



Geoconservation in Chile: State of the Art and Analysis

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Abstract

Since the 1990s, the main international organizations dedicated to the conservation of nature and geosciences have included geoconservation among their areas of research. Gradually but increasingly, Chilean institutions linked to geology are working in this line, with the common hypothesis being that the country has a significant geoheritage. However, an exhaustive recollection of the geoconservation initiatives currently being developed in Chile throws that statement into question. The analysis of that background information and its subsequent comparison with works developed by other countries in Latin America and Europe shows the still incipient state of geoconservation in Chile. The inferred causes of this underdevelopment are the lack of public politics on geoconservation, the meager collaboration between the institutions that develop the currently ongoing initiatives, and the limited knowledge from the academic and professional world in Earth sciences related to what and how to conserve.

Keywords Chile · Geoconservation · Geoheritage · Geosite · Geopark

Introduction

Problem

Located at the southern end of South America, Chile presents, like few countries in the world, very particular geological characteristics: (i) it is located in an area of convergent boundaries, where two oceanic tectonic plates (Nazca and Antartida) subduct under the South American plate, causing significant seismic activity and one of the major active volcanic chains of the world; (ii) it has an abrupt relief that, in less than 200 km, raises from sea level to almost 7000 m a.s.l.; (iii) it has more than 4300 km of continental coast area; and (iv) it presents a latitudinal variation of approximately 38°, which is reflected

in a great climatic variety (for example, the deserted climate of the Atacama Region or the ice climates of the Aysén Region).

The abovementioned characteristics, among others, make Chile a territory with great comparative advantages in terms of geodiversity, together with a worldwide recognized laboratory for the study of Earth Sciences.

With this background information, it is plausible to assume that Chile also presents an important geological heritage. However, several questions arise, for example, what is its real dimension and relevance? What actions have been taken to protect and spread it for the knowledge and use of the society? What level of development does the conservation of the geological heritage of Chile have in comparison to other countries?

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To answer these questions, this work recounts the main institutional initiatives of geoconservation worldwide. Then, the different studies about geological heritage executed to date in Chile will be analyzed. Finally, a critical reflection of the exposed background information will be made.

Definitions

It is possible to find a great amount of scientific literature with definitions for the concepts of geodiversity, geoheritage, geosite, and geoconservation (for example, in Gray 2004, 2008; Wimbledon 2011; Brilha 2016). However, and maybe because these are concepts which are still relatively emerging, these terms have many times been used in an inadequate and/or confusing manner.

The present work does not seek to discuss the most appropriate definitions for the previously mentioned concepts; but, since they will be used systematically, they will be briefly explained below from the authors' point of view.

- **Geodiversity:** corresponds to the diversity of the abiotic nature, including its elements (for instance, rocks, minerals, structures, fossils, water, morphology, etc.), relationships, and systems.
- **Geological heritage or geoheritage:** the combination, in a determined area, of the elements of exceptional value of the geodiversity, for one or more values (scientific, aesthetic, cultural, etc.). It is important to point out that the concept of patrimony or heritage is understood by the authors as a cultural consensus, and therefore depends on the historic and social moment in which it is evaluated.
- **Geosite:** the commonly used way to refer to the in situ occurrence of the geoheritage highlighted by its scientific value.
- **Geoconservation:** discipline dedicated to the conservation of the geoheritage. Encompasses the stages of selection, characterization, quantification, protection (legally or in situ), valuing (for example, throughout the construction of infrastructure), divulgation, and monitoring of the geoheritage (Brilha 2005; Henriques et al. 2011).

International Background Information

Starting in the 1990s, the main international organizations linked to the protections of nature and geology became aware of the need to create initiatives specially consecrated to preserve the elements of exceptional value among the geodiversity of the planet. The following describes some initiatives and examples that demonstrate this situation.

Global Geosite Project

From 1996 to 2014, the International Union of Geological Science (IUGS) promoted the *Global Geosites project*. The main objective was to make an inventory of geosites at a worldwide scale (Wimbledon et al. 1999; Wimbledon et al. 2000). It is possible to read about the proposed method to make the inventory in Wimbledon et al. (1999, 2000) and Lima et al. (2010), and about its application in European countries in Wimbledon et al. (2000), Carcavilla et al. (2009), Pereira et al. (2012), and Wimbledon and Smith-Meyer (2012).

In September 2016, the IUGS approved the creation of the International Commission on Geoheritage. This demonstrates the importance that geoconservation has for this internationally renowned scientific institution.

Geoparks

The geopark concept originated in Europe at the end of the twentieth century, and constitutes a holistic idea of geoconservation and economic development. It is possible to find information about the geopark concept in Henriques and Brilha (2017), and about its history in McKeever and Zouros (2005).

Currently, there are 140¹ members in the Global Network of Geoparks of UNESCO, distributed in 38 countries, but just two of them are in South-America (Araripe in Brazil and Grutas del Palacio in Uruguay).

International Union for Conservation of Nature

The International Union for Conservation of Nature (IUCN) is probably the most internationally prestigious institution dedicated to the conservation of nature. The IUCN has gradually recognized the importance of geodiversity and geoconservation throughout three resolutions:

- Conservation of geodiversity and geological heritage (Barcelona/2008²).
- Conservation and valuation of geological heritage throughout the Program of the IUCN 2013–2016 (Jeju/2012³).
- Conservation of movable geological heritage (Honolulu/2016⁴).

