. The associated partners, through their own company or organization, will promote, support, and facilitate, encourage, and enable local projects, initiatives and events that contribute to protect and make the geopark known locally, nationally, and internationally. Partners include museums, protected areas, landowners, educational centres, and private companies.

6.5 Relevant instruments and strategies

The Cajón del Maipo geopark is intersectoral and requires collaboration with entities at different levels; therefore, it is related to various and numerous planning instruments and development strategies. Table 7 lists some of the strategic elements with which the work plan shares standards and lines of work, with which it should be coherent, pertinent, and articulated.

Table 7: Instruments and strategies related with Cajón del Maipo Geopark Project.

Instrument	Institution	Level	Topic
2030 Agenda and 17 SDG	United Nations	International	Sustainable Development
IGGP Operational Guidelines	UNESCO	International	UGGp
2030 Agenda Implementation in Chile	Ministry of External Affairs	National	Sustainable Development
National Strategy of Biodiversity Conservation 2017-2030	Ministry of Environment	National	Conservation
National Strategy of Tourism 2030	Undersecretary of Tourism	National	Tourism
National Plan for the Development of Sustainable Tourism	Undersecretary of Tourism	National	Tourism
National Plan to Promote the Mountain Tourism	Production Development Corporation	National	Tourism
Tourism Infrastructure Master Plan to 2030	Ministry of Public Works	National	Tourism
Culture National Policy 2017 – 2022	Ministry of Culture	National	Culture
National Science, Technology, Knowledge, and Innovation Policy	Ministry of Sciences	National	Science
Regional Development Strategy	Regional Government	Regional	Development
Plan of the Regional Governor	Regional Government	Regional	Development
Regional Strategy of Biodiversity Conservation 2015-2025	Ministry of Environment	Regional	Conservation
Strategic Regional Programme "Andes Santiago"	Production Development Corporation	Regional	Tourism
Metropolitan Regulatory Plan	Ministry of Urban Development	Regional	Land-planning
Local Development Plan	Municipality	Local	Local Development
Tourism Ordinance	Municipality	Local	Tourism
Environment Ordinance	Municipality	Local	Conservation
Municipal Education Development Plan	Municipality	Local	Education

7. Seven proposals for geoconservation

The strategic planning presented above allowed the identification of the problem, the definition of objectives and the proposal of a practical operational plan for its implementation. This plan has been designed to be developed in the geopark during 24 months, with the participation of local, regional, national, and international stakeholders under a defined management and governance structure. In addition, one of the purposes of this work is to contribute to the geoconservation of Cajón del Maipo by proposing concrete initiatives concordant with the planning process results described above.

The proposals have resulted from a combination of the author's own ideas, inspiration from previous projects and needs identified with the Logical Framework Approach and are feasible in the medium term, contributing to the sustainable local development and creation of a UGGp. Each proposal is briefly described in the following pages, indicating the name of the project, the objectives, the relevant background, the expected results, and the actors involved:

1. Training Course “Geotourism and heritage of Cajón del Maipo”
2. Interpretation centre “Refugios del Yeso”
3. Geotrail in the “Mirador de Cóndores” Municipal Reserve
4. Community planning for the “Humedal de Baños Morales” Municipal Reserve
5. Citizen Science Programme "Voluntarios por el Agua"
6. Interactive Exposition “Atlas de una Cordillera Viva”
7. Podcast “Conciencias de la Tierra”

Beyond the quality or originality of each one of the proposals, it is important to analyse their contribution to local sustainable development, to understand its contribution to the Cajón del Maipo Geopark project, and to understand the relevance of the initiatives regarding instruments, policies, or strategies they are aligned with, including at the national, regional, or communal scale.

7.1 Training Course “Geotourism and heritage of Cajón del Maipo”

Between July and November 2020, the first version of the official training course of the Cajón del Maipo Geopark Project was developed –"Introduction to Geotourism and to the Heritage of the Cajón del Maipo Geopark”[18] – coordinated by FUNDESO and UTEM, with the support of the Municipality of San José de Maipo and the National Commission for Cooperation with UNESCO. The course was free of charge and had 209 participants, of which 174 (83%) were residents of the commune of San José de Maipo, who work in the tourism sector or related activities, but also teachers, high school and university students, social leaders, and other relevant actors. It is important to emphasize that this training received 556 candidates, so selection criteria had to be applied to focus the target audience (Vergara et al., 2021).

The trainees participated in a total of 16 classes, given by local, national, and international experts on topics related to UGGp, sustainable development and geotourism, as well as natural and cultural heritage of the geopark (Table 8). Given the Covid-19 pandemic, the course was done remotely. Each asynchronously class lasted between 40 and 60 minutes and complementary material was made available to students. In addition, three synchronous webinars were held to clarify doubts and to promote social interaction. The course included four evaluation tests where the diagnostic test and the final cumulative test were designed to be comparable and to quantify the progress in the trainees' knowledge (Vergara et al., 2021).

Finally, 175 participants were approved, which required a 60% pass rate in the evaluations and 80% class attendance. In the diagnostic evaluation, an average grade of 4.3/10 was obtained, and in the final cumulative test, the grade was 8.8/10, quantitatively showing a remarkable progress. It is estimated that ~4,500 effective hours of training were given, with a budget of less than 5,000 euros. Following the end of the course, a satisfaction survey was sent to the students, which was answered by 115 people. To the question "Do you consider that the course and its contents were useful for your training?” An average response of 9.88/10 was obtained. To the question "Are you interested in participating in more courses organized by the Cajón del Maipo Geopark project?” 98.3% answered "Yes". In the open question on aspects to improve

[18] https://geoparquecajondelmaipo.cl/index.php/curso-en-linea/

for future editions, the most common request was to include field activities to complete the training cycle (Vergara et al., 2021).

It is difficult to quantify the impact generated by this experience in the territory, but very interesting consequences have been observed, such as the appearance of local geotourism companies, the strengthening of partnerships between local stakeholders and the emergence of local conservation initiatives. The experience described shows, on the one hand, the success obtained despite the limited budget and the pandemic context. Considering the lessons learned and the comments expressed by the participants, it is proposed to carry out a shorter version of the course which includes field trips.

Table 8: Modules, topics, and lecturers of the first training course of Cajón del Maipo Geopark.

Topics	Lecturer
Module I. UNESCO Global Geoparks	
1. UNESCO Global Geoparks	Denise Gorfinkiel, IGGP UNESCO
2. Geoparks as a tool for development	Diego Irazábal, Grutas del Palacio UGGp
3. The first Chilean Geopark: Kütralkura	Manuel Schilling, Kütralkura UGGp
4. Geotourism	Macarena Vallejos, UTEM
5. Cajón del Maipo Geopark Project	Anthony Prior, FUNDESO
Module II. Natural and Cultural Heritage of Cajón del Maipo Geopark	
6 y 7. Local Geoheritage	Camilo Vergara, FUNDESO
8. Local Biodiversity – Flora	Carlos Salas, Vivero del Maipo
9. Local Biodiversity – Fauna	Kendra Ivelic, Refugio Animal Cascada
10. Local Archeological heritage	Luis Cornejo, Universidad Alberto Hurtado
11. Local Cultural heritage	Jerónimo Vergara, FUNDESO
Modulo III. Tools for sustainable development	
12. Conservation and Climate Change	Daniel Henríquez, Meri Foundation
13. Good practices for sustainable tourism	Jorge Moller, ONG Regenera
14. Destination management	Felipe Vera, Expert of the WTO
15. Tourism in geoparks	Rodrigo Salas, Great Experience
16. The Geopark brand and geoproducts	Pilar Valenzuela and Marfilda Sandoval, UTEM

A second version of the training course is now proposed for the Cajón del Maipo Geopark community, aimed at residents of the commune of San José de Maipo who work in tourism or related activities, such as handicrafts or local products. However, the participation of teachers, high school and university students, social leaders, municipal officials, local authorities, among other relevant actors for the development of the territory and of the geopark will also be welcome.

The course will focus on four main modules: I. Geoparks as a development model, II. The geoheritage of Cajón del Maipo, III. Other heritages of Cajón del Maipo, and IV. Geotourism and geoconservation, and will be developed in 5 working days, with about 30 teaching hours (Table 9).

The course will include a theoretical-practical and competence-based approach, combining the accumulated knowledge and good practices existing in successful UGGps with the real needs and shortcomings observed in the local context. The pedagogical conceptual framework is based on Rieckmann (2018), which states that the sustainability performance depends on the interplay of knowledge and skills; values and motivational drivers; and opportunities (Fig. 20).

