



Heritage Value and Stakeholders' Perception of Four Geomorphological Landscapes in Southern Iceland

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Abstract

This paper has two main objectives: (1) to assess the heritage value of four geomorphological landscapes in Southern Iceland from a geomorphological perspective and (2) to see to what extent the heritage values assigned by different local stakeholders overlap with this assessment. The concept of “geomorphological landscape”, that we define as a landscape whose geomorphological component is of heritage interest, is a scale of analysis that can be understood by different groups of people and that reflects subjective perceptions of the landscape. The evaluation of the heritage value of four geomorphological landscapes has shown that their geoscientific, aesthetic and cultural values are particularly high. Indeed, thanks to their rarity, representativeness, integrity and paleogeographic interest, all four sites have a geoscientific value ranging from 0.81 to 0.94 (the maximum possible score is 1). They also constitute spectacular and beautiful landscapes and have acquired a relevant cultural value because of the major impacts that volcanic eruptions and glaciers advances have had on the local population. Not surprisingly, the heritage awareness of managers of protected areas is high. The interviews also show that other types of stakeholders, such as tourism services providers, tourism promoters and representatives of local authorities, are also aware, to some extent, of the high geoscientific value. The societal and institutional recognition of the heritage value of these geomorphological landscapes is closely linked to their use as territorial resources for tourism.

Keywords Geomorphological landscape · Geomorphological heritage · Geomorphosite · Stakeholders' perception · Geoconservation

Introduction

Geomorphological heritage and landscapes have one common characteristic: their existence depends on a certain socio-cultural context and on the subjective view of different observers. Indeed, considering landforms or portions of land as heritage results from a process of “heritage making” (“patrimonialisation”, Di Méo 2008), an object is considered heritage when the values assigned by society or by some actors are sufficiently important to justify its preservation and transmission to future generations. The societal process by which a geomorphological asset becomes heritage relies on the values assigned by the different stakeholders over time (Portal 2010; Reynard et al. 2011; Martin 2013). The

assignment of values differentiates landforms and geodiversity in general that may be considered value-neutral terms (Gray 2018), from geomorphological heritage, which results from the process of heritage making. From the perspective of geomorphologists, the central value of a landform is its scientific interest (Grandgirard 1997a; Reynard 2004a), i.e. its interest in understanding geomorphological processes, reconstructing the formation and the evolution of landforms, etc. To avoid confusion, the prefix “geo” could be added when referring to “geoscientific value”, as this relates to a site's interest in the Earth sciences. The values that justify the heritage recognition of a landform may also be related to its beauty (aesthetic value), its cultural interest or its ecological value. Reynard (2004a; 2005a) suggested calling these features “additional values”. Landforms that have a scientific and additional values are called geomorphosites (Panizza 2001; Reynard and Panizza 2005). Compared to other categories of geosites, geomorphosites have three main distinctive characteristics (Reynard 2004a, 2009; Coratza and Hobléa 2018): (1) their aesthetic value is often high, (2) they may

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be shaped by active processes (dynamic component) and (3) they vary in size, from microforms to complete landscapes, and some large geomorphosites may encompass smaller ones. Geomorphosites, as a generic term, does not have a specific scale, although the choice of a scale of analysis has implications for their description, evaluation, mapping and management. The complexity due to the multiple and nested scales was pointed out by Grandgirard (1997b), Reynard (2009), Giusti and Calvet (2010), Giusti et al. (2013) and Coratza and Hobléa (2018), but without proposing until now operational guidelines to address it.