In addition, it is important to point out that in 2013, the World Commission on Protected Areas of the IUCN

¹ <http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/> accessed October 20, 2018.

² <https://portals.iucn.org/library/node/44190> accessed November 1, 2016.

³ <https://portals.iucn.org/library/node/44015> accessed November 1, 2016.

⁴ https://portals.iucn.org/library/sites/library/files/resrecfiles/WCC_2016_RES_083_ES.pdf accessed November 1, 2016.

established a Specialist Group in Geological Heritage. This group developed, among many initiatives, the publication of a manual to implement geoconservation measures in protected areas (Crofts and Gordon 2015).

Other International Initiatives

Committed to these global projects, the ministries of Mines or Environment of several countries have led national initiatives to identify, protect, and value geological heritage.

It is possible to find great information about geoconservation programs carried out in Europe in Wimbledon and Smith-Meyer (2012). It is important to point out the case of England, which, in addition to having specific laws dedicated to geological heritage, has a vast inventory of more than 3000 geosites (Ellis 2008) and over 50 amateur groups dedicated to geoconservation.⁵

Compared to Europe, South America has had a late development with regard to geoconservation. However, the most advanced countries with regard to abiotic environment conservation are probably Brazil and Argentina (Palacio et al. 2016).

Some outstanding initiatives in Brazil are:

- Brazilian Commission of Geological and Paleobiological Sites (SIGEP) (Schobbenhaus et al. 2002; Winge et al. 2009; Winge et al. 2013).
- The Geopark program led by the Geological Service of Brazil, in particular, by the Department of Territorial Management (Schobbenhaus and Silva 2012).
- The Geological Roads Project led by the Department of Mineral Resources of Rio de Janeiro (DRM-RJ) (Sá dos Santos 2014).
- The systematic inventory of geosites of the state of São Paulo (Garcia et al. 2017), a project led by the Institute of Geoscience of the University of São Paulo.

Some outstanding initiatives in Argentina are:

- The Argentinian Geological and Mine Service (SEGEMAR), in the context of geological mapping, since 1994 includes a chapter dedicated to geosites (Etcheverria et al. 2010).
- Also, since 2004 SEGEMAR developed the project Areas of Geological Interest of the Republic of Argentina, which has the objective to identify, describe, and divulge (Fig. 1) the country's geological heritage (Miranda 2009; Etcheverria et al. 2010).

⁵ http://wiki.geoconservationuk.org.uk/index.php5?title=Main_Page accessed July 3, 2016.

Chilean Background Information

Historical Background Information in Chile

The first national initiative related to preserving elements related to the abiotic environment was probably made by Mr. Hans Brügggen. This distinguished German geologist published in 1927 in the Chilean magazine of History and Geography, a work about a group of erratic blocks located in the surroundings of the union of the Central Valley with the Andes mountain chain east of Santiago, the capital and biggest urban center of the country (Hervé 2011).

In the previously mentioned work, Mr. Brügggen wrote: "... Less safe is the future luck of these witnesses of a cold climate in our country. A block of granite, where a real quarry was installed to transform it into construction material, already disappeared. In addition, a small excavation where gravel is mined, is getting closer to the bigger block. The only way to protect these natural monuments will be to declare them, together with their immediate vicinity, as national monuments. It is a surface of half to one hectare, with its road access, which will be transformed into a small park. It will be recommended to leave the strip between the two big blocks of Picture 1 (not shown here) with its current aspect of natural vegetation. This way, the aspect that the land had when it was recently abandoned by the ice will be preserved. The plantations of the park will make a type of frame surrounding the central strip with its blocks. A small table could inform the visitors about the meaning of those blocks..."

Recent studies have shown that the remains of the last glacial period do not reach the area described by Mr. Brügggen, but rather many kilometers to the east, in the mountain chain (Ormeño 2007). Despite this background information, the work of Mr. Brügggen remains amazing, since it advances almost 80 years the first studies of the protection of abiotic nature in Chile. Additionally, it presents contemporary concepts of conservation, such as zoning and use of panels as tools to place value. These facts allow it to be said that Mr. Brügggen was a precursor of Chilean geoconservation.

Another pioneering work was made by the geologist Mr. Kenneth Segerstrom, in 1967. During the 1960s, the Institute of Geological Investigations, now known as the Servicio Nacional de Geología y Minería (National Service of Geology and Mining) (SERNAGEOMIN), made an extensive plan of regional mapping in the Province of Copiapó. In this context, Mr. Segerstrom published, among other works, a geological mapping of a transversal strip of the Atacama zone, together with a guide describing the sites of great geological relevance in the surroundings of the highway of the studied area (Segerstrom 1967; Cáceres et al. 2011). Without explicitly naming the concept of geosite, Mr. Segerstrom made perhaps the first inventory of in situ geoheritage in Chile, traveling approximately 450 km, from the coast to the border with

Fig. 1 Explicative panel of the eruptive complex of the Diamante caldera – Maipo volcano. The eruptive center is located in the border limit of Chile and Argentina. In the Argentinian sector, this part of the area is protected by the Laguna del Diamante Natural Reserve, which has free access and the sign shown in the picture. Half of the eruptive center in the Chilean territory has access roads up to the foothill of the volcano. However, the area is private, free access is not allowed, and it does not have valuing infrastructure. The picture is courtesy of SEGEMAR geologist, Mr. Fernando Miranda



Argentina, where he identified and described more than 30 sites.

