Virtual Heritage: A Model of Participatory Knowledge Construction Toward Biogeocultural Heritage Conservation

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Abstract

Virtual heritage has recently received attention as a novel path to better conserve geoheritage values and sites by means of the use of advances in digital imaging technology to synthesize, reproduce, represent, and display information. Traditionally, there have been difficulties in the inventory, quantification, and consolidation of relevant geoheritage sites, especially as concerns the limited tools for an adequate understanding of its complex nature and multiple connections to other landscape values, including biodiversity, cultural values, and the more integrative concept of biogeocultural heritage. This point of contention has been particularly felt in Latin America: although relevant heritage sites are in peril of disappearing, the application of geoheritage and geoconservation concepts has been relatively slow and there continue to be salient difficulties in reaching audiences beyond academic circles. Extant Chilean biogeocultural geoheritage is remarkable not just due to its immense and impressive geoforms, running the gamut from arid to cold–humid climates with their respective geodiversities; it also harbors natural values regarding the same geological and geomorphological richness. The remarkable cultural and historic contributions from original communities are essential to understanding the dynamically evolved Andes geosystem over vast geological periods. Based on the above, this chapter seeks to advance, first, effective action to protect geoheritage in Chile; and second, to reframe that geoheritage with other landscape, biological, and cultural values toward the more holistic concept of biogeocultural heritage, and do so by integrating aspects of ancient and current communities with deep historical ties to this diverse landscape. This goal is forwarded through the implementation of the novel languages and practices made available by geovisualization. Integrally, this is the Virtual Heritage process and includes the use of mobile apps in which wider audiences may interact across critical aspects of environmental and social conflicts.

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Keywords

Virtual heritage
Geoheritage sites
Biogeocultural heritage
Geoconservation
Geovisualization

5.1. Introduction

Currently, the inventory, conservation, and formal declaration of relevant geoheritage sites (such as geoparks and geosites) are increasingly sustained by specific technological tools that enable adequate understanding of the complex nature of geoheritage and its multiple connections. This trend has also had beneficial effects for geotourism and in generating meaningful senses of place in geosites. Ongoing developments in 'Virtual Heritage' have facilitated the synthesis, reproduction, representation, digital reprocessing, display, and conservation of different aspects of cultural heritage through advances in virtual reality (VR) imaging technology (Roussou 2009). However, it still has some shortcomings that need to be addressed, like lack of meaning or sense of place, as well as those stemming from technological limitations (Tan and Rahaman 2009).

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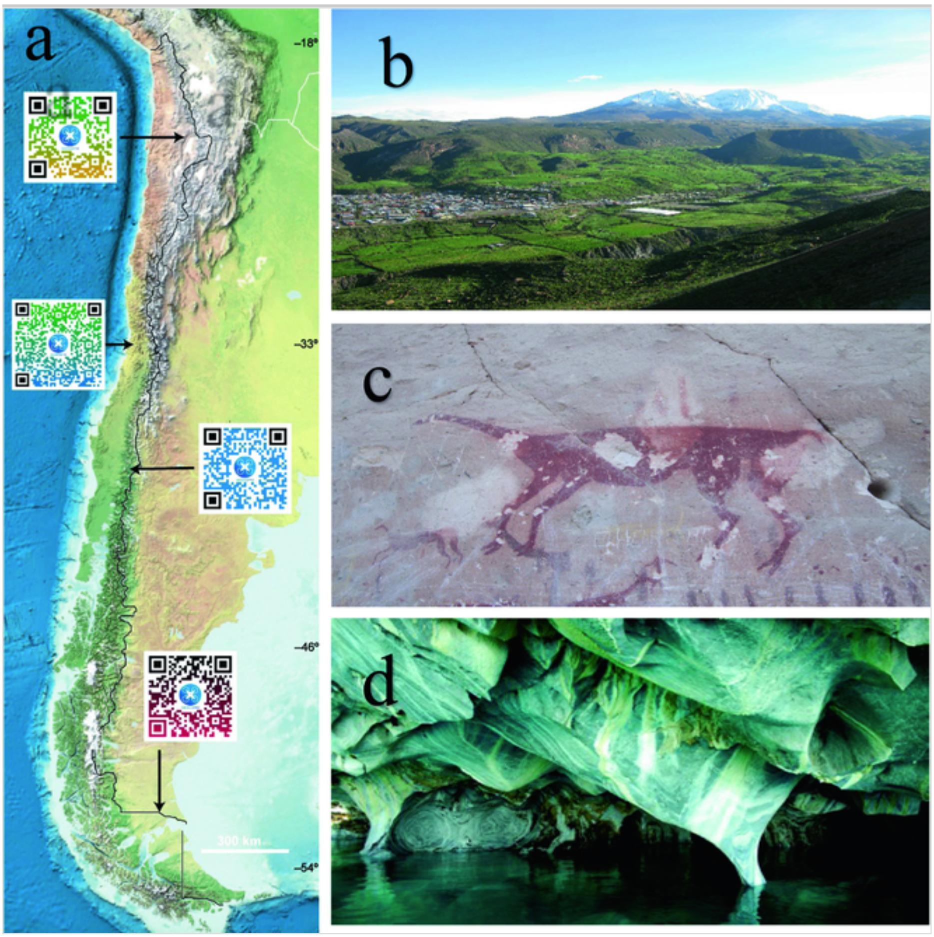
Addressing these challenges is especially critical in Latin America, where environmental conservation faces severe conflicts and territorial disputes regarding divided visions for development: there are discrepancies in social appropriations of nature between the traditional values assigned by local communities versus the exchange value promoted from the perspective of governments and capitalist companies and industries.