The objective is to raise local community and relevant actors' capacities about geotourism, local heritage and Cajón del Maipo Geopark. The work plan is composed of five main stages, which are summarized in Table 11.

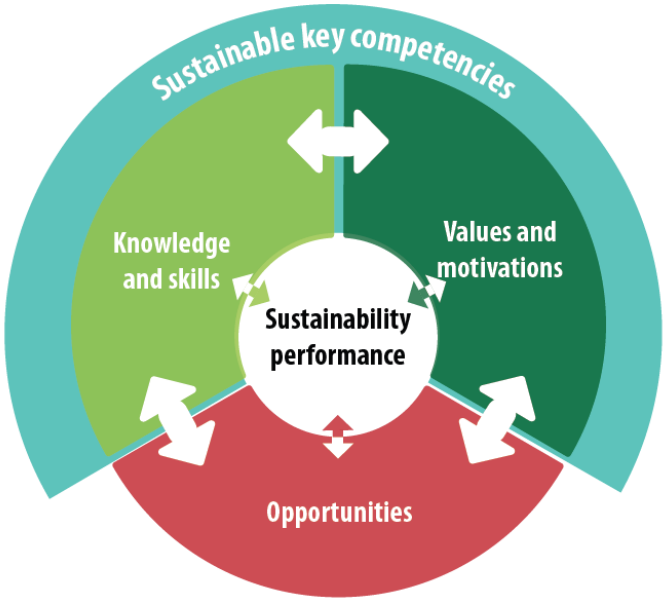


Figure 20: Conceptual framework for developing education programmes focused in competence-based sustainability performance, according to Rieckman (2018).

Table 9: Proposed preliminary schedule for the second training course of the geopark.

Introduction to geotourism and heritage of Cajón del Maipo Geopark		
	Morning	**Afternoon**
Day 1	Module I: Cajón del Maipo aspiring UGGp	Module II: Cultural Heritage
Day 2	Fieldtrip 2: Geotouristic route in El Volcán Valley	
Day 3	Module III: Natural Heritage	Module III: Geoheritage
Day 4	Fieldtrip 2: Geotouristic hike in Mirador de Cóndores	
Day 5	Final workshop and assessment	

Table 10: Main stages of the work plan proposed for the development of the training course.

Stage	**Task**	**Description**
Initiation	Identify the areas addressed during the course.	Collection and synthesis of information, based on accumulated knowledge, good practices of successful geoparks, and the needs of the territory, which will include as main sources: (i) bibliography, (ii) survey to potential course participants, and (iii) a participatory workshop. Look for sponsorships. Contact teachers.
Design	Develop the outline of the training course.	Definition of learning outcomes and objectives, which will consider the level of knowledge, skills, attitudes, and ethics towards conservation of the respondents of the survey. The Learning Objectives will be formulated under the revised Bloom Taxonomy, and following the S.M.A.R.T. framework (Anderson and Krathwohl, 2001). Preliminarily, it is proposed to develop it in 4 main modules.
Development	Develop the modules, curricula, and related material of the training course.	Methodology: This stage is the most time-demanding of the process and is where the elements that make up the course will be developed, including videos, PowerPoint presentations and infographics; reading material and references; quizzes and practical assessments; learning tools; and a Brief user guide for attendees.
Implementation	Offer and implement the course.	The implementation includes the following aspects: 1. Enrollment and registration. 2. Academic management and technical support. 3. Assessment and certification. 4. The organization of course opening and closing ceremonies.
Evaluation and Follow-up	Acquire lessons learned, consolidate results and project into the future.	At this stage, the corresponding evaluations and accountability reports will be elaborated, with respect to technical and financial aspects. Also is included a satisfaction survey. Follow-up and support modalities will be explored to promote networking and continuous improvement. Whatsapp groups and mailing lists will be created, and a series of Webinar events where students can show their progress.

7.2 Interpretation centre “Refugios del Yeso”

Despite the high heritage value and the large number of tourists that visit Cajón del Maipo, to date there is no interpretation centre about its natural and/or cultural heritage. This is one of the weaknesses identified by the team in relation to the creation of a UGGp, where the existence of this type of space is indispensable. According to the IUCN (Crofts et al., 2020), interpretation is a method of communication that aims to reveal the significance of an area's resources, rather than just to convey factual information. The guiding principle of effective interpretation is "through interpretation, understanding; through understanding, appreciation; through appreciation, protection".

In this context, FUNDESO, the Chamber of Tourism and the Refugios del Yeso tourist centre have started to work together to create the first interpretation centre in the Cajón del Maipo Geopark under a public-private management model. A formal agreement of collaboration is under construction.

This project is located at Refugios El Yeso heritage site, a singular architectural complex which has spontaneously acquired a cultural attraction character due to its proximity to other attractions such as the Embalse El Yeso Geosite. The camp, formed by fifteen pavilions of parabolic section and four orthogonal ones, were built as camp for the workers of the construction of the Reservoir "El Yeso" in the year 1954 (Fig. 21).

Figure 21: Refugios El Yeso heritage site.

The objective of this project is to use one of these pavilions to provide a space for information, orientation, and awareness about natural heritage for visitors and students in Cajón del Maipo Geopark. The proposed topic for the Refugios del Yeso interpretation centre is the local natural and cultural heritage, with emphasis on geoheritage of El Yeso Valley.

Preliminarily, the following axis of contents are proposed:

1. Geoheritage of El Yeso Valley;
2. Archeological heritage of El Yeso Valley;
3. History of Campamentos del Yeso;
4. Glaciers, lakes, and the importance of water.

A broad spectrum of visitors is expected at this facility, mainly:

- Elementary and high school students from the Metropolitan Region, in fieldtrips associated with natural sciences, history and geography.
- Tourists who are interested in getting to know the place from a cultural and natural points of view.
- University students and scientists, who will be able to use the facilities as a base of operations for their research and teaching activities.

A preliminary project is currently under construction to apply for funding, based on some examples (Fig. 22). The interpretation centre is expected to be built during the year 2023, including a small cafeteria and a souvenir shop offering sustainable tourism products.

Figure 22: Examples of interpretation centres visited by the author while preparing this dissertation. a) Villuercas-Ibores-Jara UGGp interpretation center, and b) Peneda-Gerês National Park interpretation center.

7.3 Community planning for the “Humedal de Baños Morales” Municipal Reserve

The “Humedal de Baños Morales” (HBM) is a *vega*, a typical high Andean wetland ecosystem of central Chile. Due to its social and environmental importance, since 2019 the Municipality of San José de Maipo is working to create its first Municipal Nature Reserve (RENAMU) in this place, managed at a local level and together with the community. The reserve was officially inaugurated in February 2022 by the mayor of San José de Maipo and community representatives[19].

Figure 23: Humedal de Baños Morales Municipal Reserve.

This project aims to contribute to the creation of the Municipal Reserve through research, environmental education, and community planning for the protection of the wetland and its ecosystem services.

To achieve this, a virtuous alliance has been generated between the municipal administration, the community, and a technical team, moving towards the development of a management plan based on environmental education and community ownership, following the adaptive management proposed in the "Open Conservation Standards" model, focusing on its first two stages[20] (Fig. 24). This methodology was developed by the Conservation Measures Partnerships (CMP) with the purpose of unifying the work of design, management, and monitoring of conservation projects, the essential steps for the successful achievement of objectives and goals.

[19] Revista Cajón del Maipo: Inauguran el primer humedal urbano de San José de Maipo en Baños Morales. https://revistacajondelmaipo.cl/2022/02/12/inauguran-el-primer-humedal-urbano-de-san-jose-de-maipo-en-banos-morales/

[20] Nature Conservancy: The Open Conservation Standards. https://conservationstandards.org/about/

Figure 24: Adaptative management of the Open Conservation Standards. Source: CMP (2020).

The HBM presents many threats and is deteriorated, due to climate change, cattle ranching, and invasive tourism. The main needs to be addressed are to bridge the gap in ecosystem understanding and valuation of the wetland and its ecosystem services by the surrounding community.

The main objective is to contribute to community ownership and social valuation of HBM through a programme of environmental education and participatory management, within the framework of its declaration as a Municipal Nature Reserve. This will be done by encouraging joint work between researchers and members of the Cajón del Maipo community, which is expected to promote a process of sustainable environmental conservation over time.