Similar “inventories” were developed in the contexts of field trips or excursions of the first geological congresses of Chile. Standing out among these were the Guides of Geological Excursions prepared by Pacci and Pérez (1979) for the II Chilean Geological Congress made in 1979 in Arica. In these guides, the authors invite readers to know the main geological characteristics of the provinces of Arica and Parinacota through the visit of 37 sites. Among them, some of great scientific value stand out, such as the rocks of the Complejo Metamórfico Belén (Montecinos 1963), one of the oldest units of geology in Chile with ages of deposition of 850 My (Pankhurst et al. 2016), and other with cultural value, such as the Morro de Arica National Monument.

It is difficult to find other geoconservation works during the twentieth century in Chile. However, several protection initiatives of nature in general, which indirectly related to geoheritage, were carried out under the framework of declaring territories as protected areas. Examples of this situation include the recognition as a Historic Monument of the site “Footprints of extinct animals in the area denominated Termas del Flaco” in 1967,⁶ or the recognition as Santuario de la Naturaleza (Environmental Sanctuary) of the sites “Granito Orbicular” (Orbicular Granite) in 1981 and “Capilla de Mármol” (Chapel of Marble) and “Dunas de Concón” (Dunes of Concon) in 1994 (CONAMA 2008). These four places were, some years later, also recognized as geosites by the Geological Society of Chile (SGCh) (Fig. 2).

⁶ http://www.monumentos.cl/catalogo/625/articles-36913_documento.pdf

Recent Background Information in Chile

Detection Program and Establishment of Geosites in Chile

At a national scale, the first works about geoheritage were led by the SGCh, especially by Mr. Francisco Hervé, who was vice president of the IUGS between 1992 and 2000. While there, he became aware of the *Global Geosites project* and the program of geoparks sponsored by UNESCO.

Committed to these initiatives, the SGCh created the Group of Specialists in Geoheritage, and since 2007, it promotes the Program of Detection and Establishment of Geosites in Chile.

It is important to specify that in the context of this program, the SGCh understands a geosite as “an outcrop or several neighbor outcrops that contain a geological object of value that is worth preserving⁷”. This denomination differs from the most current and used practice (Brilha 2005; Brilha 2016) in this work, which is to use the term “geosite” exclusively to mean places that present exceptional scientific value.

The procedure for an element or geological place of interest to be considered in the national inventory requires the following stages (Calderón et al. 2009):

- (i) Application of place of interest, for a natural person or institution through the presentation of a standard sheet compiled by the SGCh, where general characteristics of the site (name, location, geological interest, geological description, etc.) are described;

⁷ www.sociedadgeologica.cl

- (ii) The group of specialists in geopatrimony evaluates the merit of the application and recommends its approval or declination to the board of the SGCh;
- (iii) The board resolves whether the applicant achieves the merits to be part of the national inventory.

Taking the appropriate safeguards that every situation requires, the places or elements applied that are approved are exposed in the SGCh website with the purpose of informing their value and promoting mechanisms for their preservation and knowledge from the society. As of June 2016, the national inventory has 63 geosites⁸ (Fig. 2).

According to the guidelines of the *Global Geosite program*, Mourgues et al. (2012) proposed a list of 22 geological frameworks for the Chilean territory (for example, Accretion Complexes, Batholiths of the Cenozoic and large copper porphyries and gold deposits, Atacama Desert, and Ice Fields and Antarctic Inlandsis, among others), with the purpose of all geodiversity being homogeneously represented in the national inventory. This work still must be discussed by the national geological community; however, it is expected that, in the near future, it will help to structure and improve the characterization of the geoheritage present in the country.

Aspiring UNESCO Global Geoparks in Chile

As of June 2016 in Chile, there are three projects for the creation of geoparks that follow the guidelines of UNESCO: Kütralkura in Araucanía Region, Puchuncaví in Valparaíso Region, and Cajón del Maipo in the Metropolitan Region (Fig. 2).

Among the initiatives mentioned previously, the Kütralkura geopark project is, by far, the most developed. Its progress occurred mainly between 2009 and 2013 under the framework of the project “Geopark Model in Chile, Stage 1,” executed by SERNAGEOMIN with support from the Regional Government of Araucanía, the Corporación Nacional Forestal (CONAF) (Forest National Corporation) and the Ministry of Environment, among other institutions. The objective of the project was to promote the creation of the first geopark in Chile around Llaima volcano and Conguillío National Park.

Kütralkura is a denomination in Mapudungun (Mapuche language) which means “Fire Stone”. The territory of the geopark project comprises ~8100 km² where ~50,000 people live. Among them are numerous Pewenche-Mapuche indigenous communities, and several settlers and farmers dedicated primarily to farming and agriculture. The landscape of Kütralkura is a consequence of ~200 Ma of geological history, pointing out as modeling agents the Llaima, Lonquimay,

Sollipulli, Tolhuaca, and Sierra Nevada volcanoes (Schilling et al. 2012).