These challenges represent a constant threat to geoheritage and underscore the urgency in addressing geoconservation and sustainability. Furthermore, other aspects of landscape values remain to be combined with geographical and geological values, such as biologically and culturally relevant aspects of the territory. This interplay within different spheres has been called biogeocultural heritage as a term that encompasses the diverse aspects of these complex landscapes (Ray and Gregg 1991; Gordon et al. 2018; Manríquez et al. 2019a).

Fig. 5.1

Remarkable features of Chilean biogeocultural heritage: **a** examples of virtual journeys, by drone; **b** traditional terrace agriculture in the northern *Altiplano*; **c** Detail of pictography along with the "Inca Road System" (*Qhapaq Ñam*); **d** The "Marble Cathedrals" in the humid south. (Photographs by A. Moreira-Muñoz and Gaspar Gálvez)



In this sense, virtual reality has the potential of integrating all these aspects in an attractive and meaningful virtual space. Local communities today need to be more active and engaged, i.e., actors in the conservation of all the different aspects of heritage.

Instead of passive observation, freely accessible geographic information tools and web 2.0 platforms facilitate the development of citizen science by non-experts and can promote the development of local environmental conservation strategies. This scenario demonstrates that it is important to promote—beyond scientific circles or public and private institutions—environmental conservation through the development of citizen science. This would open transdisciplinary knowledge dialogues among these actors, and thus advance toward stronger social cohesion.

As a case in point, Chile—from the northern Atacama desert toward the southern temperate forests, channels, fjords, and ice fields (Fig. 5.1)—encompasses a remarkable diversity of landscapes and forms that constitute a rich biogeocultural heritage. Indeed, the Chilean Andes range is home to the highest concentration of active volcanoes; in the north, the highest plateau ("*Altiplano*"); remarkable longitudinal tectonic reliefs, such as the Coastal Cliff along the north, the Coastal *Cordillera*, and the intermediate depression; and in the south, dense outcrops of small islands, fjords, and glacial forms, and the largest ice field of the southern hemisphere.

Those shapes—related to Nazca and Antarctic subduction beneath the South America Plate—generate remarkable and distinctive landscapes along latitudinal and altitudinal gradients. Additionally, Chile harbors a long littoral of over 4,000 km, with many important morphological and paleontological features, and is recognized worldwide for its large cliffs, dune fields, wave-cut platforms at different heights above sea level, and macrofauna fossil sites.

Additionally, the above features are usually inseparable from traditional cultural elements of the landscape, such as "*bofedales,*" traditional agriculture terraces in the north (Fig. 5.1), pictographs in rock caves (Fig. 5.1), or ancient routes like the "Inca Road System" (*Qhapaq Ñam*) that unite Andean biogeocultural heritage. These elements encompass a diversity of forms, which further adds to the challenge for adequate communication and visualization at different scales (Manríquez et al. 2019b).

In practice, designing biogeocultural heritage conservation and geosites creates an opportunity to reunite relevant geological landmarks with both biotic values and those of culture; this acquires special relevance in times of global and local climatic and social changes. The valuation and conservation of different aspects of heritage have implications for future and current generations of students and the general public.

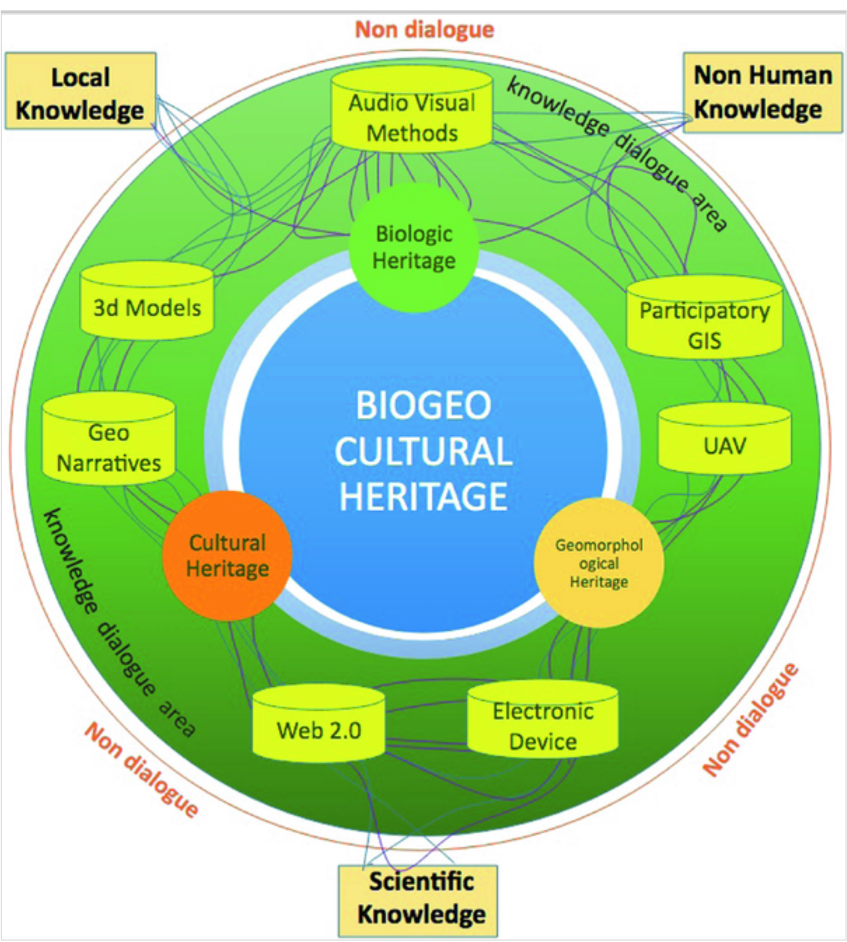
Today, significant pressures are associated with consequences from mining and energy extractivism and the deployment of transnational infrastructure works that consider the Andes Mountains a mere barrier to economic integration and capitalist development (Mansilla et al. 2019). The urgency of actions regarding such heritage continues to increase as its importance dwindles in society; for example, tourists damaged recently the most emblematic geoglyph from northern Chile, the "*Tarapacá* Giant." This is not merely a recent phenomenon: mineral activity and rallies like Dakar are known to generate profound damages to Atacama heritage. In spite of fees and national and international concerns, there continues to be neglect toward the importance of our heritage. In this sense, the use of new technologies and tools opens a world of possibilities for participation, social integration, and interaction with biogeocultural heritage.