The main activities of the project are the following:

- Basic research on the wetland: The aim is to characterize the social and environmental value (geological, ecosystemic, hydrological, cultural, and recreational) of Baños Morales wetland under a scientific and holistic vision. It will be based on bibliography, interviews to experts and locals, and participatory workshops.
- Environmental Education: A process that begins with the sensitization about HBM, with a workshop that presents its importance, invites them to discover it in a tour and collects their experiences and milestones; it continues with the invitation to develop a sense of responsibility and get involved in its protection with a massive cleanup event and finally interpretative routes are developed for the social promotion of the value of the wetland, aimed at its inhabitants.
- Material development: Different support materials will be developed during the project, based on the information gathered in the basic research phase, including an illustrated infographic summary of the wetland, for physical reproduction and digital dissemination, and an 8-minute mini-documentary on the project and the wetland.

The project has been formulated in accordance with the terms and conditions of the Chilean Ministry of the Environment's Environmental Protection Fund for the Conservation of Urban Wetlands (FPA Conservación de Humedales Urbanos[21]) and has been awarded with $6,000,000 CLP (6,672 euros).

[21] https://fondos.mma.gob.cl/que-es-fpa/

7.4 Geotrail in the Mirador de Cóndores Municipal Nature Reserve

The Mirador de Cóndores geosite is located on the southeastern flank of the Colorado River valley and is an excellent place to observe geological and geomorphological features of the Andean Mountain range (Fig. 25). On the ascent path from the road to the viewpoint, it is possible to observe outcrops of different types of Cenozoic rocks and Quaternary deposits. The viewpoint is located on a plateau formed by volcanic, volcanoclastic, and sedimentary strata that dip 15-20° to the southeast and allows to observe the summit of the Tupungato volcano to the northeast, the highest point of the Cajón del Maipo at 6570 m asl. According to the geoheritage inventory, it is a geosite with very high tourism potential (Vergara et al., 2019).

The Mirador de Cóndores Municipal Nature Reserve is an initiative that arose from the decision of the Mayor of San José de Maipo to manage this iconic and highly visited geosite trough the creation of the second RENAMU of the commune. The idea is to promote conservation, environmental education, and sustainable tourism, and generating a participatory management model that coordinate public and private entities, the organized local community, academia, and organizations dedicated to the preservation of natural and cultural heritage. The "Mirador de Cóndores Technical Board" was constituted in February 2022 in order to develop and implement a sustainable Management Plan for this issue (Municipality of San José de Maipo, 2022).

Figure 25: Mirador de Cóndores Geosite.

What gives the place its name is the possibility to watch Andean Condors (*Vultur gryphus;* Fig. 26), one of the largest flying birds on the planet, which is also considered a national symbol not only in Chile but in several other Andean countries (Bolivia, Peru, Colombia, Argentina, and Ecuador). These birds are considered vulnerable by the IUCN, and in particular in this place there have been reported cases of damage to the specimens due to massive and uncontrolled tourism during the last 5 years. In fact, in 2021 a controversial cover page was published in a national newspaper showing tourists harassing a condor at the edge of the cliff of the Mirador de Cóndores (Fig. 27).

Figure 26: Andean Condor in the Mirador the Cóndores. In the background is the Tupungato volcano.

FUNDESO's specific objective within this technical board is to promote the interpretation and management of the geological heritage and geotourism resources of Mirador de Cóndores Natural Reserve. The purpose of this proposal is to provide technical inputs, systematized information, and audiovisual material for the development of educational and tourist interpretation tools on the geological heritage of the geosite. The expected products and results are the following:

- Local inventory of sites of geological interest and other sites of tourist interest;
- Video capsule of the Geological Heritage of the Mirador de Cóndores;
- Proposal for an interpretation programme of its geological heritage;
- Field training and transfer activities for local guides and municipal officials.

This project will be implemented in 2023 with the support and participation of other stakeholders of the technical board, including the municipality, the Chamber of Tourism, and the Local Guides Association.

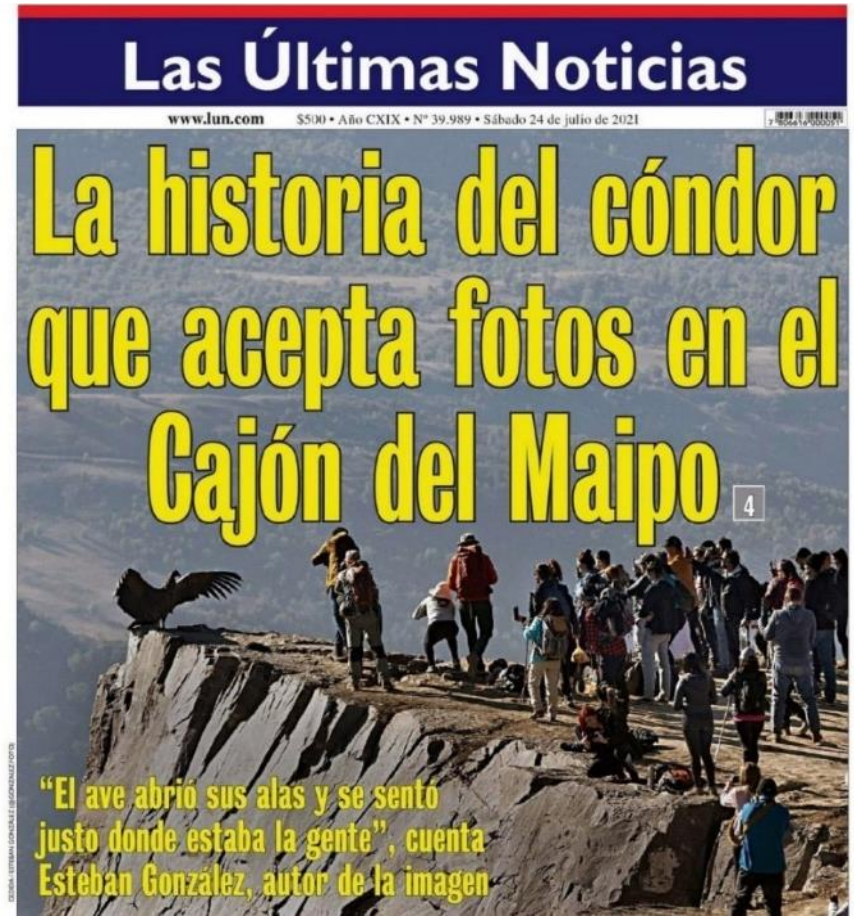


Figure 27: Controversial front page of the newspaper Las Ultimas Noticias, showing tourists harassing an Andean condor at the Mirador de Cóndores.

7.5 Citizen Science Programme "Voluntarios por el Agua"

The Cajón del Maipo Geopark includes the headwaters of the Maipo River basin and its tributaries, which are home to 832 glacial bodies, which together cover 378 km^2 (7.6% of the communal area), including a wide variety of glacier types, deposits, and landforms. The glaciers, together with the rivers, lakes and wetlands of the basin are the main source of water for consumption, agriculture, hydroelectric power, and industry in the Metropolitan Region of Santiago, which concentrates about 40% of the country's population.

Since 2010, this region has experienced the so-called "Megadrought of Central Chile", observed by an increase of ~0.8 °C in mean annual air temperature and a reduction of up to 40% in annual precipitation (Fuentealba et al., 2021). Recent studies show that glaciers are retreating drastically (Farías-Barahona et al. 2019; Fig. 28A), while lake water volume and river flow is decreasing (Fuentealba et al., 2021; Fig. 28B). These negative trends are driven by climate change but are being accelerated by anthropogenic activities in the region (e.g., mining) and have serious implications for the future water security of the city of Santiago (Farías-Barahona et al., 2020). Despite clear trends, there is little information regarding the water quality of the rivers, which is proposed to be addressed from a citizen science perspective.