Among the activities developed during the execution of the project, it is important to mention the following accomplishments (Schilling et al. 2012):

- Elaboration of an inventory of about 50 geosites (Martínez 2010; Partarrieu 2013);
- Realization of training workshops during 2011, with the participation of local actors related to tourism, education, conservation, and public management of the territory;
- Execution of the education project, “Explorers of Llaima volcano,” in which 100 children who live in the surroundings of the volcano (one of the most active in South America) participated;
- Designation of 15 geotouristic routes that are currently offered by local touristic operators;
- Construction of interpretative panels for 16 geosites, and adaptation of the Environmental Interpretation Centre of the Conguillío National Park;
- Elaboration of a geotouristic guide, an audiovisual documentary, promotional spot, and website about the project.⁹

Currently, there are works in progress to equip an administrative structure, and it is expected that in the short term, it will become the first geopark on the UNESCO Global Network in Chile.

On the other hand, the Puchuncaví geopark is led by a working table directed by the Puchuncaví town hall, and integrated by representatives of universities, environmental communities, private institutions, and local and regional authorities (Andrade and Zora 2014).

The project comprises the totality of the Puchuncaví Township, an area of 301 km² located on the coast of central Chile, north of Valparaíso Region, and inhabited by approximately 15,000 people. This township is associated with strong and contaminant industrial activity, including three coal-fired thermoelectric plants and a maritime terminal with four docks (Barrera and Andrade 2012).

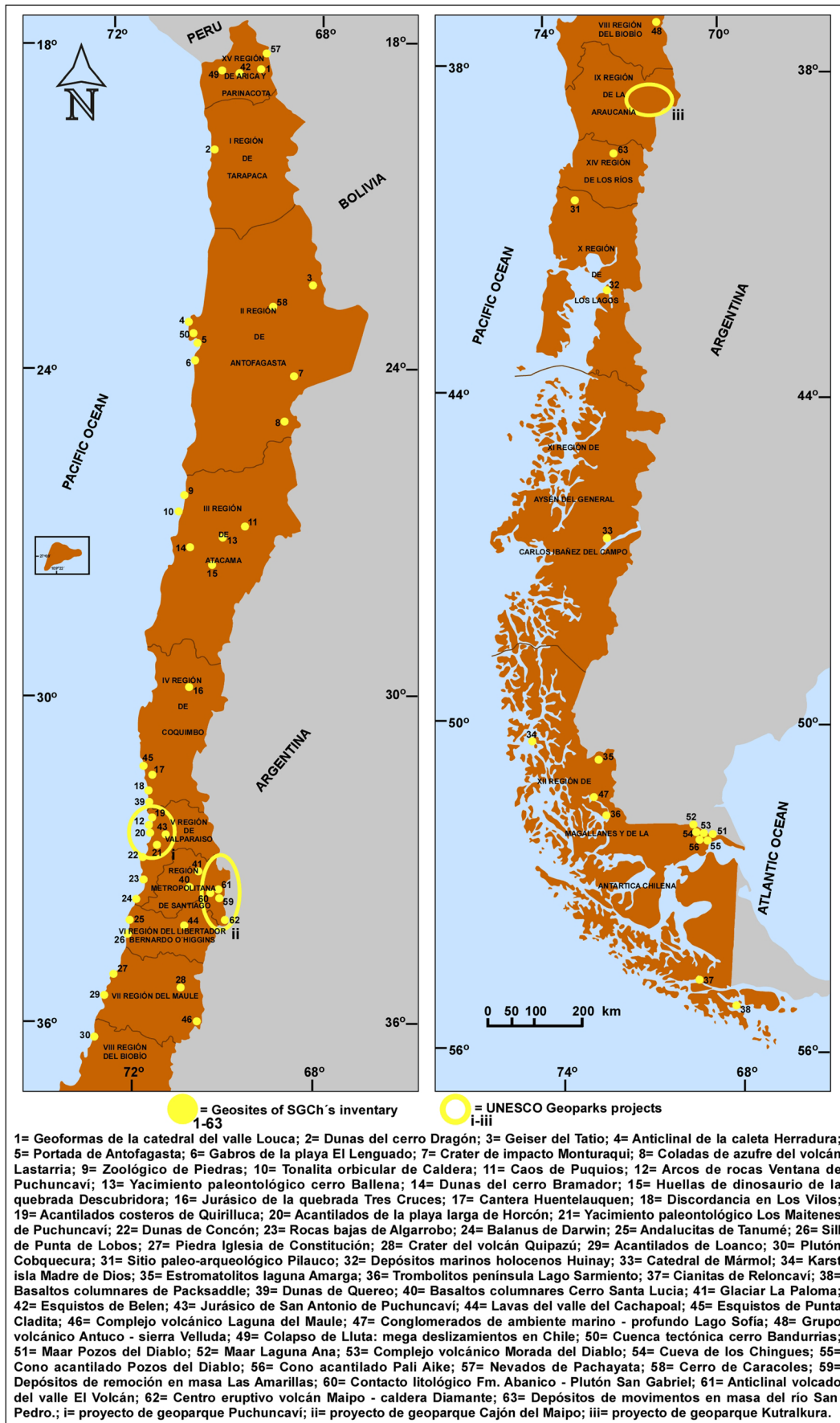
However, Puchuncaví is also known for its important natural patrimony, in particular, its paleontological heritage. This situation was evident to the local and national community with the findings of the Los Maitenes deposit of Puchuncaví in 2007. This finding led to the foundation of the Natural Museum of History of Puchuncaví in 2011, and to combining efforts and wishes to change the image and vocation of the township through a UNESCO geopark¹⁰ (Andrade and Zora 2014).