A clear distinction has to be made between landforms (value-neutral) and geomorphosites (part of the natural heritage, Brilha et al. 2018; Gordon 2019). Similarly, by definition, a landscape is differentiated from a portion of land because it has different values related to human perception (Backhaus et al. 2008), while a portion of land is value-neutral. As a consequence, the perception of a landscape, of its beauty and its cultural value, can be very different depending on individual and cultural factors. A landscape may also be considered part of heritage, sometimes only by some people, and perhaps for different reasons. Some landscapes have gained international recognition for their scientific value, particularly the sites included in the UNESCO World Heritage List under the criterion *viii* — “to be outstanding examples representing major stages of earth’s history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features” (UNESCO, World Heritage Centre 2019). The Dolomites and Mount Etna (Italy), Yellowstone, Grand Canyon and Yosemite national parks (USA), the Giant’s Causeway (UK), Ha Long Bay (Vietnam) and Vatnajökull National Park (Iceland) are some emblematic examples of the 93 sites on the World Heritage List that meet criterion *viii* and which contain many interesting landforms and geomorphological specificities. Obviously, besides their scientific interest, most of these sites are also landscapes of particularly high aesthetic value. Sixty-one of the sites that meet UNESCO criterion *viii* are also recognized under criterion *vii* — “to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance” — and ten of them, such as Tongariro National Park (NZ) and Uluru-Kata Tjuta (Australia), also meet cultural criteria. Several World Heritage sites inscribed exclusively for cultural criteria are also examples of high quality geoheritage (Migoñ 2018), such as Pingvellir (Iceland), the site of an open-air parliamentary assembly since 930, which is also an excellent and accessible example of continental rifting geomorphology.

As the example of the UNESCO World Heritage sites suggests, we assume that it is relevant to consider geomorphological heritage and landscapes together when defining their heritage value, as most geomorphosites also have a

high landscape value (Reynard 2009; Coratza and Hobléa 2018; Reynard and Giusti 2018). This allows the perspectives of different stakeholders to be better reflected than with a narrower approach focusing only on the landforms themselves, taken separately. In this article, we suggest using the concept of “geomorphological landscape” (Reynard 2005a) that we define as *a landscape whose geomorphological component is of heritage interest*. With this concept, we try to use a scale of analysis that can be understood by different groups of people, including scientists, site managers, visitors and tourism promoters, and that considers subjective and individual perceptions of landscapes.

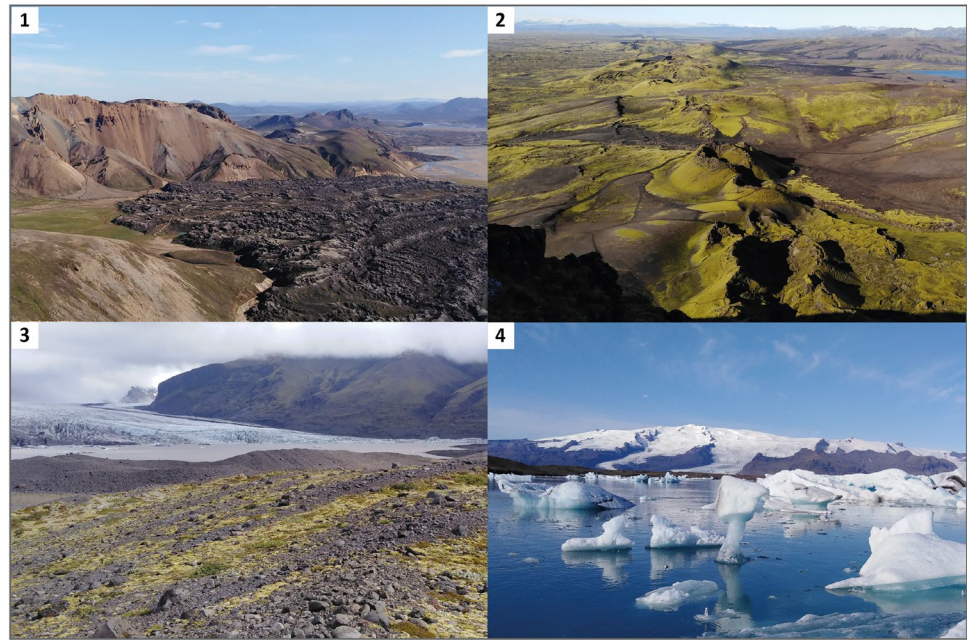
This paper has two main objectives: (1) to assess the heritage value of four geomorphological landscapes in southern Iceland from a geomorphological perspective and (2) to see to what extent the heritage values assigned by different local stakeholders overlap with this assessment. The four geomorphological landscapes are Skaftafell Glacier, Laki craters, Torfajökull caldera in the vicinity of Landmannalaugar and Breiðamerkur Glacier and its proglacial margin, including Jökulsárlón (Fig. 1). All these four landscapes are very interesting from a geomorphological point of view, and at the same time, they have a high aesthetic value and are popular tourist sites. First, the heritage value from a geomorphological perspective is evaluated. We then present the views of 12 stakeholders, representatives of tourist services providers and tourist offices, managers of protected areas, geopark managers and mayors of local municipalities. This leads to a discussion on the values assigned to the four geomorphological landscapes and on the degree of heritage awareness by the stakeholders, compared to what geoscientists consider important to conserve for future generations.