5.2. Virtual Heritage and Dialogue Among Knowledges

Virtual heritage is the application of information and communication technologies to cultural heritage (Cayla and Martin 2018). It is capable of representing all elements of Geoheritage, scientific knowledge, local knowledge, and non-human knowledge, merged, integrated, and exposed to wider audiences through Digital media, Geonarratives, GIS, UAV, and audiovisual methods (Fig. 5.2). The connections among all these tools and cultural, biological, and geological heritage converge into the complex concept of Geoheritage. Adequate applications of Virtual Heritage for heritage conservation, however, require avoiding several pitfalls, for example, focusing only on (touristic) products and not heritage valuation processes themselves (Tan and Rahaman 2009).

Fig. 5.2

A Virtual model for the inventory and valuation of biogeocultural heritage (based on concepts by Tan and Rahaman 2009; Escobar 2014; Cayla and Martin 2018)



As shown in Fig. 5.2, the notion of Biogeocultural Virtual Heritage that we intend to promote focuses on transdisciplinary knowledge dialogue (Escobar 2014) among scientific, local and non-human knowledge—the latter of which has not been had an effectively representative dialogue.

Modern scientific knowledge has commonly maintained an arrogant perspective, discarding experience produced from local knowledge (De Souza Santos 2007). At the same time, its hierarchical position with respect to other social actors has impeded the production of constructivist knowledge. In contrast, the knowledge of local inhabitants is based on spatial practices located in the context of ecological relationships with their living spaces, in a process known as territorial ontologies (Blaser 2013). This experience allows them to have tools to generate creative strategies for environmental conservation. Likewise, recent perspectives in postcolonial geographies, animal geographies, and posthuman geographies point to the need to recognize non-human actors, such as rivers, mountains, flora, fauna, etc., beyond their status as objects, and rather as entities with the capacity to generate knowledge with an agency, and from which it is possible to learn and design other worldviews (Panelli 2009).

The dialogue among these multiple knowledges allows reconstruction of relational territorial ontologies that have been lost to the horizon of the modern development project that has laid the foundations of the current socio-environmental crises as manifested in the framework of climate change and globalization.

In this context, emerging technologies for geovisualization and the consolidation of Virtual Heritage are presented as devices to communicate knowledge and to cross borders of knowledge. These technical tools facilitate the communication of geographic information on biogeocultural heritage, as well as the multiple knowledges involved in its management.

The development of virtual environments offers immense possibilities; however, adequate development requires addressing several aspects or shortcomings, including interactive engagement with the public (game-based); constructivist interpretations; and the building of a meaningful 'virtual' sense of presence and place through hermeneutic virtual environments (Champion and Dave 2002, cited by Tan and Rahaman 2009). Some of the emerging tools in the field of Biogeocultural Virtual Heritage, also shown in Fig. 5.2, are listed below.

(a) Participatory GIS: Geographic Information Systems (GIS) had previously only been made available to experts; however, they are increasingly becoming available to widespread use. This trend is closing social gaps in communities or local institutions with low budgets. Platforms such as QGIS or gvSIG allow free access for the visualization, creation, and analysis of spatial data. Additionally, recent developments in web platforms such as Google Maps, Google Engine, or Mapbox have facilitated many geovisualization tasks.

(b) UAV, unmanned aerial vehicles: Growing access to aerial images through UAVs (drones) facilitates monitoring current states of biogeocultural heritage. At the same time, these devices are used for qualitative methodologies like guided tours of drone flights through biogeocultural heritage areas or regions (Ray and Gregg 1991). Here, inhabitants, through the lenses connected to the camera of the device, comment on their meanings and memories about these places.

(c) Web 2.0: Virtual platforms that facilitate communication among multiple actors who, in this case, interact with biogeocultural heritage. Web 2.0 refers to the capacity of a network to provide for the development of information through interaction and collaboration, in this case, geographic and geovisualization projects. An example of this comes from support provided by Wikimapia.

(d) Electronic Devices: Devices through which actors connect several of the tools indicated above. For example, to collect georeferenced information in real time, and incorporate it into collaborative mapping projects or for tracking paths in the pursuit of heritage recognition or monitoring, devices may include cameras, augmented reality telephone applications, and QR codes to allow a greater degree of interaction with the geovisualization of data.

(e) 3D-Printed Terrain Models: Digital manufacturing tools currently provided by 3D printers make it possible to represent relief models easily and economically. Printing 3D terrain models also aids local communities in approximating geographical representations: whereas traditional map formats require knowledge of reading charts, 3D terrain models facilitate the recognition of geomorphological formations and biogeocultural heritage sites.

(f) Geonarratives: The life histories and biographies of inhabitants, investigated through spatiotemporal geovisualization (Kwan and Ding 2008). Although geonarrative prototypes have been supported by 3D models made in Geographic Information Systems, there is potential for expansion in open platforms like ESRI Story Maps or Google Earth.