Together with the abovementioned background information, it is important to point out as advances of the geopark project that in the Puchuncaví county, there have been two

⁸ Accessed July 4, 2016 from the website of the SGCh in www.sociedadgeologica.cl.

⁹ www.kutralkura.cl

¹⁰ <https://vimeo.com/175591234>



◀ **Fig. 2** Approximate location of geosites of the Program of Detection and Establishment of Geosites in Chile and the project of geoparks that follow the guidelines of the Global Network of UNESCO. The information of the geosites was taken from the website of the SGCh on July 4, 2016

workshops about geoheritage, three theses of ecotourism students about the geoheritage present in the territory, a preliminary registry of 17 sites of geological interest, and, as of June 2016, the township has four places recognized as geosites for the SGCh (Andrade and Zora 2014; Zora and Andrade 2015).

In a state still incipient compared with the geopark projects of Kütralkura and Puchuncaví, the Cajon del Maipo project has been stimulated by the SGCh. Located in the central Andes, 50 km from Santiago, the San José de Maipo township, also known as Cajón del Maipo, is a well-known ecotourism destination with more than 160 My of geological history and wide geodiversity, which have been deeply studied by recognized researchers such as Charles Darwin, Ignacio Domeyko, and the founding geologists of the Universidad de Chile (University of Chile).

As a first stage for the future creation of a geopark, an inventory of the main places with scientific value present in the area (Benado et al. 2013) and a TV documentary¹¹ to get to know the project were made. It is important to point out that four sites of the inventory mentioned previously were recognized later as geosites of national interest by the SGCh (Fig. 2).

Other Institutional Initiatives

Other initiatives of institutional geoconservation, but of a more limited scope, that have been made in Chile include:

- At a regional scale, SERNAGEOMIN has also addressed the geoheritage subject since 2000. Under the framework of the Serie de Geología Ambiental de la Carta Geológica de Chile (Environmental Geology Series of the Chilean Geologic Chart), professionals of this institution have identified and described areas of patrimonial interest in the cities of Puerto Montt – Frutillar (Antinao et al. 2000), Osorno (Pérez et al. 2003), Valdivia (Arenas et al. 2005), and Antofagasta (Falcón et al. 2014);
- Chilean Antarctic Institute (INACH), in collaboration with CONAF, the National Tourism Service (SERNATUR), and the National Oil Company (ENAP) individualized 11 geosites in the XII region of Magallanes and Antártica Chilena, materialized the construction of explicative panels in some of them, and created an attractive website to spread it.¹² Although

many of these geosites present a great scenic value and scientific interest, none of them are part of the national inventory led by the SGCh, since they have not been applied for its consideration (Hervé et al. 2012);

- The Center of Geomatics of the University of Talca, with the support of Dresden University, Germany,¹³ is developing the Maule Geologic Route project. This initiative seeks to place value on the geoheritage of the Maule region and includes, over a long-term period, the creation of a geopark under the support of UNESCO. As a first step, a regional inventory of 21 geosites was made. To date, the publication of a book that explains the geology of the region together with a museum that shows the geodiversity present in its territory is being developed. It is important to point out that, unfortunately, socialization of this work has been limited, not reaching for example, the Group of Specialists in Geoheritage of the SGCh;
- The Regional Secretary of Mining in Aysen Region, from December 2015, is executing the program, “Strategy for the geological patrimony management of the Aysén region”. The program is especially dedicated to the conservation of geosites in the region and includes, among its components, the realization of an inventory, protection measurements, divulgation, and value (Benado 2014). This program is the first initiative of geoconservation financed through the Fondo Nacional de Desarrollo Regional (National Fund of Regional Development).

Further to the initiatives previously described, it is important to name the works, often anonymous or unknown, made to preserve the ex situ geoheritage in different museums across the country. The following initiatives stand out:

- Geological Museum of SERNAGEOMIN that keeps a website of the museum and has collections of minerals, rocks, and fossils. In addition, they make important works of divulgation, such as permanent and itinerant exhibitions, guided visits to the museum, and basic geology workshops for high school teachers (Ross 2009);
- Museum and Paleontological Park in Caldera, where the great richness of marine vertebrate fossils present in the geological units surrounding this city are shown;
- Atacama Desert Museum, an institution in which the geologist Mr. Guillermo Chong has had an essential role, keeps an exhibition where the development and geological history of the Atacama Desert is explained (Hervé et al. 2012).

¹¹ <https://www.youtube.com/watch?v=pgp38LDzCY>

¹² <http://www.inach.cl/geositios/> accessed November 1, 2016

¹³ <http://www.otalca.cl/link.cgi/SalaPrensa/RSU/5791> accessed November 1, 2016

Particular Initiatives

Together with the institutional projects previously described, for some years, several academics and students of geology have conducted research projects related to geoconservation.