Landscape and Geomorphological Heritage

Different Landscape Approaches

The concept of landscape is at the crossroads of two approaches: naturalistic and humanistic (Bertrand and Dollfus 1973; Berque et al. 1994; Reynard 2004b, 2005a; Wylie 2007). The naturalistic approach, developed in the eighteenth century mainly with the works of Alexander von Humboldt (Waage 2013; Reynard and Giusti 2018), aims to describe the *objective landscape* as an arrangement of biotic, abiotic and anthropogenic elements. This definition of the landscape refers to a portion of land, which includes not only natural elements, but also the cultural agents that shape the landscape. From a geomorphological point of view, the landscape consists of landforms and a set of processes responsible for their formation and evolution, including anthropogenic ones. Carl Sauer (1925) defined landscape as “an area made up of a distinct association of forms, both physical and cultural”.

Fig. 1 (1) Laugahraun lava, in the vicinity of Landmannalaugar, (2) Laki craters viewed from Mt. Laki (3) moraine deposits in the proglacial margin of the Skaftafell Glacier, (4) icebergs on the proglacial lake Jökulsárlón. Öræfajökull in the background. Photos: J. Bussard, 2020



However, the naturalistic approach neglects the question of how the landscape is perceived by its observers (Luginbühl 2007). In the 1970s, with the rise of humanistic geography, the *subjective landscape*, i.e. as seen and perceived by humans and not only as a functional entity, gained interest. Meinig (1979) underlined that “any landscape is composed not only of what lies before our eyes but what lies within our heads”. Landscape is therefore not just an arrangement of biotic, abiotic and anthropogenic elements; it has also a subjective dimension due to the complex relationship between the landscape and its observers. The subjective dimension of the landscape is not only related to individual perception: the way people appreciate the landscape is largely influenced by cultural patterns and by the social context in which they are embedded. To reflect this observation, Backhaus et al. (2007; 2008) suggested differentiating four “poles” of landscape perception: physical, subjective, intersubjective (social practices) and symbolic (cultural patterns).

The European Landscape Convention (art. 1, al. a) defines the landscape as “an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe (2000)). This broad definition reflects a compromise found to give a shared meaning to this polysemous concept, and with the use of generic terms such as “area” and “people”, it results in a very inclusive definition. In other international conventions or treaties, the meaning of landscape can be classified into three categories (Seguin 2017): (1) the aesthetic face of territory (sensitive, visual, aesthetic approach), (2) the natural face of territory (natural, biological, elements-based approach) and (3) a place where population lives (political, societal, structuralist approach). In Iceland, the concept of “landslag” finds deep

roots in Icelandic culture (it was already mentioned in medieval literature, the “Sagas of Icelanders” (Waage 2012)) and gained a specific attention with the development of hydro- and geothermal power production in the uninhabited highlands of the country (Benediktsson 2007). Both for the lay Icelandic public and for experts in nature conservation, landscape is often equated with beauty and aesthetic judgment (Waage 2010; Jóhannesdóttir 2017) and therefore “describes a particular experience of the world; a meaningful experience of human-nature relations” (Waage 2013).

These various approaches show that there are many different reasons to consider that landscape may have a heritage value. In this paper, we propose a detailed analysis of one of the heritage characteristics of the landscape: its geomorphological component (Reynard and Giusti 2018).

Geomorphological Heritage

The study of the heritage recognition of geomorphological objects, a societal process according to which a landform becomes heritage, and specifically the analysis of heritage trajectories (Portal 2010; Reynard et al. 2011; Bétard et al. 2017) makes it possible to understand the values attributed to heritage by various stakeholders over time (Martin 2013). Heritage trajectories depend on the awareness of different stakeholders of the heritage values of a site, particularly during the initial phase of the process that Sellier and Portal (2018) call the appropriation phase. Although heritage inventories are generally produced by scientists, decisions concerning the management of heritage sites are linked to political choices of elected representatives, land use planners, landowners, etc. (Poiraud and Dandurand 2017).