5.3. Examples of Visualization for Environmental Assessment and Site Monitoring

Spatial information acquisition at different scales is currently quite feasible (Table 5.1). For the last five decades, aerial photographs were the most important media for acquiring spatial information and making maps. Although satellite imagery and digital processing have fully replaced aerial photographs, historical photogrammetric surveys still provide information on large swaths of territory. Similarly across

Latin America, aerial photographs facilitate image overlap and stereographic visualization (3D vision). In Chile, some of the aerophotographic surveys still available are Trimetrogon (1944–45), Hycon (1955), OEA (1960), USAF (1970), SAF (1980), and Geotec (1980). Digitally treated historical aerial photographs enable stereographic and time modeled changes of any place and give a different value to biogeocultural heritage (Table5.1).

Table 5.1

Examples of geoheritage sites and features based on different scales of reference, as proposed by (Brocx and Semeniuk 2007)

Scales	Frame of reference	Geovisualization tool	Examples
Regional	100 km × 100 km or larger	Satellite images, Google Earth	The Atacama erg
Large	10 × 10 km	Fine Satellite images	Debris flows
Medium	1 km × 1 km	Aerial photographs, UAV	Aspects of Biogeoheritage at the National Park
Small	10–100 m × 10–100 m	UAV	Los Dedos paleontological site
Fine	1 m × 1 m	Photography	Taffonis, Granito orbicular
Very fine	1 mm × 1 mm or smaller	Microscope	Mineral crystals

Another important source of spatial information has been satellite images, which cover large surfaces over wide temporal frames. Depending on spatial and temporal resolution, a diversity of images taken by different satellites can be applied to different necessities, such as finer resolution urban planning (e.g., Sentinel images) or regional studies (NOAA images). Indeed, dramatic land use changes occurring in the most populated areas of Central Chile have been reported by means of remote sensing (Landsat images) (Schulz et al. 2010), as well as the impacts of immense wildfires from recent summers related to increases in global temperatures (Modis images) (Bowman et al. 2018).

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But for detailed aspects of reality, even most accurate satellite images do not reach a resolution. It is here that the rapid increase in the use of UAV drones in environmental and geographic studies, especially in coastal environments, provide a valuable niche (Mancini et al. 2013; Gonçalves and Henriques 2015; Turner et al. 2016) (Table 5.1). The coastal interface of contact between the lithosphere, atmosphere, hydrosphere, and biosphere is a perfect example for detailed studies and is also where many environmental conflicts arise (see next section for case studies).

While traditional forms of research, representation, and exhibition of heritage are still in use, there have been significant advances in linking heritage values through Augmented Reality (Noh et al. 2009). Several examples of recent advances in geovisualization are presented below, as well as paths toward reinforcing Virtual Heritage in Chile.

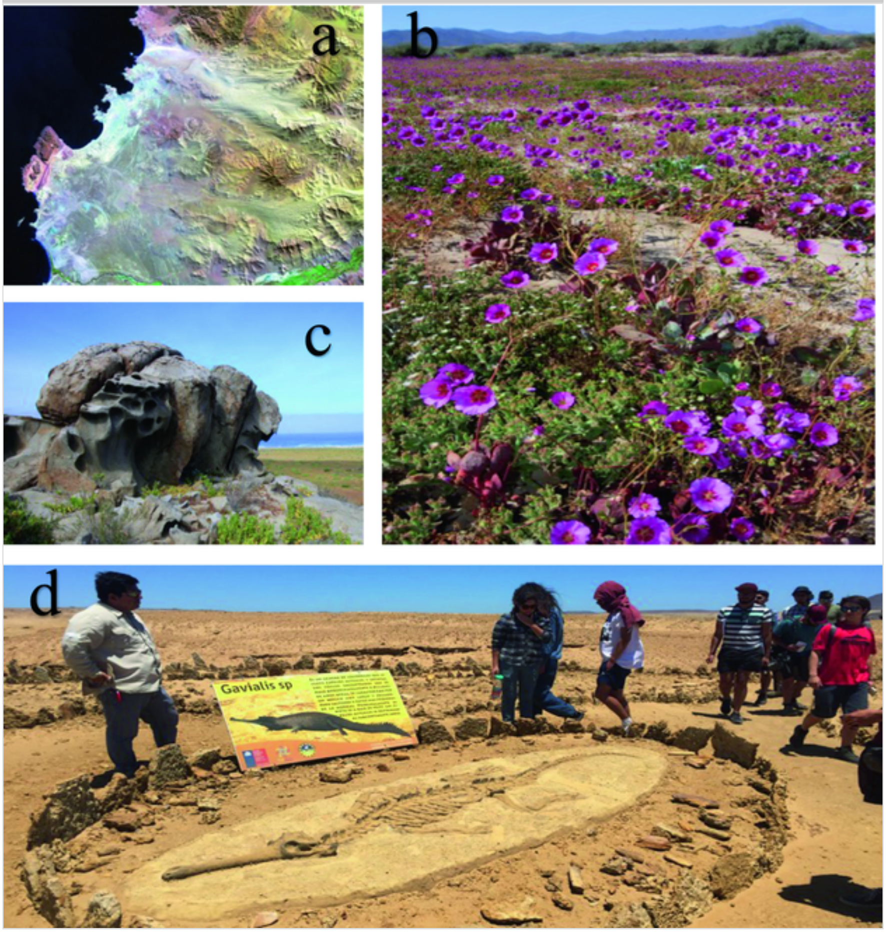
5.4. Case Studies

5.4.1. Atacama Virtual Heritage

Among several features in this region, Atacama is the driest place on earth (Fig. 5.3). Interaction between the Nazca and the South America plates leaves units of relief, oriented north–south, which rises from sea level to over 6,000 m high, in a horizontal east–west average width of 250 km.