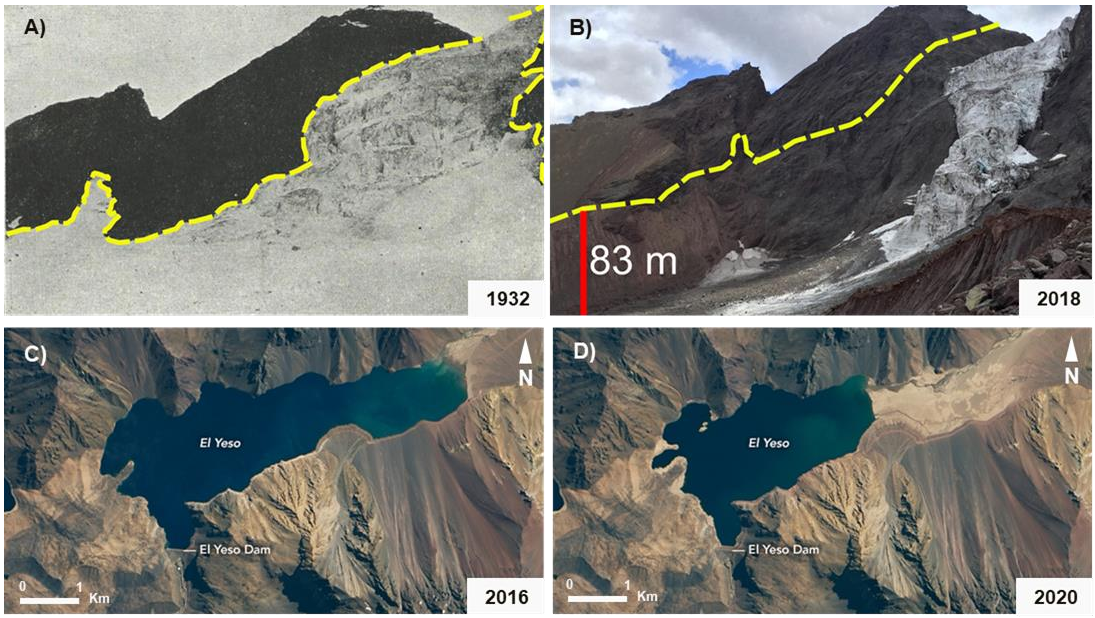


Figure 28: A) and B) Changes observed in the El Morado hanging glacier geosite for the period 1932-2018 (Farías-Barahona et al., 2020). C) and D) Satellite images of the Embalse El Yeso geosite in the years 2016 and 2020, respectively (source: NASA).

In April 2022 a citizen science project "Voluntarios por el Agua" has started, with the objective of developing a monitoring system for the Maipo River, empowering the citizens on water crisis through participatory strategies.

This citizen science programme measures the "vital signs" of the Maipo River and its tributaries using low-cost sensors operated by community volunteers, including measurements of pH, hardness, turbidity, and other related parameters (Fig. 29). It started 6 months ago with monthly measurements taken in 5 specific locations. The programme has more than 50 volunteers and has been selected for the Public Science 2021 Contest of the Chilean Ministry of Science. The “Comité Ambiental Comunal” (CAC) of San José de Maipo is coordinating the programme, under the coordination of Zoe Fleming, a researcher at the University of El Desarrollo.

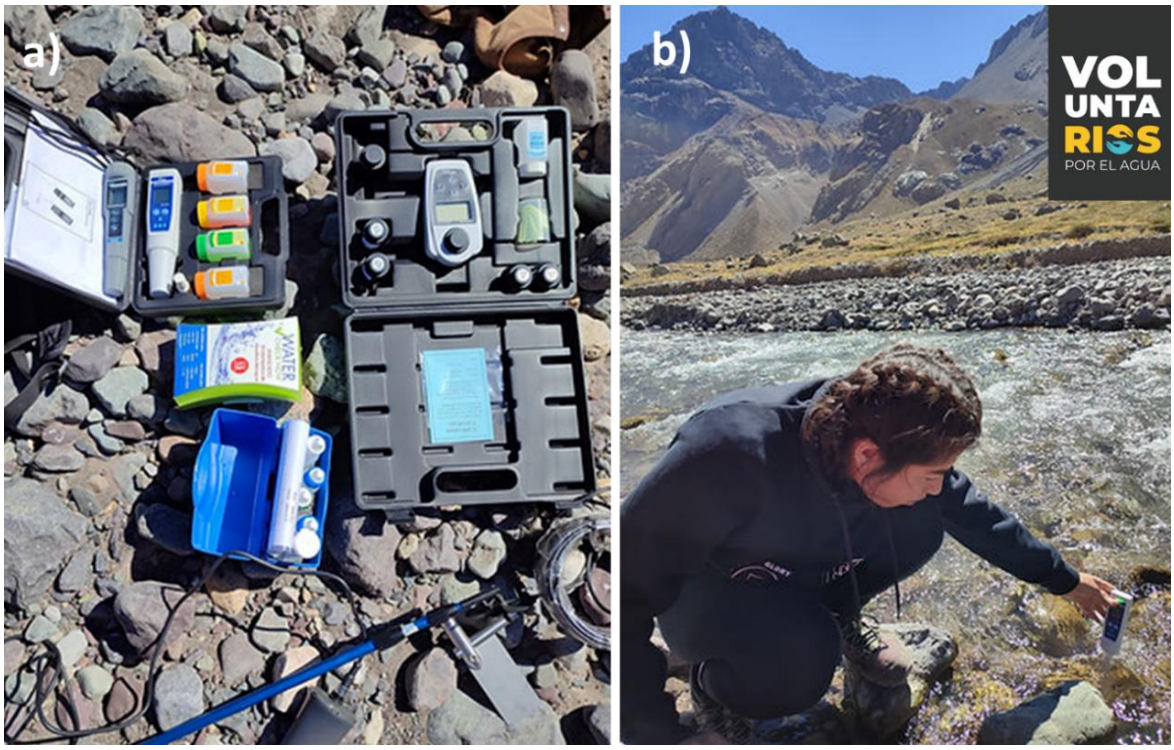


Figure 29: a) Multiparameter low-cost kit for water and river monitoring. b) A volunteer taking measurements of the water parameters. Source: Zoe Fleming web page[22].

[22] https://www.zoefleming.com/water-volunteers

7.6 Educative Programme “Atlas de una cordillera viva”

As demonstrated in previous chapters, Cajón del Maipo has a cultural and natural heritage of high importance, which presents a high risk of degradation due to its intrinsic fragility and natural and anthropogenic threats. All this is aggravated by the low knowledge and lack of appreciation of local natural and cultural heritage by society in general, including communities, authorities, students, and visitors, which explains the scarcity of initiatives aimed at the sustainable development of the territory.

The science outreach project "Atlas de una Cordillera Viva: un viaje por la memoria natural y cultural del Cajón del Maipo" is an idea born in response to SDG 4 of the UN Agenda 2030, which underlines that education is the key catalyst for all the others SDGs. This project seeks to disseminate the value and vulnerability of Cajón del Maipo heritage through an interactive audiovisual production with an holistic approach, including geological, hydrological, biological and cultural scientific aspects. Thus, it is intended that the community and visitors can understand the memory of the territory in order to contextualize the present crisis, and from this, project future scenarios. This is intended to promote an integral understanding of the territory in the context of education for sustainable development. The topics of the seven episodes of this production are presented in figure 30.

The project seeks to develop an audiovisual product in an innovative support such as videomapping, a technique that allows the projection of animations or images on irregular surfaces achieving an artistic and unusual effect. The surface on which the projection will be made corresponds to a model that represents the relief of the Cajón del Maipo (an example of this type of model is shown in figure 31).

This audiovisual production will be distributed online and in person, with the aim of generating a significant experience for students and teachers from local schools; tourism students from the Liceo Polivalente and higher education institutions in the region; local workers and entrepreneurs related to tourism; as well as members of the local community in general and visitors. The project has formal letters of support from the Municipality, local schools, Chamber of Tourism, etc. and it will be submitted to the Public Science 2022 Contest of the Ministry of Science.

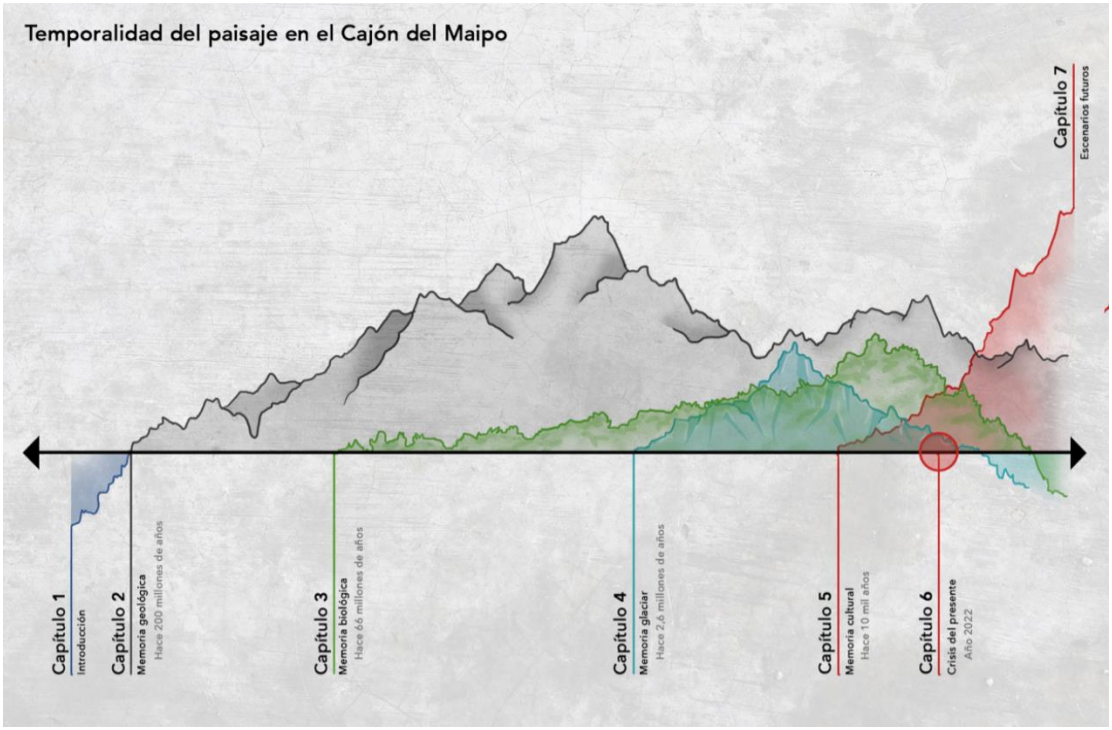


Figure 30: Episodes of the audiovisual production “Atlas de una cordillera viva”

Figure 31: Example of projection in a topographic relief model (Terras de Cavaleiros UGGp).