Geoscientists, but also other types of collective or individual stakeholders, are key players in raising awareness of heritage, but their intervention is not sufficient to ensure that a site gains a heritage recognition by a wider public. Stakeholders may also have contradictory views on the management issues of a geomorphosite (Gauchon 2012). Conflicts can occur when specific uses do not consider a geomorphosite as heritage, or when geomorphosites constitute a territorial resource (Gumuchian and Pecqueur (2007)), particularly if non-geoscientific stakeholders reverse the hierarchy between geoscientific and additional values (Hobléa et al. 2017). Uses of geomorphosites as a resource can be of two types: (1) uses for sociocultural development, with an objective of environmental education and (2) uses for economic exploitation and for territorial development (Bétard et al. 2017). These two approaches are not necessarily incompatible or conflicting; geotourism (Hose 1995; Newsome and Dowling 2010) and geoparks (Zouros 2004; Martini 2010) are trying to accommodate both. However, the use of geomorphosites for territorial development purposes can lead to various types of damages if the heritage values are not sufficiently taken into account by the stakeholders involved or in the management measures. This can particularly be the case when the exceptional aesthetic characteristics of a geomorphological landscape tend to mask its interest in understanding the Earth's history and geomorphological processes (Cayla et al. 2012; Reynard 2021).

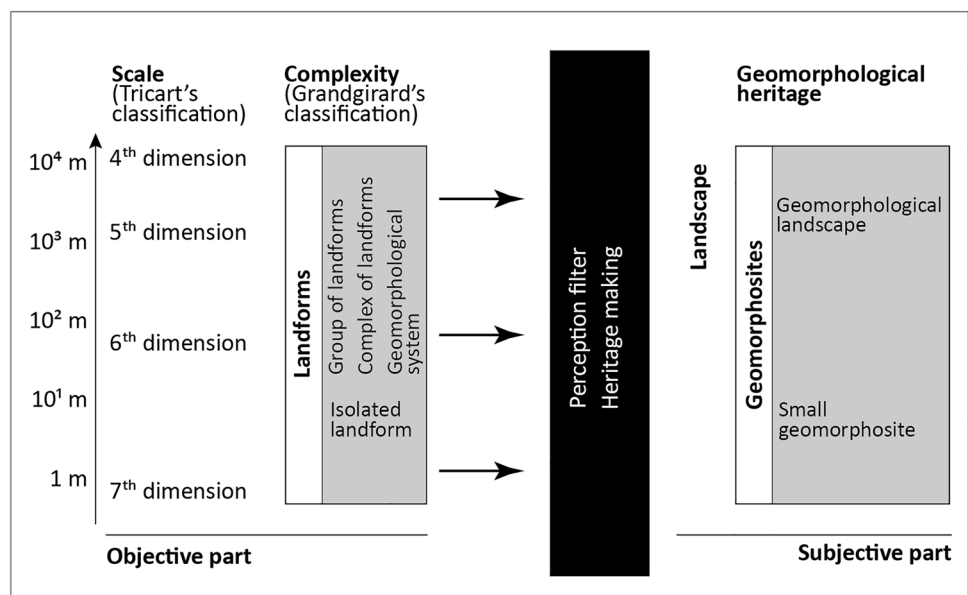
Geomorphological Landscapes as a Scale of Analysis

We have highlighted the difference between portions of land or landforms that are value-neutral terms and landscapes or geomorphosites that have acquired a value due

to human perception. For the same reason, we distinguish a portion of land made up of several landforms and a geomorphological landscape, which has a heritage value. In the literature, the concept of geomorphological landscape has been widely used, for example in the “World Geomorphological Landscapes” publication series edited by Piotr Migoń, but only one definition of the concept was proposed: a geomorphological landscape is “a portion of Earth relief viewed, perceived and sometimes exploited by Man” (Reynard 2005b, 2009). In that sense, landforms are the objective part of the landscape (Reynard 2005a), and geomorphological landscapes result from the subjective perception of these landforms. Several authors (e.g. Chen et al. 2015; Necheş and Erdeli 2015; Portal 2017) used the term “geolandscape” as a synonym.