Fig. 5.3

Remarkable features of Atacama biogeocultural geoheritage: **a** the inland dune system; **b** tafonis at the Atacama coast; **c** blooming desert; **d** *Los Dedos* paleontological site at *Caldera* (Photos by A. Moreira-Muñoz; with permission of the IGM Military Geographic Institute of Chile)



Of these, one of the greatest structural geological geoforms is the Atacama megafault, whose system has a 1,000 km N–S distance. From the western view, there is a large cliff named "*farellón costero*" that reaches 1,000 m above sea level (Paskoff 1989). From the eastern view, the tectonic fault scarp can be seen.

The coastal zone also has interesting geoheritage elements. The tafoni near *Caldera*, for example, show the natural weathering of a coastal saline environment on granitic rocks. Another site hosts orbicular granite, a Jurassic granitic rocky outcrop with spherolithic cores ("orbicules") originated by deep magmatic processes. These spherolithic cores are compound inclusions of tonalite mineral cores with many other minerals in a porphyritic matrix (Aguirre et al. 1976). This geoheritage, located mainly at the coast, is periodically (every 7 years) dressed by an ephemeral botanical cover associated with ENSO (El Niño Southern Oscillation), known as the "blooming desert" (Chávez et al. 2019), which is a marvelous example of the combination of geo- and biological heritages.

The Atacama coast is also home to one of the most important fossil deposits in Chile, *Los Dedos* paleontological site. Nearby paleontological sites include "*Cerro Ballena*" with more than 50 perfectly preserved whale fossils. North of *Copiapó* is an extensive sand dune system. The Atacama Erg, covering 240 km^2 (Araya 2001), has sands from the beaches and old wave-cut platforms since the Pleistocene carried inland to a distance of more than 60 km, following relief corridors (Paskoff and Manríquez 2003). The complex dunes include transverse, seif, ankle-pattern, pyramidal, or barchans forms, visible from the air with detailed morphologies, physiognomy, and internal dynamics through high-resolution satellite images or UAV.

5.4.2. *Kütralkura* Geopark, 3D Model of *Llaima*, and Mapuche Culture

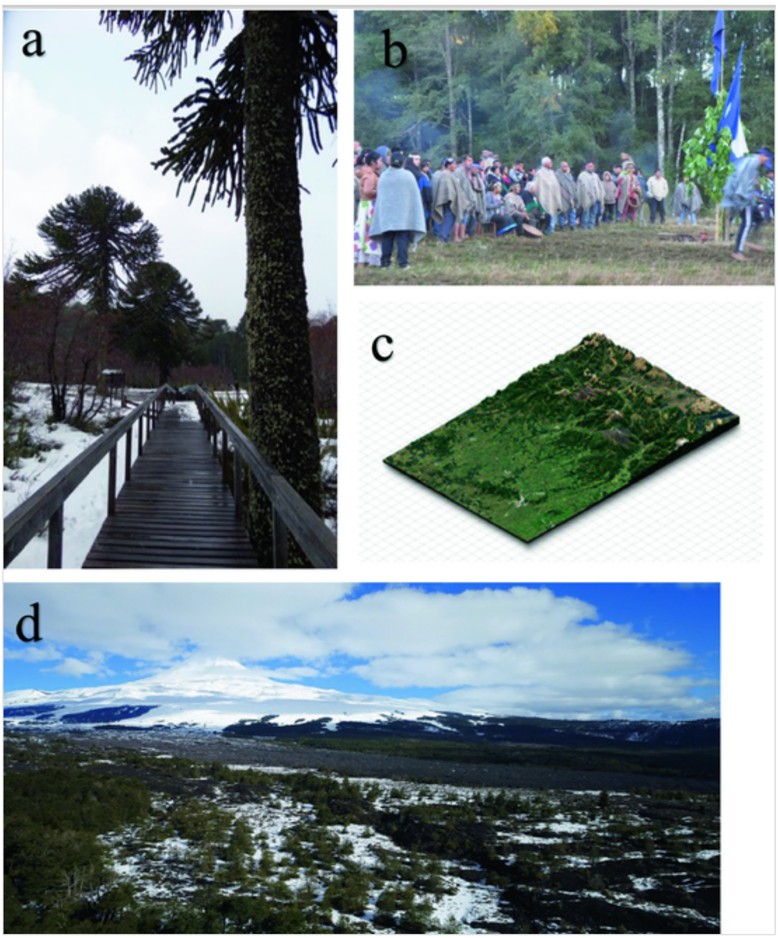
The *Kütralkura* geopark is the first Chilean Geopark (Schilling 2014). It encompasses around 8,000 km^2 and some 50,000 people, mainly pertaining to the Mapuche-Pewenche ethnic groups. *Kütralkura* means "stone of fire" in Mapudungun language, referring to the *Llaima* volcano—within the geopark (*Conguillío* National Park) in the *Araucarias* Biosphere Reserve—that watches over most of this originally indigenous territory (Fig. 5.2).

Participatory mapping and new visualization tools have allowed the recent publication of the first "Mapuche Atlas" (Melin et al. 2018), a collaborative and intercultural work for the reconstruction and territorial defense from the Mapuche perspective, including that of the natural territory surrounding *Curacautín*. Through this project, the construction of at least two hydroelectric plants has been stopped by community action. The Atlas intends to deepen and expand the territorial and cultural knowledge of the area through cartographic models of reconstructed ancestral Mapuche territory. It does so from the orality that emanates from the Mapuche's own knowledge in conjunction with information available from historical sources and UAV technology support (QR in Fig. 5.1). This product integrates an approach from the perspective of Participatory Action Research, which not only addresses problems and alternative solutions from a local perspective but also allows dialogue with the cultural perspectives and knowledge of the Mapuche people. It is a clear advance in the construction of interculturality through practice and action.