From 2007 until today, at the University of Chile, several theses to apply for the degree of Geologist aiming to identify and evaluate places of special geological interests, in several areas of the country, have been carried out, including Torres del Paine National Park (Fernández 2007), Conguillío National Park (Martínez 2010), Pale-Aike National Park (Mardones 2012), coastal areas in the Atacama Region (Ramírez 2012), Lonquimay township in the Araucaria region (Partarrieu 2013), urban area of Santiago (Rodríguez 2013), and Puchuncavi township in the V region of Valparaíso (López 2015). Also, in 2014, at the Universidad de Concepción, the first thesis to apply for the title of geologist where geoconservation topics are dealt with was developed, with a study in the Nevados de Chillan Volcanos Complex (Rivera 2014). In addition, a thesis to apply for a master's degree in the Minho University, Portugal, was developed with a study about geosites present in San Jose de Maipo Township, and the potential of this township to be a UNESCO Geopark (Benado 2013).

Regarding the scientific presentations related to geoconservation in Chile, an exhaustive review of the proceedings of the main geological congresses and symposia made from 2009 to 2015 shows that at least 87 presentations were made. Those meetings correspond to XII Chilean Geological Congress, 2009; I Geopark and Geotourism in Chile symposium, 2011; XIII Chilean Geological Congress, 2012; XI European Geoparks Conference, 2012; XII European Geoparks Conference, 2013; I Argentinian Symposium of Geological Patrimony, Geoparks and Geotourism and III Latinomaerican Geopark Meeting, 2013; II Geopark and Geotourism in Chile Symposium, 2014; and XIV Chilean Geological Congress, 2015. Together with that, it is important to point out the work published in 2011 by Guijón et al., 2011 which is the only research about geoconservation published in scientific journals with peer review.

Legal Precedent and Protected Areas

In Chile, there are a large amount of laws, regulations, and conventions, some strictly national and others of international scope, that refer to nature's conservation.¹⁴

¹⁴ https://www.leychile.cl/Consulta/aportar_leychile accessed December 30, 2017

The main Chilean environmental legislation is the “Ley sobre Bases Generales del Medio Ambiente” (Law about the General Basis of the Environment) from 1994 (Ley 19.300 1994¹⁵). This law defines the basic concepts and instruments for environmental management, establishes sanctions for those who damage nature and the natural environment, creates audit instruments, generates an economic fund specifically for environmental protection, and creates the Ministerio del Medio Ambiente (Ministry of Environment), among other things.

In its original version, this law does not mention the word “geology” and there is almost no reference to the abiotic aspects of nature and the environment. This situation was corrected in the “Modificación del reglamento del Sistema de Evaluación Ambiental” (Modification of the Environmental Evaluation System's regulation), from the year 2002 (Decreto 95 2002¹⁶), with the incorporation of the obligatory nature of the realization of studies of “Geology and geomorphology, considering the volcanic, geomorphologic and seismic risks of mass removal in relation to geological structures, and to surface conditions,” for all projects that are introduced to the Sistema de Evaluación de Impacto Ambiental (Environment Impact Evaluation System (SEIA)).

The same law mandates that all projects inside or near Áreas Protegidas (Protected Areas) must be introduced to the SEIA. Today, in Chile, there are at least 32 types of Protected Areas (Sierralta et al. 2011) with diverse objectives (tourism encouragement, scientific activities, etc.), and which are managed by a variety of state offices and dependencies.

None of these types of Protected Areas has as a strict objective, in a wide sense, the conservation of geoheritage. However, the specific case of Monumentos Nacionales (National Monuments), in the Categoría Monumento Arqueológico (Archeological Monument Category), establishes that paleontological pieces and the places where they are found are defined as a National Monument by virtue of law, in addition to establishing sanctions for those who carry out any excavation work without the proper authorization (Ley 17.288 1970¹⁷).

Additionally, several of the types of Protected Area, because of the wide character of their definitions, or by some key word in their formulation (for example, “rocks,” “hydrological,” or “geology,” among others), allow the inclusion of abiotic elements. Among all these laws and regulations, those that are more functional to the geoheritage definition given in point 1.2 of this paper are the ones for Santuarios de la Naturaleza (Environmental Sanctuary) and Monumentos Naturales (Natural Monuments).

¹⁵ <https://www.leychile.cl/Navegar?idNorma=30667&idVersion=2018-01-04>

¹⁶ <https://www.leychile.cl/Navegar?idNorma=205385&idVersion=2018-01-04>

¹⁷ <https://www.leychile.cl/Navegar?idNorma=28892>

According to the law Ley 17.288 from 1970,¹⁸ Environmental Sanctuaries are defined as “Land or sea sites that offer special possibilities for the study and research in geology, paleontology, zoology, botany or ecology, and that have natural formations whose conservation is of interest for science or the state.” Their audit is assigned to the Ministerio de Educación (Education Ministry), through the Consejo de Monumentos Nacionales (National Monuments Council), and they can be private or state-owned areas.