Geomorphological landscapes constitute the category of geomorphosites that has the largest scale (Fig. 2). This scale corresponds to the fourth and the fifth dimensions suggested by the geomorphologist Jean Tricart (1965), i.e. a hectometric, kilometric or plurikilometric scale, which includes a portion of land that can be seen by the human eye from a viewpoint. Tricart's dimensions 1–3 are larger (from the planet Earth to hundreds of square kilometres) and go beyond what can be appreciated from a viewpoint. Therefore, a relief belonging to one of these dimensions cannot be considered a geomorphosite (Migoń and Pijet-Migoń 2017). The sixth dimension corresponds to areas of a few dozen metres and can be applied to the constituting landforms of a landscape. Many medium scale geomorphosites belong to this category. The seventh and eighth dimensions refer respectively to microforms (maximum 1 m) and to microscopic elements that are not significant in a geomorphological landscape.

Fig. 2 Scale classification and perception filter, from objective landforms to geomorphosites and geomorphological landscapes (after Tricart 1965; Grandgirard 1997b; Reynard 2004b; Giusti et al. 2013)



Because of its larger size and more encompassing scale, a geomorphological landscape is likely to be more complex, in terms of geomorphological processes responsible for its formation and variety of landforms, than a small geomorphosite, although this complexity is not systematically related to spatial scale. Grandgirard (1997b) proposed to call “complex of landforms” the geomorphological objects that include several types of landforms and “geomorphological system” when they are formed by several processes. Conversely, an “isolated landform” and a “group of landforms” refer to geomorphological objects that include only one type of landforms and that are formed by only one main process. A geomorphological landscape can fall into any of the four categories of Grandgirard’s classification, but because of its large scale, it is more likely to be a complex of landforms or a geomorphological system. The four geomorphological landscapes studied in this paper belong to these two categories (Fig. 2).

The choice of geomorphological landscape as a scale of analysis is particularly appropriate to compare the geoscientific view with that of a wider public on the heritage values attributed to the landscape. Unlike geomorphosites, the notions of heritage and landscape are not restricted to Earth sciences (Giusti and Calvet 2010) and therefore can be used in a discussion with different types of actors. The choice of this broad scale is not intended to restrict the analysis to large objects, but on the contrary allows considering objects of different sizes that make up the landscape.

Methodology: Assessment Method and Interviews

The research question is answered in two steps. First, the heritage value of four Icelandic geomorphological landscapes is assessed from a geoscientific perspective using detailed evaluation criteria. Secondly, a series of interviews are conducted with local stakeholders and managers to assess their perception of the heritage value of the landscapes.

Geomorphological Landscape Assessment Method

As the concept of geomorphological landscape has not been used much in the literature, no formalized method exists to assess its heritage value at its specific scale. However, many methods that have been developed to assess the heritage value of geosites (Brilha 2016; Mucivuna et al. 2019; Németh et al. 2021) and they can be used to assess geomorphological landscapes, as the latter constitute a category of geomorphosites. Most methods distinguish three groups of values (Coratza and Hóbléa 2018): (1) geoscientific value, assessed quantitatively according to criteria of integrity, representativeness, rarity and paleogeographic interest (Grandgirard 1997a), (2) additional values (aesthetic, ecological, cultural, socioeconomic) and (3)

use values, such as accessibility, visibility, visit conditions, educational interest and protection status. Here, we consider that the use and management characteristics are not part of the substantive quality of a geomorphosite (Reynard et al. 2016) and are therefore not included in the evaluation of its heritage value. Besides, assigning a score to use characteristics is not neutral: it means that the author takes a stand in favour of certain interests. The issue of accessibility is a good example: the tourism development potential of an easily accessible site is greater than for a remote site, but at the same time, a good accessibility can increase the risk of degradation due to the pressure of human activities. Therefore, a clear distinction has to be made between heritage values and use characteristics.

Regarding additional values, the most frequently assessed are cultural, aesthetic, ecological and economic values (Mucivuna et al. 2019). However, we consider that the economic value is related to the uses of geomorphosites and is not an intrinsic value. For this reason, we will not evaluate it as a heritage value. In addition, there are particularly few discussions in the literature about the evaluation of the ecological value of geomorphosites and the detailed criteria for evaluating it are not clearly defined (Bussard and Giaccone 2021). Therefore, in this article we will not be able to give an accurate evaluation of the ecological value. Finally, as aesthetic and cultural values have an important subjective dimension (related to individual or collective perception of what is aesthetic or not, of what is culturally important or not), we will assess these values in a qualitative manner only, without assigning scores.