The geopark designation looks to improve the quality of life of its inhabitants through the development of geotourism, education in geosciences, and geoconservation (Schilling 2014). *Kütralkura* geopark harbors a great geodiversity; a geological history that spans more than 200 million years, including recent notable active volcanic processes; and a remarkable biodiversity centered on the figure of the sacred "*pehuén*" tree (*Araucaria araucana*). The species, an iconic "living fossil," has only recently been confirmed as living as long as a thousand years (Aguilera et al. 2018). Additionally, the *pehuén* is an important element of biogeocultural heritage in a remarkable relationship with the Mapuche culture (Fig. 5.4).

Fig. 5.4

Remarkable features of the Biogeocultural Mapuche heritage: **a** Araucaria forest in *Conguillío* National Park; **b** traditional *nguillatün*, Mapuche ceremonial ritual; **c** terrain model of the geoheritage of the Araucanía region; **d** *Volcán Llaima* at the core of *Kütralkura* Geopark. (Photos by P. Mansilla)



5.4.3. Un-Habited Spaces of Patagonia

The cultural and geological landscape of mythical Patagonia and southernmost Chile (*Magallanes*) is shaped by a rich array of landscapes encompassing wonderful features of the physical geography (Coronato et al. 2017), rich biodiversity and impressive botanical landscapes, which have been documented in the stories of travelers and explorers since the times of Hernando de Magallanes and Antonio Pigaffeta.

The most striking feature of the western edge of the southern tip of South America that faces the Pacific Ocean is its great territorial fragmentation, a complex maze of multiple channels and islands of varying size.

In this regard, its unique views are due to two essential processes. Firstly, a tectonic collision process between the Antarctic and the South American plates, which manifests itself at 46° South latitude. This interaction, though poorly understood due to lack of seismic records, consists of a slow subduction process on the order of 20 cm/year (Charrier et al. 2007). Additionally, the Scotia plate in the extreme south of South America lies between the South America and Antarctic plates, contributing to further doubts in the context of interaction.

Secondly, Quaternary glaciations have structurally contributed to this territorial fragmentation, the high density of fractures and faults in the crust, and the deepening of ancient river valleys today transformed into fjords that take on the appearance of narrow, high-walled rocky corridors. Research suggests that quaternary glaciation covered the entire territory with inland ice (Laugenie 1982; Heusser 2003), of which only three ice cores remain as evidence: the Northern Ice Field, the Southern Ice Field, and the ice field located on the Darwin Mountain Range known as the Austral Ice Field (Fig. 5.5).

Next, the foremost morphological and structural feature of the Andes mountain range at these latitudes is undoubtedly the Patagonian Mountain Range. This great structural axis, formed by intrusive rocks that are part of the Patagonian batholith or the Andean *Aysén* batholith (Skármeta 1978), is found from 42° to 56°S and is more than 1500 km long.

Regarding culture, the population of Patagonia is intermittent, with marked stages of development and decline in relation to economic exploitation of natural resources associated with cycles of livestock, oil, and methanol production. These create a rural under population subjected to processes of depopulation and repopulation (Martinic 2006). This is in addition to the mobile practices of its inhabitants, characteristics of the territoriality and coping with the geographical and environmental characteristics of extensive Patagonia (Bascopé 2018).

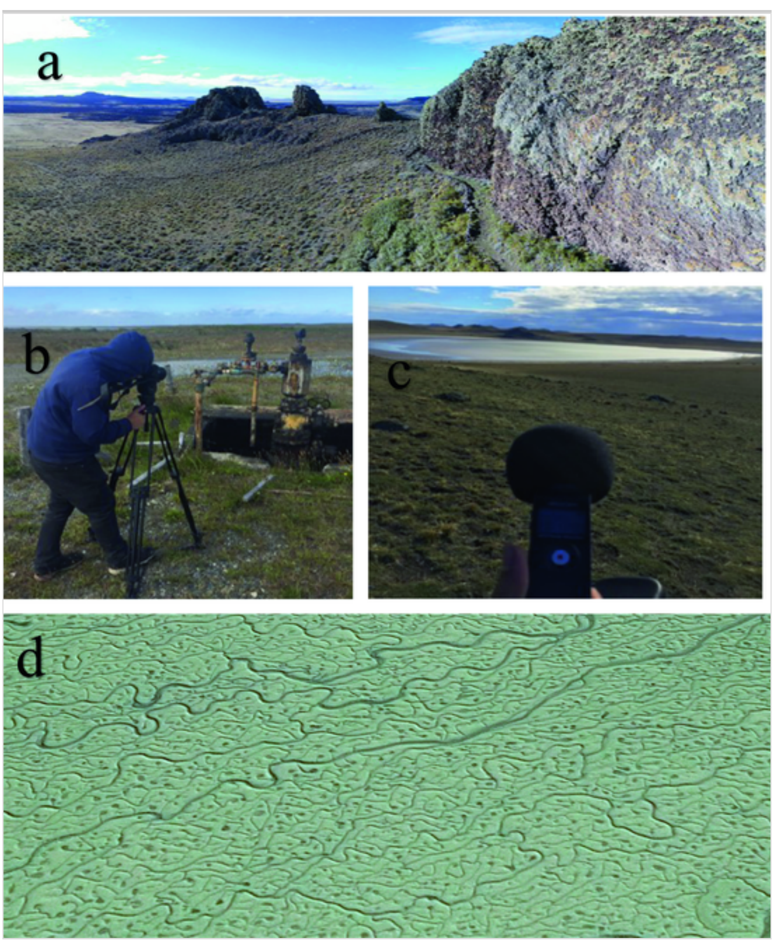
All these features represent a paradoxically contested heritage, termed by Arqueros et al. (2015) a “heritage in extinction.” In this context, one of the greatest challenges for the valuation and preservation of biogeopatrimony in Patagonia is related to its systematization and communication in highly fluid territorial contexts.