7.7 Podcast “Conciencias de la Tierra”

One of the biggest problems for the development of geoconservation in Cajón del Maipo, and in Chile, is the lack of public understanding and knowledge about geosciences. Hence, social networks and digital platforms are a high-impact and low-cost tool for geosciences popularisation; Just as an example, the Facebook fan page of Cajón del Maipo Geopark has 12,400 followers[23] and the Instagram profile has 8,800 followers[24]. These tools, underutilized to date, have a high potential growth if approached systematically.

More specifically, the production of audiovisual spots is very efficient considering the cost/benefit they bring. An experience in the Cajón del Maipo Geopark was the production of the video "El Patrimonio Geológico del Cajón del Maipo" (2 min 49 seconds), which was published in 2018. With a production cost of less than 2,000 euros, it reached 353,200 people, with more than 103,500 reproductions in Facebook[25]. Another successful case, although with less impact, was the video "Geositio Remoción en Masa Las Amarillas". In these two specific cases, the interest of the public by this type of content, requiring a low investment, was clearly expressed. Therefore, we can deduce that this is an appropriate channel to develop communication initiative for the geopark.

Another relevant aspect is the quantity and quality of information and scientific research that is developed in the geopark that has not been properly communicated to the community, in topics that include geosciences, such as geological hazards, volcanology, or geology, but also other territorial aspects of broad interest such as biodiversity, archaeology, and culture. Therefore, there are a variety of topics, quality contents and possible interviewees of high interest for the community on these different topics, which need channels for their dissemination.

To disseminate the geoscientific knowledge developed in the Cajón del Maipo it is proposed to develop an audiovisual project on topics related to Earth sciences, environment and conservation, using an objective and scientifically rigorous perspective

[23] Facebook fan page: https://www.facebook.com/geomaipo
[24] Instagram profile: https://www.instagram.com/geoparque_cajondelmaipo/
[25] Patrimonio Geológico del Cajón del Maipo: www.facebook.com/geomaipo/videos/2138579413068350

but in a friendly way. The social networks of the geopark will be used for its diffusion (Instagram, Facebook and Youtube).

The main element of each video will be an interview to an expert who has developed some research on the topic, which will be complemented with scripted narration, images, and clips.

The name of the project is Conciencias de la Tierra, which is a play on words that expresses the two main intentions of the project: to raise awareness on environmental issues and to disseminate content on Earth sciences and the environment.

It is proposed to produce a first season of 8 chapters, with 20 minutes each. The topics and interviewees are summarized in table 11.

A pilot episode is being developed (episode 4) about the Laguna Negra geosite, which was studied by NASA as a planetary analogous by the Planetary Lake Lander[26] project, with the idea of developing strategies to explore the lakes of Titan (Parro et al., 2018; Pedersen et al., 2015). The interviewee was Nathalie Cabrol[27], NASA researcher and director of the Carl Sagan Institute, who was the leader of the Planetary Lake Lander project explorations at Laguna Negra (Fig. 32).

Figure 32: a) Logo of the podcast. b) Cap of the pilot with logo and translation. c) Cap of the interview with Nathalie Cabrol, researcher of NASA.

[26] SETI Institute: Planetary Lake Lander Project. https://www.seti.org/planetary-lake-lander
[27] SETI Institute: Nathalie Cabrol profile. https://www.seti.org/our-scientists/nathalie-cabrol

Table 11: List and description of the episodes of the Conciencias de la Tierra Podcast for its first season.

Episode	Interviewee	Synopsis	Topic
1. Cajón del Maipo Geopark	Anthony Prior, Executive Secretary of Cajón del Maipo Geopark	Cajón del Maipo has a geoheritage of international importance. Volcanoes, glaciers, and fossils that we must protect. We invite you to get to know them.	Cajón del Maipo Geopark Project
2. Cajón del Maipo is a school of geology	Reynaldo Charrier, Professor of the University of Chile	The Cajón del Maipo records the history of the Andes Mountain Range. Almost 200 million years of evolution make it a school of geology. Today we will talk to one of its most important researchers.	Geology of Cajón del Maipo
3. The Cajón glaciers are dying	David Antonio Farías Barahona. Researcher at Friedrich-Alexander-Universität	The Maipo River basin is the source and reserve of Santiago's water. In its upper areas there are more than 800 glaciers, which are receding at an accelerated rate. How does this affect us? Today we will talk to one of its greatest connoisseurs.	Glaciers of Cajón del Maipo and CC impacts
4. The Laguna Negra Geosite: a paradise out of this planet	Nathalie Cabrol, Director, SETI Institute Carl Sagan	The Laguna Negra is a place full of secrets. It has been studied by NASA for extraterrestrial reasons that very few know about. Today we will talk to a world eminence about this hidden wonder.	Laguna Negra as a terrestrial analogue
5. Many hazards, how to deal with them?	Gabriel González, Main Researcher, CIGIDEN	Active geology is not only wonderful, but also dangerous. Volcanoes, earthquakes, landslides, and a megadrought - how can we deal with them?	Geohazards and disasters in local history
6. The cradle of Chilean mountaineering	Álvaro Vivanco, past president, German Andean Club of Santiago	Summits over 6000 meters, and so close to the city. Let's review the historical expeditions and their relationship with science, in one of the historical places of mountaineering.	History of mountaineering and emblematic peaks
7. Native peoples and their relationship with geology	Luis Cornejo. Director of the Department of Anthropology, U. Alberto Hurtado.	An extreme territory inhabited for 10,000 years. Incas, Aconcaguas and Chiquillanes, how was their life in this place? Let's ask those who know more	Archeological sites of the Geopark
8. Before the mountains there was an ocean	Christian Salazar, Head of Geology School, Universidad Mayor	Marine fossils at an altitude of 3000 meters. Ammonites, ichthyosaurs, and other strange creatures tell us stories of a remote past.	Paleontological sites of the Geopark Main discoveries

The project will be approached with an audiovisual production format, which includes 3 main phases: Pre-production, Production and Post-production.

7.8 Summary

The proposals described above are not only ideas but each one presents different levels of progress in terms of management, funding, or implementation. Furthermore, they are projects that FUNDESO intends to promote over the next 2 years, with the support and participation of other relevant actors and stakeholders in the context of the Cajón del Maipo Geopark.

It is expected that these ideas, in addition to generating direct and indirect results and impacts, may be replicable and/or adaptable in other territories of the country, the region and the world that are working on the development of aspiring geoparks.

As a summary, Fig. 33 shows the strategic components of the Geopark Programme 2023-2024 in which each of the initiatives is framed, and in table 12 are shown the projects with their respective objectives, antecedents, and expected outcomes.

An essential tool for the proper management of the geopark that should be developed is a system for recording, controlling, and monitoring the activities and progress of the geopark, both at the general level and at individual level of tasks.