Interviews with Stakeholders and Managers

Twelve semi-structured interviews were conducted in August and September 2020. Four interviewees are from the tourism sector (tourism service providers, representative of a regional tourism office), four are managers of protected areas (national park and nature reserve), two are representatives of a geopark and two are mayors of local municipalities. All interviews were conducted in English and lasted 45 to 90 min. Eight interviews were carried out at the interviewees’ workplace in Iceland (Kirkjubæjarklaustur, Höfn, Reykjavik and Selfoss), one in a café (Skaftafell) and three remotely, by videoconference. We adopted the methodology of the problem-centred interview, which aims at optimizing “the respondents’ possibilities to explicate themselves” (Witzel and Reiter 2012) and focus on the individual perspective on specific problems. Consequently, the semi-structured interview guideline that we used was adapted for each of the interviewees according to the specificities of the study sites. This allowed flexibility in the discussion, according to the respondent perspectives on the issue. The guideline was structured to obtain data about individual perspective on the heritage value of geomorphological landscapes and on issues and adaptation measures related to tourism management and

territorial planning. For data processing, each interview was audio recorded and a detailed summary was systematically produced, with an exact transcription of key passages.

Study Area

Four sites in Southern Iceland were studied (Figs. 1 and 3): (1) Torfajökull caldera in the vicinity of Landmannalaugar, (2) Laki craters (Lakagígur) and Skaftáreldahraun lava flow, (3) Skaftafell Glacier and its proglacial margin, (4) Breiðamerkur Glacier and its proglacial margin, including Jökulsárlón proglacial lake. All four sites reflect geomorphological specificities of Iceland, with the presence of numerous landforms related to volcanic eruptions, to glacial, periglacial and fluvio-glacial processes or to the combination of several processes. The sites were chosen for two reasons: they have a very high heritage value and are popular tourist sites.

The caldera of the Torfajökull volcano (Fig. 4) is the largest rhyolite outcrop (McGarvie 1984; Gunnarsson et al. 1998)

and the most powerful and extensive geothermal area in Iceland (Ivarsson 1992; Björnsson 1996; Sæmundsson 2009). It has an exceptional diversity of landforms that originates from different processes: volcanism, geothermal processes, frost weathering, glacial erosion, and the combination of several of these processes. The very colourful and varied landscape is not only due to volcanic eruptions but is also the result of erosion (Etienne 2004). Indeed, erosion exposed at the surface rocks that have been highly altered by geothermal heat in depth, taking on colours ranging from orange to green, blue, yellow, red and grey. Landmannalaugar is located at the entrance of the caldera, at the foot of a black obsidian lava, the Laugahraun, which dates from the year 1477 (Macdonald et al. 1990). Since the construction of a mountain hut in 1951, visitors have been coming here in the summer to enjoy the landscape and to bathe in the hot springs (Haraldsson 2011). Integrated into the Fjallabak nature reserve in 1979, this area is increasingly popular for outdoor activities (Sæþórsdóttir 2013), although access via an unpaved track is impossible without a 4×4 vehicle.