To address this challenge, we have developed work that rescues geographical geonarratives of the inhabitants of this territory, who, through their stories, name, and identify their places of cultural significance and the spatial practices in relation to these places. Based on these accounts, Geographic Information Systems are used to register places and routes.

Subsequently, fieldwork activities include audiovisual recordings of these places through film equipment and drone devices. These materials are edited and published to contribute to the continued narrative-building regarding the biogeopatrimony present in these spaces. Such video support allows for more effective communication of territorial memories and local heritage and extends the diffusion of the results.

Fig. 5.5

Remarkable aspects of southern Patagonia biogeocultural heritage: **a** 360° photography recorded by means of drone devices, inside an ancient volcano crater that served as a settlement for ancient indigenous peoples, in *Pali Aike* National Park; **b** Audiovisual record of biogeocultural heritage sites affected by oil extraction projects; **c** Records of soundscapes associated with biogeocultural heritage sites, in this case, the sounds of birds and fauna associated with bodies of water inside *Pali Aike* park; **d** Fluvio glacial sedimentary deposits near the glacial arc of terminal moraine at Magellan Strait, as viewed from satellite images (Photos by P. Mansilla)



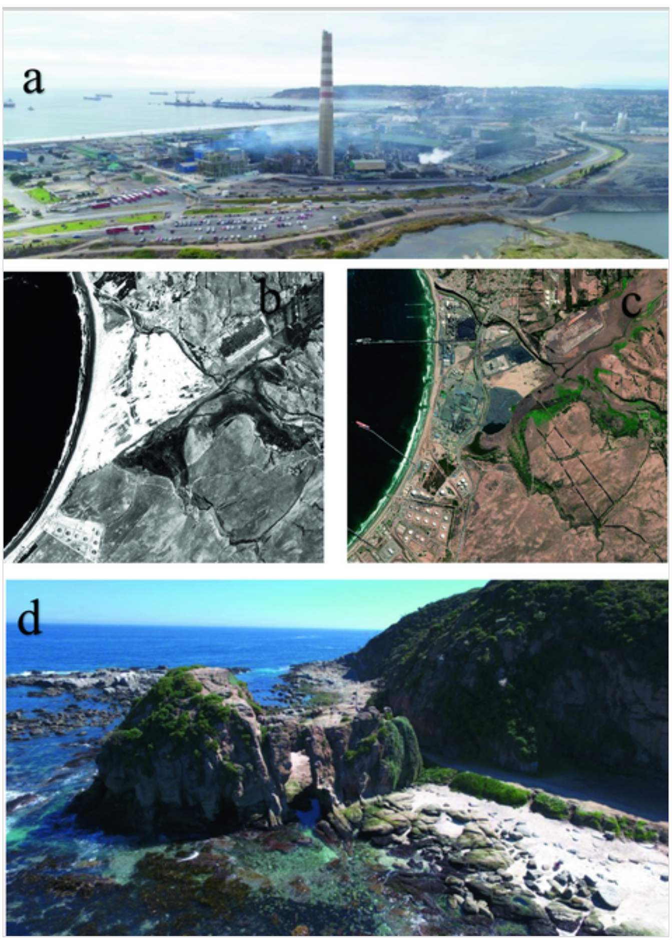
Indeed, further proposals regarding geosites and aspects of geoheritage have been undertaken in the extreme south of Chile and Argentina. Emblematic geosites already recognized include the Magallanes drumlins, the Mylodon cave, the *Torres del Paine* intrusive complex, and the *Pali Aike* volcanic field (Fig. 5.5), among others. Briefly, the Mylodon cave, a paleontological site, shows evidence of ancient human intermingling with prehistoric mylodon—an extinct Pleistocene herbivore—dating back to 12,000 years BP. *Pali Aike*, additionally, is considered a keystone of regional geoarqueological heritage (Barberena et al. 2006). Proposals to integrate geosites with tourism have been already undertaken by Mazzoni (2017) and Mazzoni et al. (2016).

5.4.4. High-Resolution Imaging by UAV at a Sacrifice Zone (*Quintero-Puchuncaví*)

The "*Loncura* dune field" (32°45′S), in Quintero bay, is a natural site in maximum degradation. The 1920 topographic map and 1955 Hycon aerial photo survey show a triangular dune field, bordered by a small river and the *Puchuncavi* wetland, with a surface of 182 ha, to the west (Fig. 5.6).

Fig. 5.6

Integration of different visualization tools (aerial photographs and UAV imaging) at a coastal "sacrifice zone": **a** *Las Ventanas* industrial complex, UAV photo; **b** 1955 Hycon aerial photo showing the original *Loncura* dune field; **c** 2018 image showing the *Las Ventanas* complex industrial above the old dune field; **d** Natural arch, *Quintero* coast next to *Las Ventanas* complex (Photos by P. Mansilla and with permission of the IGM Military Geographic Institute of Chile)



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Currently, the field is a narrow beach with a foredune running parallel to the coast. There are deflation corridors—longitudinal dunes orientated NE–SW—transversal dunes and scattered vegetation. The development of "*Las Ventanas*" complex industrial, currently the most polluted place in Chile, which began construction in the mid-twentieth century, has constantly ablated the riches of this place. Today, this dune field has been reduced to 12.6% of its original surface, which is now rife with pollutants and has altered aeolian morphologies. Some kilometers to the west of the *Las Ventanas* complex is the interesting paleontological site, "*Los Maitenes de Puchuncavi,*" at grave risk of disappearing due to pollutants affecting the fossils there?