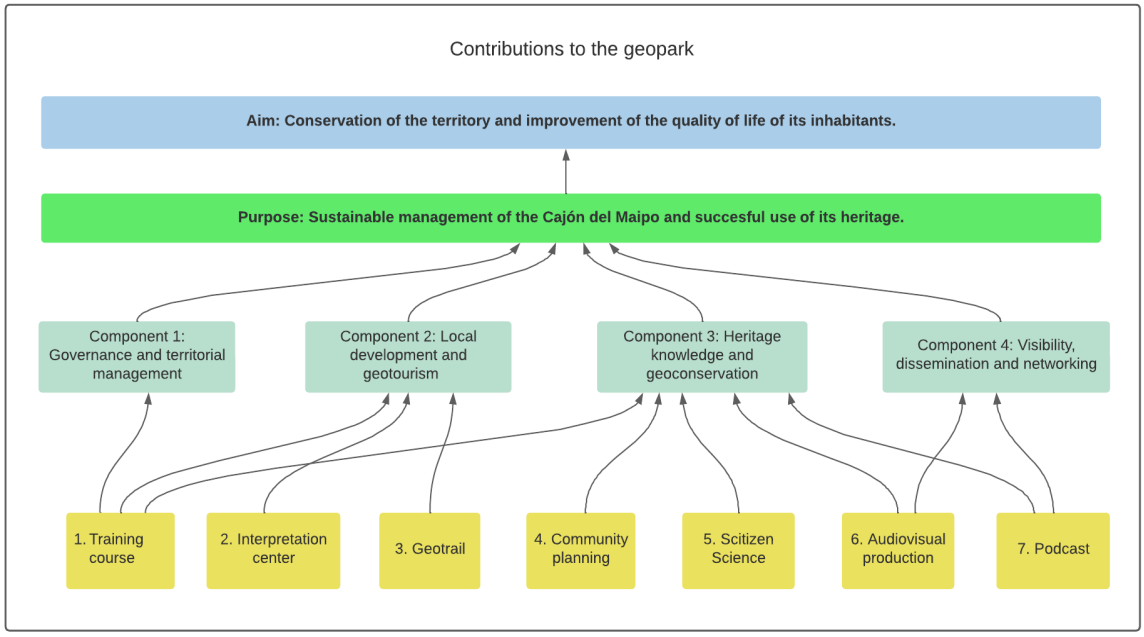


Figure 33: Contribution of the proposals for geoconservation to the Geopark Programme 2023-2024.

Table 12: Summary of the proposals for geoconservation.

Project	Objectives	Description	Antecedents	Expected outcomes
1. Training Course “Geotourism and heritage of Cajón del Maipo”	To install capacities in the local community and relevant actors about geotourism, local heritage and the Cajón del Maipo Geopark.	Official training course of the geopark for the local community, for tourism workers, handicrafts and local producers, teachers, university students, social leaders, municipal officials, local authorities, among other actors.	It is proposed to develop a second version of the successful online course of 2020, which had more than 200 participants.	40 people trained and certified with a 30-hour course.
2. Interpretation center “Refugios del Yeso”	To provide a space for information, orientation, and awareness about natural heritage for visitors and students in Cajón del Maipo.	Design and development of an interpretation centre about local natural heritage, with emphasis on geoheritage of El Yeso Valley, installed in a heritage building with historical importance.	There is a work agreement to be signed between the stakeholders in process.	Design and implementation of the first interpretation centre of the geopark in El Yeso.
3. Geotrail in the Mirador de Cóndores Municipal Nature Reserve	To develop education and geotourism interpretation tools on the geoheritage of the Mirador de Cóndores Municipal Reserve.	Characterization of the sites and elements of geological interest associated with the route, as a first step for the integration of geoconservation in its management plan and its tourist/educational use.	Is part of the creation of the Mirador de Cóndores Municipal Reserve, which has a Working Group led by the Municipality.	Inclusion of geoheritage and geoconservation in the management of the Reserve.
4. Community planning for the “Humedal de Baños Morales” Municipal Reserve	To contribute to community ownership and social appreciation of the Baños Morales Wetland and its natural values.	Programme of environmental education and participatory management, within the framework of its declaration as a Municipal Nature Reserve. This will be done by encouraging joint work between researchers and members of the community.	Is part of the creation of a Municipal Reserve in the area. It has been awarded by the Environmental Protection Fund of the Ministry of Environment.	Contribute to the Management Plan of the Municipal Reserve and implement programme of environmental education.
5. Citizen Science Programme "Voluntarios por el Agua"	To develop a monitoring system for the Maipo River that is low cost and sustainable over time, empowering the citizens through participatory strategies.	Citizen science program that measures the "vital signs" of the Maipo River and its tributaries using low-cost sensors operated by community volunteers, including measurements of pH, hardness, turbidity, and other related parameters.	It started 6 months ago and has taken 3 monthly measurements in 5 points. It has over 50 volunteers and was awarded in the Public Science Contest of the Ministry of Science.	Monitoring system of the Maipo river vital signs in at least 5 stations monthly operated by volunteers.
6. Interactive Exposition “Atlas de una Cordillera Viva”	To contribute to the appropriation of scientific knowledge about the value and vulnerability of Cajón del Maipo through an interactive audio-visual production based on video mapping.	Interactive audio visual production, with a holistic approach and including scientific knowledge in geological, hydrological, biological, and cultural aspects. It will use videomapping projected on a model representing the relief of Cajón del Maipo, based on a high-resolution digital elevation model.	Has formal support from the Municipality, the local schools, the Chamber of Tourism, etc. It will be submitted to the Public Science 2022 Contest of the Ministry of Science.	Get the funding in the Public Science Contest and implementation of the expositions programme.
7. Podcast “Conciencias de la Tierra”	To disseminate and popularise the geoscientific knowledge about Cajón del Maipo Geopark.	Geoscience outreach project for social networks, consisting of a season of 8 episodes in which experts who have studied the Cajón del Maipo from different disciplines will be interviewed. Each episode will have scripts and graphics to support the interviews.	To date, two interviews have already been recorded, with expert geoscientists collaborating with NASA and National Geographic, who have studied sites at Cajón del Maipo.	Emission of the first season, composed by 8 episodes.

8. Conclusion

The main purpose of this dissertation is to promote geoconservation and sustainable development in Cajón del Maipo Geopark Aspiring Geopark. This was approached from different perspectives and with different techniques, which allowed to understand the constrains of this case study and to project possible solutions.

A general conclusion, although it may seem obvious, is that geoparks are holistic, multisectoral and multilevel development projects, which implies countless challenges and different ways of facing them, where geoconservation is necessary but not sufficient. Therefore, in this work we have considered different aspects related to public policies, the interests of stakeholders and communities, the values and threats of geoheritage, and possible ways to assure its management and governance. Only by considering all these "ingredients" can a geopark be conceptualized in a broad and holistic manner and adapted to local social and cultural contexts.

Regarding the characterization of the case study, the following specific conclusions can be drawn:

- It has been demonstrated that the natural, cultural, and especially the geological heritage has a high scientific, touristic, and educational values, fully complying with the requirements demanded by UGGp. However, there are clear gaps and needs associated with its management.
- This territory faces great challenges, such as degradation due to unsustainable exploitation of its natural resources, mass tourism, the effects of climate change and risk of disasters, which represent serious threats to its community.
- The Cajón del Maipo geopark is a community initiative that attempts to contribute to address the problems described above by creating a UGGp.
- There is a record of the geopark's progress in all aspects related to its management, including advances in governance, planning, research, education, geotourism, protection, visibility, among others.
- The management structure, however, is not formal and lacks the funding required for the long-term implementation of an UGGp, which is a serious weakness.

These diagnostic elements made it possible to define proposals and recommendations, among which the following are considered:

- The geopark should strengthen its work through planned action. In particular, it is recommended to work on four thematic axes, which are consistent with the pillars of the UGGp and with the relevant development strategies and policies.
- The management structure needs to develop a multilevel and participatory governance, including a Geoparks Association, a Geoparks Council, a Local Board, a Scientific Committee, and links with partners.
- Finally, and as a final result, seven proposals have been presented to be developed in the geopark, which are the result of a combination of the author's own ideas, inspiration from previous projects and the needs identified during the planning process.
- It is expected that these contributions, in addition to generating results and direct and indirect impacts, can be replicable and/or adaptable in other territories that are working on the development of geoparks.

As a personal reflection of the author, I firmly believe that the Cajón del Maipo Geopark is a great opportunity for local development relevant to the needs and singularities of the territory, due to its participatory nature and holistic approach. It is urgent that the actors of the territory build a joint vision towards sustainability, which is not only a necessity, but also a responsibility to the future generations.

9. References

Alvarado, P., Barrientos, S., Saez, M., Astroza, M., & Beck, S. (2009). Source study and tectonic implications of the historic 1958 Las Melosas crustal earthquake, Chile, compared to earthquake damage. Physics of the Earth and Planetary Interiors, 175(1-2), 26–36. https://doi.org/10.1016/j.pepi.2008.03.015

Anderson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. New York: Longman

Atlantic Geoparks (2022). Geopark Management Toolkit, help for aspiring Geoparks. Retrieved 24 May 2022 from https://www.geoparktoolkit.org/.