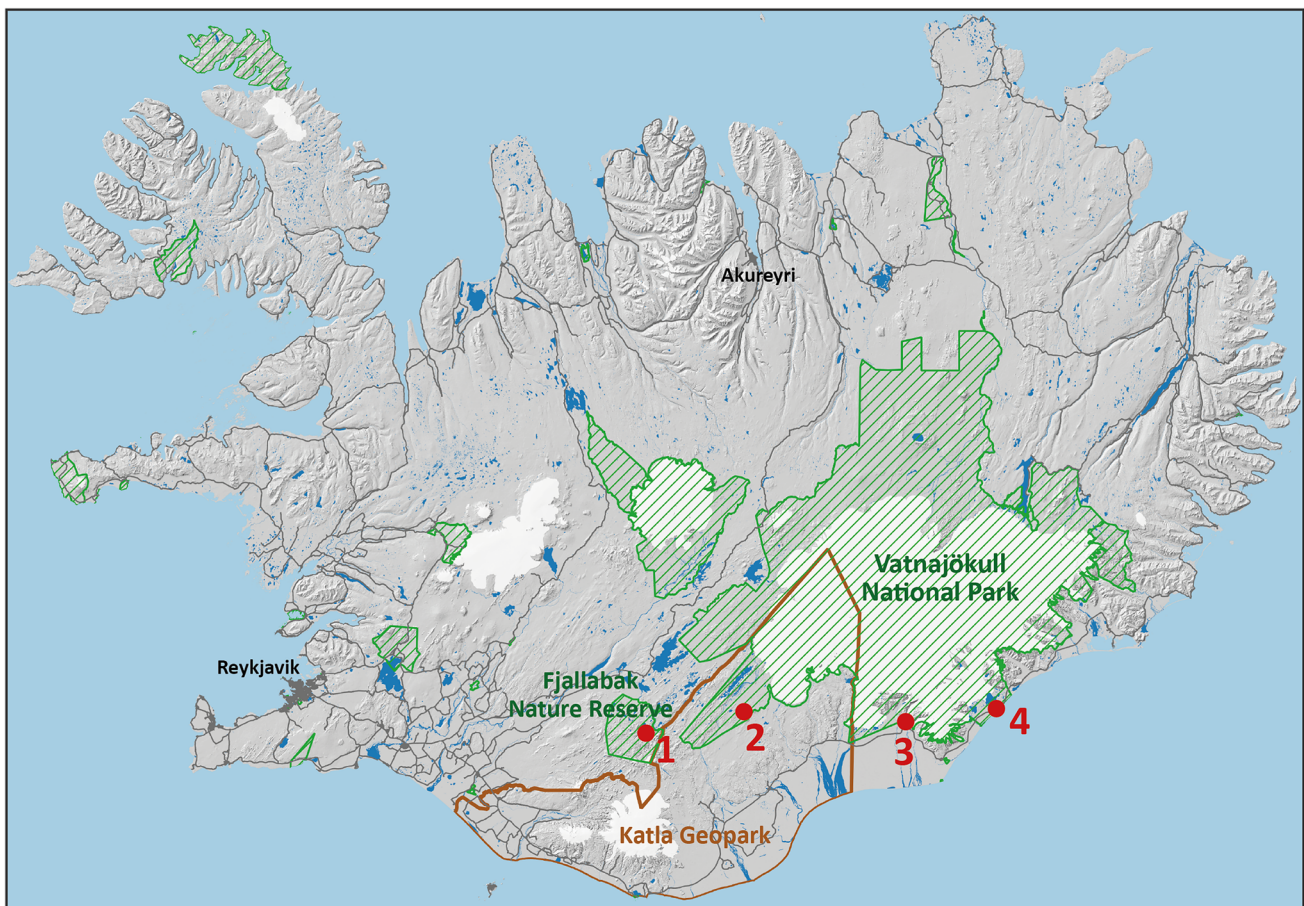


Fig. 3 Location of the four geomorphological landscapes studied; (1) Torfajökull caldera in the vicinity of Landmannalaugar, (2) Laki craters (Lakagígur) and Skaftáreldahraun lava flow, (3) Skaftafell Glacier

and its proglacial margin, (4) Breiðamerkur Glacier and its proglacial margin, including Jökulsárlón proglacial lake