According to the law Ley 18.362 from 1984,¹⁹ Natural Monuments are “Usually a reduced area, characterized by the presence of native flora and fauna species or by the existence of relevant geological sites from a scenic, cultural, educational or scientific point of view.” The management of Natural Monuments is assigned to the Ministerio de Agricultura (Agriculture Ministry) through CONAF, and they are state-owned.

A detailed analysis of the available data, directly and through the links suggested by the website “Registro Nacional de Áreas Protegidas²⁰” (National Registry of Protected Areas), property of the Ministry of Environment, allows us to conclude that as of 2017, there are 49 zones declared as Environmental Sanctuaries and 16 as Natural Monuments, among which only 13 and 4, respectively, seek the conservation of geoheritage elements.

It is important to note that an Environmental Sanctuary or a Natural Monument seeks the conservation of geoheritage only if some element of geodiversity is explicitly mentioned in the declaration documents, and/or if it is explicitly defined as a geoheritage conservation object in the management plans or its associated studies.

Analysis

The recommendations given by Mr. Brügger, almost 90 years ago, were not considered. Today, there is no certainty if the great blocks that he described and whose conservation he recommended still exist or were destroyed, as he predicted in his early work.

To avoid this situation again, and increasingly aware of the values and threats of abiotic nature, institutions and national professionals of the Sciences of the Earth and environment have taken actions over the last two decades to preserve the geoheritage of Chile. Among these actions, the Detection and Establishment of Geosites Program in Chile and the Kütralkura geopark project stand out, first for their scientific importance and scale, and secondly as a great tool to get to know the themes related to geoconservation.

However, none of these actions have been entirely finalized. The number of geosites of the Detection and Establishment of Geosites of Chile Program is relatively small considering the supposed potential of the national territory, quantity of years that the program has been in operation, and the national inventories of other countries with much less surface than Chile (Table 1). On the other hand, the Kütralkura geopark project has not yet established an administrative structure that assures its management in time, and that can sustain its application to the Global Network of Geoparks led by UNESCO.

The national inventories of geosites and territories established as UNESCO geoparks are transversal and common in a large portion of the countries where works of geoconservation are made. Given that, Table 1 allows us to have an international perspective of progress made in Chile in this discipline to date. It is possible to conclude that the geoconservation is a subject that is still incipient in Chile; therefore, the real dimension and relevance of its geoheritage is still unknown.

Together with that, it is important to note that the different institutions that have or are developing initiatives of geoconservation in Chile rarely collaborate or support each other; for example, SERNAGEOMIN does not have the policy to apply the geosites they designate to the framework of the geological charts to the inventory of the SGCh; the initiatives developed by the INACH and the Center of Geomatics of the University of Talca, to date, have never socialized with other institutions or groups that work in geoconservation, and neither have presented their advances in congresses or symposia carried out in the country.

This fact shows that the actions made to date in geoconservation in Chile have been inorganic, in that the projects developed a reflection of individual wills, and not of a public policy in that matter.

Other relevant analysis is obtained by grouping the 88 papers about geoconservation in Chile that have been presented in congresses and symposia alike (and the 1 in scientific with peer review journal), between 2009 and 2015, in some of the different stages of geoconservation named by Brilha (2005) and Henriques et al. (2011). In Graphic 1, we can see that more than half of the works have been compelled to the realization of inventories, which correspond to the initial stage of a strategy of geoconservation, while the works related to later stages, like, for example, valuation or monitoring are rare or null. Other big groups of works have been grouped as “others”, since they correspond to difficult works to frame in some category, for example, the progress studies of the geopark projects (16 of 23) or cultural studies and geological risks in areas that seek to be geoparks.

¹⁸ <https://www.leychile.cl/Navegar?idNorma=28892>

¹⁹ <https://www.leychile.cl/Navegar?idNorma=29777>

²⁰ <http://areasprotegidas.mma.gob.cl/> accessed 30 December 2017

Table 1 Background information related to geosites inventories and number of UNESCO geoparks in Portugal, Great Britain, Spain, and Chile, indicating also the surface and number of geological Frameworks defined in each country. The data related to the surfaces of each country was taken from the website (<http://datos.bancomundial.org/indicador/AG.SRF.TOTL.K2>) of the World Bank on June 10, 2016. The number of frameworks and geosites of Portugal was taken from Pereira et al. (2012). The number of frameworks and geosites of Great Britain was taken from Ellis (2008). The number of frameworks and geosites from Spain was consulted on February 10, 2016 from the website of the

Institute of Geology and Mine of Spain (<http://www.igme.es>). The data about the number of geosites of the inventory of Chile was consulted from the SGCh website (<http://www.sociedadgeologica.cl>) on July 4, 2016. The data about frameworks of Chile was taken from Mourgues et al. (2012) and is questioned, since it has not been validated by the national geological community. The quantity of geoparks was taken from the official page of UNESCO on October 20, 2018 (<http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/list-of-unesco-global-geoparks/>)

Territory	Surface (km ²)	No. of frameworks	No. of geosites	No. of geoparks
Portugal	92.220	27	322	4
Great Britain	~229.848	~100	~3.000	6
Spain	505.940	21	144	12
Chile	756.096	22?	63	0