Ayala, Á., Farías-Barahona, D., Huss, M., Pellicciotti, F., McPhee, J., & Farinotti, D. (2020). Glacier runoff variations since 1955 in the Maipo River Basin, in the semiarid Andes of central Chile. The Cryosphere, 14(6), 2005–2027. https://doi.org/10.5194/tc-14-2005-2020

Barcaza, G., Nussbaumer, S. U., Tapia, G., Valdés, J., García, J.-L., Videla, Y., Albornoz, A., & Arias, V. (2017). Glacier inventory and recent glacier variations in the Andes of chile, South America. Annals of Glaciology, 58(75pt2), 166–180. https://doi.org/10.1017/aog.2017.28

Benado, J. (2013). Patrimonio geológico del proyecto Geoparque Cajón del Maipo (Santiago, Chile). Tesis para optar al título de Magíster en Patrimonio Geológico y Geoconservación (inédito), Universidad de Minho. Braga, Portugal. p. 142

Benado, J., Brilha, J., Schilling, M. (2013). Patrimonio Geológico del proyecto Geoparque Cajón del Maipo (Chile): resultados finales. En actas del I Simposio Argentino de Patrimonio Geológico, Geoparques y Geoturismo y III Encuentro Latinoamericano de Geoparques, pp. 228. San Martín de los Andes, Argentina

Benado, J., Hervé, F., Schilling, M., & Brilha, J. (2019). Geoconservation in Chile: state of the art and analysis. Geoheritage, 11(3), 793-807.

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

Brilha, J. (2018a). Geoheritage: inventories and evaluation. In Geoheritage (pp. 69-85). Elsevier.

Brilha, J. (2018b). Geoheritage and geoparks. In Geoheritage (pp. 323-335). Elsevier.

Bunster, T. (2017). Propuesta metodológica para cuantificar el valor patrimonial desde el punto de vista del desarrollo minero en el Cajón del Maipo. Tesis para optar al título de ingeniera civil en minas, Universidad de Santiago de Chile, 63 pp.

Cabeza, Á., Espinosa, H., and Gutiérrez, A. (2011). El Patrimonio del Cajón del Maipo: Huellas de la Naturaleza, Historia e Identidad. 195 p. ISBN: 9563455576).

Cajón del Maipo Geopark Project (2020). El proyecto Geoparque Cajón del Maipo. Retrieved 23 May 2022 from https://geoparquecajondelmaipo.cl/index.php/proyecto-geoparque-cajon-del-maipo/

Canesin, T. S., Brilha, J., & Díaz-Martínez, E. (2020). Best practices and constraints in geopark management: Comparative analysis of two Spanish UNESCO Global Geoparks. Geoheritage, 12(1), 1-9.

Charrier, R., Baeza, O., Elgueta, S., Flynn, J. J., Gans, P., Kay, S. M., et al. (2002). Evidence for Cenozoic extensional basin development and tectonic inversion south of the flat slab segment, southern central Andes, Chile (33°–36°S.L.). Journal of South American Earth Sciences, 15, 117–139. https://doi.org/10.1016/s0895-9811(02)00009-3

Charrier, R., Pinto, L. & Rodríguez, M.P. (2007). Tectonostratigraphic evolution of the Andean Orogen in Chile. In: Moreno, T. and Gibbons, W. (eds) The Geology of Chile. Geological Society, London, 21-114.

Charrier, R., Ramos, V.A., Tapia, F. and Sagripanti, L., (2015). Tectonostratigraphic evolution of the Andean orogeny between 31º and 37ºS (Chile and Western Argentina). In: Sepúlveda, S. A., Giambiagi, L. B., Moreiras, S. M., Pinto, L., Tunik, M., Hoke, G. D. & Farías, M. (eds.) Geodynamic Processes in the Andes of Central Chile and Argentina. Geological Society, London, Special Publications, 399:13-61. doi 10.1144/SP399.20

CONAF (2022). Parque Nacional Glaciares de Santiago: Polo de investigación y de turismo de interés especial. Retrieved 08 March 2022 from https://www.conaf.cl/parque-nacional-glaciares-de-santiago-polo-de-investigacion-y-de-turismo-de-interes-especial/

Cornejo, L., & Sanhueza, L. (2011). Caminos que cruzan la cordillera: el rol del paso del Maipo en la ocupación de la Cordillera en Chile Central. Revista Chilena de Antropología, (23).

Darwin, C.R. (1845). Journal of researches into the natural history and geology of the countries visited during the voyage of H.M.S. Beagle round the world, under the Command of Capt. Fitz Roy, R.N. John Murray 2d. edition, 528 p., London.

Deckart, K., Pinochet, K., Sepúlveda, S.A., Pinto, L. & Moreiras, S.M. (2014). New insights on the origin of the Mesón Alto deposit, Yeso valley, central Chile: A composite deposit of glacial and landslide processes? Andean Geology, 41: 248-259.

Estay, C. (2022). Propuestas para la gestión y el aprovechamiento geoturístico del patrimonio geológico de la comuna de San José de Maipo, Región Metropolitana, Chile. Tesis para optar al título de Geógrafo. Universidad de Chile, Saniago.

Farías, M., Charrier, R., Carretier, S., Martinod, J., Fock, A., Campbell, D., Cáceres, J., and Comte, D. (2008), Late Miocene high and rapid surface uplift and its erosional response in the Andes of central Chile (33°–35°S), Tectonics, 27, TC1005, doi:10.1029/2006TC002046.

Farías, M., Comte, D., Charrier, R., Martinod, J., David, C., Tassara, A., et al. (2010). Crustal-scale structural architecture in central Chile based on seismicity and surface geology: Implications for Andean Mountain building. Tectonics, 29, TC3006. https://doi.org/10.1029/2009tc002480

Farías-Barahona, D., Wilson, R., Bravo, C., Vivero, S., Caro, A., Shaw, T. E., ... & Braun, M. H. (2020a). A near 90-year record of the evolution of El Morado Glacier and its proglacial lake, Central Chilean Andes. Journal of Glaciology, 66(259), 846-860.

Farías-Barahona, D., Ayala, Á., Bravo, C., Vivero, S., Seehaus, T., Vijay, S., ... & Braun, M. H. (2020b). 60 years of glacier elevation and mass changes in the Maipo River Basin, Central Andes of Chile. Remote Sensing, 12(10), 1658.

Farías-Barahona, D., Vivero, S., Casassa, G., Schaefer, M., Burger, F., Seehaus, T., ... & Braun, M. H. (2019). Geodetic mass balances and area changes of Echaurren Norte Glacier (Central Andes, Chile) between 1955 and 2015. Remote Sensing, 11(3), 260.

Figueroa, R., Bonada, N., Guevara, M., Pedreros, P., Correa-Araneda, F., Díaz, M. E., & Ruiz, V. H. (2013). Freshwater biodiversity and conservation in mediterranean climate streams of Chile. Hydrobiologia, 719(1), 269-289.

Folchi, M., & Godoy, F. (2016). La disputa de significados en torno al Proyecto Hidroeléctrico Alto Maipo (Chile, 2007-2015). Historia Ambiental Latinoamericana y Caribeña (HALAC) revista de la Solcha, 6(1), 86-104.

Fuentealba, M., Bahamóndez, C., Sarricolea, P., Meseguer-Ruiz, O., & Latorre, C. (2021). The 2010–2020 'megadrought' drives reduction in lake surface area in the Andes of central Chile (32º-36ºS). Journal of Hydrology: Regional Studies, 38, 100952.

Giambiagi, L.B., Tunik, M., Ramos, V.A., and Godoy, E., (2009). The high andean Cordillera of central Argentina and Chile along the Piuquenes pass-cordon del Portillo transect: Darwin´s pioneering observations compared with modern geology. Revista de la Asociación Geológica Argentina, v. 64, p. 43-54.

González, T. (2017). Aproximación a un plan de desarrollo local con enfoque territorial para la cuenca alta del río Maipo. Integración de valores y servicios socio-ecosistémicos, conectividad, resiliencia y adaptación al cambio global. Master Thesis, FUNGOBE, EUROPAC, Universidad Autónoma de Madrid, Spain.

Herrera, M.J. (2016). Estimación de las altitudes de las líneas de equilibrio en glaciares de montaña para el último ciclo glacial-interglacial en los andes de Santiago, Chile central (Doctoral Dissertation). Universidad de chile, Facultad de Ciencias Físicas y Matemáticas, 122 p.

Mardones, V., Peña, M., Pairoa, S., Ammirati, J. B., & Leisen, M. (2021). Architecture, Kinematics, and Tectonic Evolution of the Principal Cordillera of the Andes in Central Chile (∼33.5°S): Insights from Detrital Zircon U-Pb Geochronology and Seismotectonics Implications. Tectonics, 40(7), e2020TC006499.