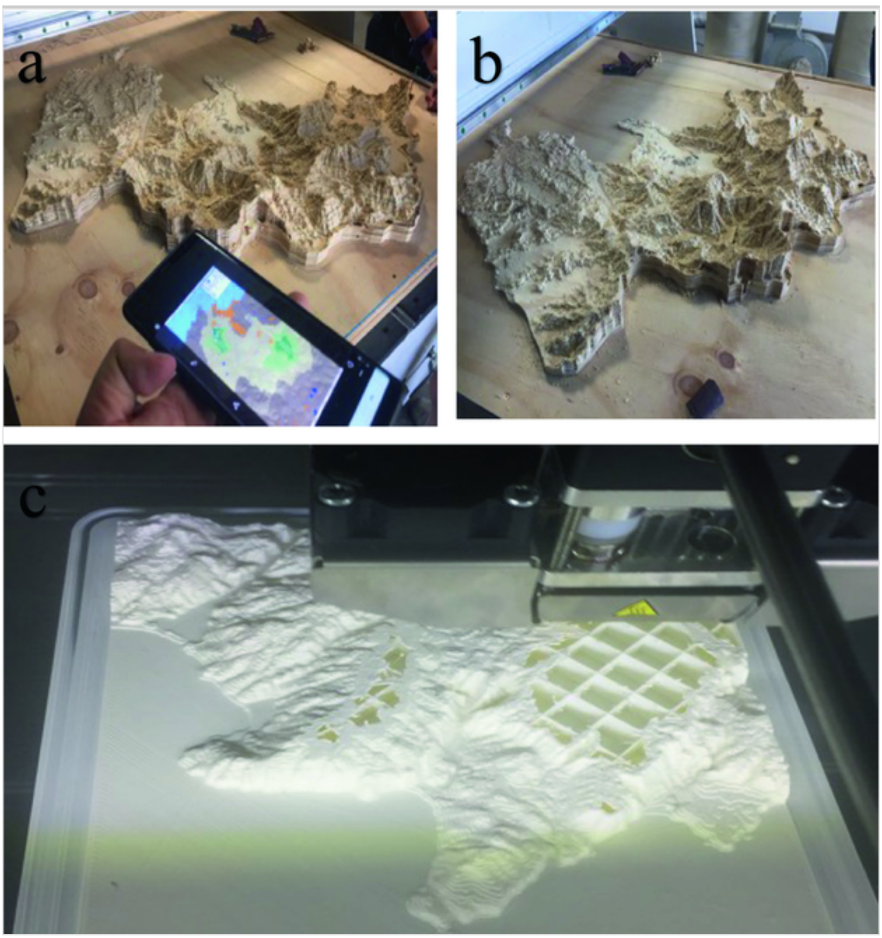
Changes in historical land uses show the disappearance of sand dunes and the associated geological and biological values. However, even though there are still surviving paleontological sites of unquestionable geoheritage (Andrade et al. 2009), they have been classified a "sacrifice zone." Since the installation of industries in the 1960s, the area has undergone spoliation from the respective pollutants, and the air, soil, and water have been systematically poisoned (Muñoz et al. 2019). This has occurred to such an extent that nearby schools have been shuttered, and there are periodic environmental emergencies that sharply and negatively affect the quality of life of the people, with no end in sight. In one of the worst years to date, hundreds of cases were recorded in 2018 due to noxious chemicals, resulting in demonstrations against the "sacrifice zone" determination for industrial use, the low regulations, and the socio-environmental considerations (Pasten 2019).

5.4.5. An Integrated Geobiocultural Approach to Virtual Heritage

To address the above concerns, the authors are integrating all features mentioned throughout this paper into a mobile phone application, tentatively called "Geoscopio." This app is a platform for generating interactive channels in an information space, collected by a diversity of actors participating in Geoheritage and Environmental conservation (Fig. 5.7). Such applications—be they strictly virtual heritage, or virtual and augmented reality—can help the design of "Virtual Geographic Environments (VGEs)," considered the "new generation of geographic analysis tools" (Lin et al. 2013) and serve as primers for future Geography and Geology teaching (Lv and Li 2016).

Fig. 5.7

3D model impressions: **a**, **b** in wood, for outreach and participatory actions toward the recognition of biogeocultural heritage; **c** through 3D Ultimaker 2+ printer, with PLA filament



This will provide students with better comprehensions of the functioning of geosystems and the importance of conserving geoheritage and geodiversity (Brocx and Semeniuk, 2007; Gordon et al. 2018). It also opens the real possibility of building a future ethical framework for protecting geoheritage and its related fields in Latin America (Acevedo and Martínez Frías 2018).

5.5. Conclusions

This contribution proposes to advance and consolidate the concept of 'Biogeocultural Virtual Heritage' through the enhancement of geovisualization tools, toward a better understanding and conservation of biogeocultural heritage in Chile throughout its diverse landscapes and biogeocultural regions. This project implies the integration of traditional aspects of geoheritage with other important values of the landscape, such as the biological and cultural values of ancient and current communities with deep historical roots in these diverse landscapes. This goal is forwarded through the implementation of the novel languages and practices made available by geovisualization, which provides specific protocols and methods for effective participation and societal relationships to environmental problems and their possible solutions.

Although these devices do not themselves overcome the challenges of biogeocultural heritage conservation, they do reduce imbalances in the cultural capital of local actors living in territories where geoheritage is most evident. Advances toward the conservation of biogeocultural heritage will only be possible if we develop techniques and protocols for a better societal comprehension of these elements as parts of a rich and complex array of geosystems, landscapes, and heritages throughout Chile and the southern Andes. This requires encouraging interactive engagement and constructivist interpretation in citizens, scientists, and non-human actors to give sense to natural spaces and to environmentally devastated spaces, like *Las Ventanas* industrial complex.

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