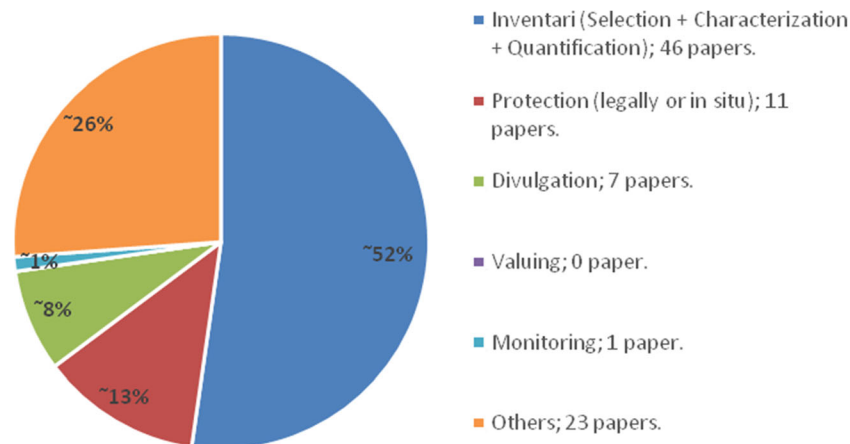
This background information allows us to infer that, besides what was previously exposed, there is a small stock of knowledge about the different stages that a geoconservation strategy implies (and/or undervaluing of the relative importance of the same) in the Chilean academic world.

Chile's environmental legislation analysis shows us that (i) unlike European countries such as Spain and Portugal (Wimbledon and Smith-Meyer 2012), geodiversity, geoheritage, and geosite concepts, mentioned in point 2.1 of this paper, are not part of Chile's legal framework; (ii) there are figures of Protected Areas that allow geoheritage protection. Although at least 33% of the geosites from SGCh's records (Fig. 2) are not granted any level of protection, and only 27% of Environmental Sanctuaries and 25% of Natural Monuments, the two more functional

figures of geoheritage, seek the protection of geodiversity elements.

It is feasible to conclude that there is an underappreciation of the values and uses of geodiversity in Chilean environmental legislation. It is deduced that the causes of this situation are complex and diverse, but it is clear that the absence of an institution that watches over geoconservation and the lack of Earth Sciences professionals in decision-making positions is one of the causes.

Since 2014, the Chilean parliament has been discussing a bill that creates a new "Servicio de Biodiversidad y Áreas Protegidas y el Sistema Nacional de Áreas Protegidas" (Biodiversity and Protected Areas Service and the National System of Protected Areas), which expects to complete the environmental institutionalism and cover up the current management gaps.



Graphic 1 Thematic distribution of the works about geoconservation in Chile developed between 2009 and 2015. The information was taken from a qualitative analysis of the papers presented in: XII Chilean Geologic Congress, year 2009; I Symposium of Geoparks and Geotourism in Chile, year 2011; XIII Geologic Congress of Chile, year 2012; XI European Geoparks Conference, year 2012; XII European

Geoparks Conference, year 2013; I Argentinian Symposium of Geoheritage, Geoparks and Geotourism and III Latin-American Meeting of Geoparks, year 2013; II Symposium of Geoparks and Geotourism in Chile, year 2014; XIV Chilean Geological Congress, year 2015; *Geoheritage Journal*

In this context, during 2015 and 2016, the SGCh sent a technical report to the Comisión Nacional de Medio Ambiente (National Commission for the Environment) of the Chilean senate, with observations and notes to the bill, and required a meeting to expose the current situation of the national geological heritage.

The technical report states the need for the creation of a División de Geodiversidad y Patrimonio Geológico (Geodiversity and Geological Heritage Division), similar to the existing División de Biodiversidad (Biodiversity Division). This new division would have the objective of managing in a sustainable way the abiotic natural resource, and assuming the commitment to carry out the identification, characterization, and protection of geological heritage, and also to assure its disclosure, valuation, and monitoring.

Unfortunately, the SGCh has not received an official answer from the senate's commission, and the chance of a meeting to make an exposition was not welcomed by the lawmakers.

Conclusions

The exhaustive review developed in this work concludes that Chile, although it probably has comparative advantages in terms of geodiversity, presents significant delays in relation to European and even South American countries, in geoconservation.

Given this situation, the dimension and relevance of the national geoheritage is still unknown, a fact that represents potential threats for the future of Chilean society. The causes inferred for this underdevelopment are the lack of public politics on geoconservation, the meager collaboration between the institutions that develop the currently ongoing initiatives, and limited knowledge from the academic and professional world in Earth Sciences related to what and how to conserve.

The current discussion in the parliament of the bill that creates a new “Servicio de Biodiversidad y Áreas Protegidas y el Sistema Nacional de Áreas Protegidas” represents a big opportunity, in the short run, to repair this situation. Nevertheless, evidence shows that for the SGCh observations to be considered, the collaboration of other institutions (for example, SERNAGEOMIN or CONAF) and universities is necessary.

Over the medium and long term, the diversification of geoconservation initiatives undertaken by the SGCh and universities is a feasible strategy to raise social awareness regarding the values of, and threats to, geoheritage in Chile. For the SGCh, this diversification could include the disclosure of its records, while for universities, it could include leading projects on geosite protection.

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- Annex The following is a list of the 88 papers, on topics related to geoconservation in Chile, analyzed in the present work
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