Martini, G., Zouros, N., Zhang, J., Jin, X., Komoo, I., Border, M., Watanabe, M., Frey, M.L., Rangnes, K., Van, T., Melo, J., Patzak, M., Hilario, A., Nakada, S., Sá, A. (2021). UNESCO Global Geoparks in the "World after": a multiple-goals roadmap proposal for future discussion. Episodes Journal of International Geoscience, 45(1), 29-35.

Ministerio de Economía (2017). http://www.censo2017.cl/

Moreiras, S.M. & Sepúlveda, A. (2015). Megalandslides in the Andes of central Chile and Argentina (32º-34ºS) and potential hazards. In: Sepúlveda, S. A., Giambiagi, L. B., Moreiras, S. M., Pinto, L., Tunik, M., Hoke, G. D. & Farías, M. (eds.) Geodynamic Processes in the Andes of Central Chile and Argentina. Geological Society, London, Special Publications, 399:329-341. doi 10.1144/SP399.18

Municipalidad de San José de Maipo (2022). Acta Instalación de Mesa Técnica para la creación de Plan de Manejo para la Reserva Natural Municipal Mirador de Cóndores: definición de imagen objetivo, metodologías de trabajo y calendarización de actividades. Unpublished. San José de Maipo.

Muñoz, M., Farías, M., Charrier, R., Fanning, C. M., Polvé, M., & Deckart, K. (2013). Isotopic shifts in the Cenozoic Andean arc of central Chile: records of an evolving basement throughout cordilleran arc mountain building. Geology, 41(8), 931-934.

Muñoz-Gómez, M., Payacán, Í., Gutiérrez, F., Farías, M., Charrier, R., & Polvé, M. (2020). Silicic volcanism triggered by increased denudation rates in the Quaternary Andean arc of central Chile between 33° 50'-34° 30' S. Lithos, 354, 105242.

Nacif, S., Triep, E. G., Spagnotto, S. L., Aragon, E., Furlani, R., & Álvarez, O. (2015). The flat to normal subduction transition study to obtain the Nazca plate morphology using high resolution seismicity data from the Nazca plate in Central Chile. Tectonophysics, 657, 102-112.

Obaid, A. (2016). Tecnociencia. 30 Rutas de Turismo Científico en Chile. Editorial Compass Ltda. ISBN: 978-956-9248-31-3

Ormeño, A. (2007). Geodinámica de la hoya hidrográfica del río Maipo en la zona cordillerana de la Región Metropolitana: Implicancias neotectónicas. Tesis (Master thesis). Santiago, Universidad de Chile, Departamento de Geología, 177.

Ortegón, E., Pacheco, J. F., & Prieto, A. (2005). Metodología del marco lógico para la planificación, el seguimiento y la evaluación de proyectos y programas. Cepal.

Parro, V., Blanco, Y., Puente-Sánchez, F., Rivas, L. A., Moreno-Paz, M., Echeverría, A., ... & Cabrol, N. A. (2018). Biomarkers and metabolic patterns in the sediments of evolving glacial lakes as a proxy for planetary lake exploration. Astrobiology, 18(5), 586-606.

Pedersen, L., Smith, T., Lee, S. Y., & Cabrol, N. (2015). Planetary Lake Lander - A robotic sentinel to monitor remote lakes. Journal of Field Robotics, 32(6), 860-879.

Peña-Guerrero, M. D., Nauditt, A., Muñoz-Robles, C., Ribbe, L., & Meza, F. (2020). Drought impacts on water quality and potential implications for agricultural production in the Maipo River Basin, Central Chile. Hydrological Sciences Journal, 65(6), 1005-1021.

Pincetti, G. (2016). Hidrogeoquímica e hidrodinámica de las fuentes termales del Río Yeso y Río Volcán, Cordillera de los Andes, Región Metropolitana. Memoria para optar al título de geólogo, Universidad de Chile, Departamento de geología.

Poiraud, A., Chevalier, M., Claeyssen, B., Biron, P. E., & Joly, B. (2016). From geoheritage inventory to territorial planning tool in the Vercors massif (French Alps): Contribution of statistical and expert cross approaches. Applied Geography, 71, 69-82.

Reynard, E., Perret, A., Bussard, J., Grangier, L., & Martin, S. (2016). Integrated approach for the inventory and management of geomorphological heritage at the regional scale. Geoheritage, 8(1), 43-60.

Rieckmann, M. (2018). Learning to transform the world: Key competencies in Education for Sustainable Development. Issues and trends in education for sustainable development, 39, 39-59.

Riesner, M., Lacassin, R., Simoes, M., Carrizo, D., & Armijo, R. (2018). Revisiting the crustal structure and kinematics of the Central Andes at 33.5 S: Implications for the mechanics of Andean Mountain building. Tectonics, 37(5), 1347-1375.

Salazar, C., Stinnesbeck, W. & Álvarez, M. (2020). Ammonite Biostratigraphy and Bioevents in the Jurassic – Cretaceous boundary transition of central Chile. Cretaceous Research. https://doi.org/10.1016/j.cretres.2019.104282

Sánchez, A., Bunster, T. y Peña, F. (2018). Del geopatrimonio al turismo minero, trabajo en progreso en el Cajón del Maipo. Actas XV Congreso Geológico Chileno, p. 158-161.

Santucci, V. L., Kenworthy, J. P., & Mims, A. L. (2009). Monitoring in situ paleontological resources. Geological Monitoring, 189-204.

Shaw, T. E., Ulloa, G., Farías-Barahona, D., Fernandez, R., Lattus, J. M., & McPhee, J. (2021). Glacier albedo reduction and drought effects in the extratropical Andes, 1986–2020. Journal of Glaciology, 67(261), 158-169.

Sociedad Geográfica de Documentación Andina (2022). Montañas y Rutas. Retrieved March 03, 2022, from www.andeshandbook.org/montanas_y_rutas

Stern, C. R. (2004). Active Andean volcanism: its geologic and tectonic setting. Revista geológica de Chile, 31(2), 161-206.

Thiele, R. (1980). Hoja Santiago. Región Metropolitana. Carta Geológica de Chile. Instituto de Investigaciones Geológicas, 39, 1–51.

UNESCO (2015). UNESCO Global Geoparks Operational Guidelines. http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/IGGP_UGG_Statutes_Guidelines_EN.pdf

UNESCO (2016). UNESCO Global Geoparks, Celebrating Earth Heritage, Sustaining local Communities. UNESCO, France. http://www.globalgeopark.org/. 15/11/2016.

UNESCO (2019a). UNESCO Global Geoparks. http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/frequently-asked-questions/what-is-a-unesco-global-geopark/

UNESCO (2019b). Eleven sites and extensions in Asia, Europe, and South America receive UNESCO Global Geopark Label. Retrieved March 03, from https://en.unesco.org/news/eleven-sites-and-extensions-asia-europe-and-south-america-receive-unesco-global-geopark-label

United Nations (2015). Transforming our world: The 2030 agenda for Sustainable Development. Resolution adopted by the General Assembly on 25 September 2015. United Nations A/RES/70/1

Vergara-Daskam, C., Estay-Daskam, C., and Prior Carvajal, A. (2021). Inventory of geoheritage as a tool for local sustainable development in Cajón del Maipo Geopark Project, Central Chile, EGU General Assembly 2021 https://doi.org/10.5194/egusphere-egu21-9236, 2021.

Vergara, C., Contreras., M., Estay., and Prior (2017). Propuesta para un plan de acción del proyecto Geoparque Cajón del Maipo. Unpublished. San José de Maipo.

Vergara, C., Estay, C., Contreras, M., Prior, A., Godoy, V., Zapata, J. (2019). Geodiversidad, patrimonio geológico y geositios del Cajón del Maipo: La capital geológica de Chile. Proyecto Geoparque Cajón del Maipo. FUNDESO Cajón del Maipo, Santiago, 164 p.

Vergara, C., Vallejos, M., Estay, C., y Prior, A. (2022). Resultados del primer curso oficial del Geoparque Cajón del Maipo: instalando capacidades para el desarrollo sostenible en las comunidades locales. IV Simposio Nacional de Geoparques y Geoturismo en Chile en el Geoparque Mundial de la UNESCO Kütralkura, Temuco, Chile.

Vergara, I., Garreaud, R., & Ayala, Á. (2022). Sharp Increase of Extreme Turbidity Events Due to Deglaciation in the Subtropical Andes. *Journal of Geophysical Research: Earth Surface*, *127*(6), e2021JF006584.