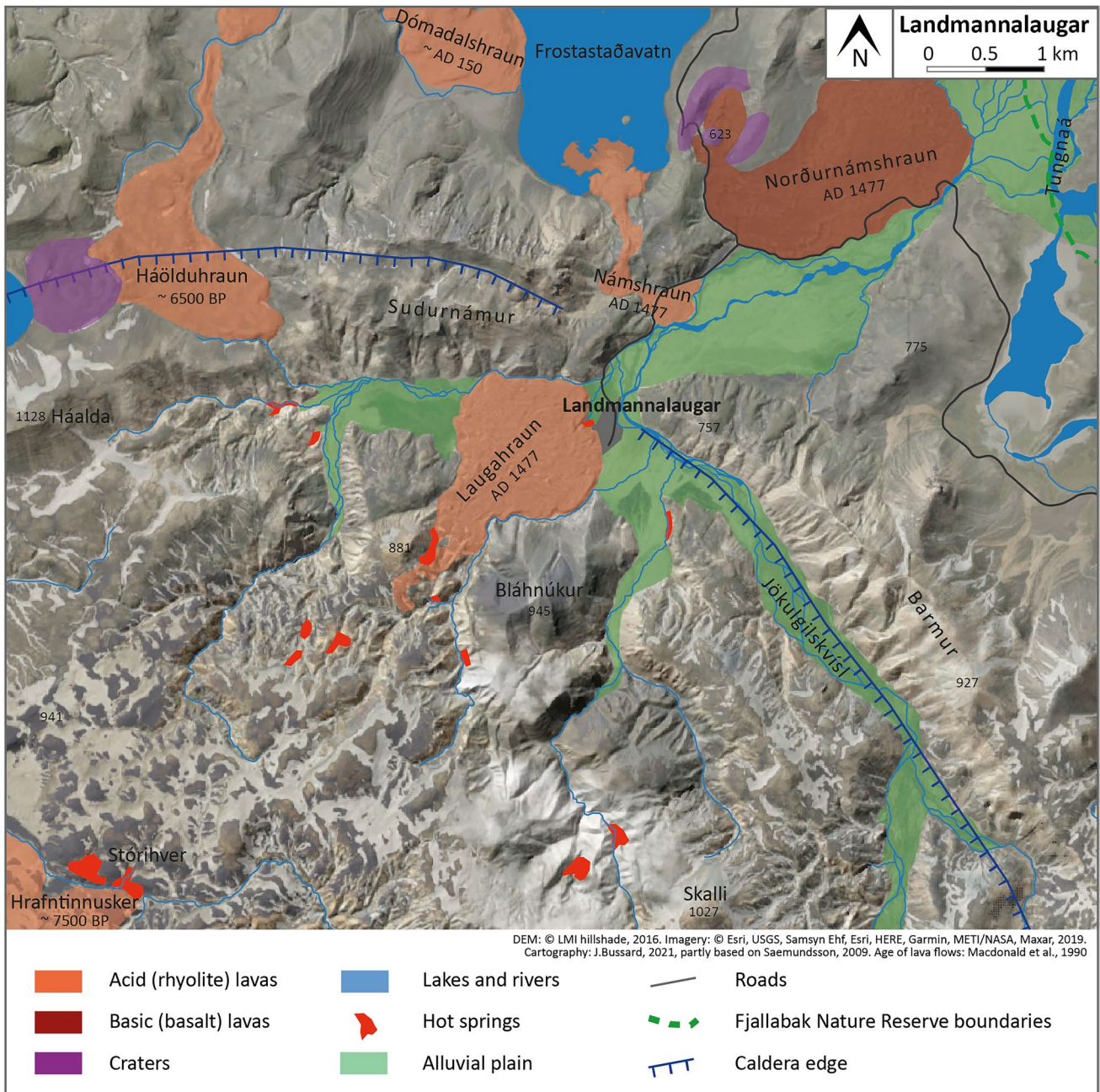


Fig. 4 Simplified geomorphological map of Torfajökull caldera in the vicinity of Landmannalaugar

The Laki craters (in Icelandic: *Lakagígar*) are the results of a volcanic eruption called Skaftár Fires that occurred in 1783–1784 AD, considered one of the largest and most devastating lava eruptions ever witnessed by humans (Thordarson and Self 1993; Baldursson et al. 2018). The Laki vent system is a series of about 140 cones and craters lined up over a length of 27 km along fissures (Fig. 5). The name Laki comes from a small, older hyaloclastite mountain located in the middle of the eruptive fissures of 1783 that offers an excellent view point for today’s

visitors. The 45 km long unpaved track that leads to Mount Laki crosses several rivers, which limits accessibility to well-equipped visitors. The basaltic lava (called *Skaftáreldahraun* in Icelandic) flowed down to the lowlands in two lobes: the first one (*Eldhraun*), at first confined in the Skaftá river gorges, spread out in a vast fan, and the other one (*Brunahraun*) follow Hverfisfljót River to the lowland, covering altogether an area of 599 km². The lava surface is mostly pahoehoe-like, but can also be rougher and jagged in some places. Today, most of the lava surface

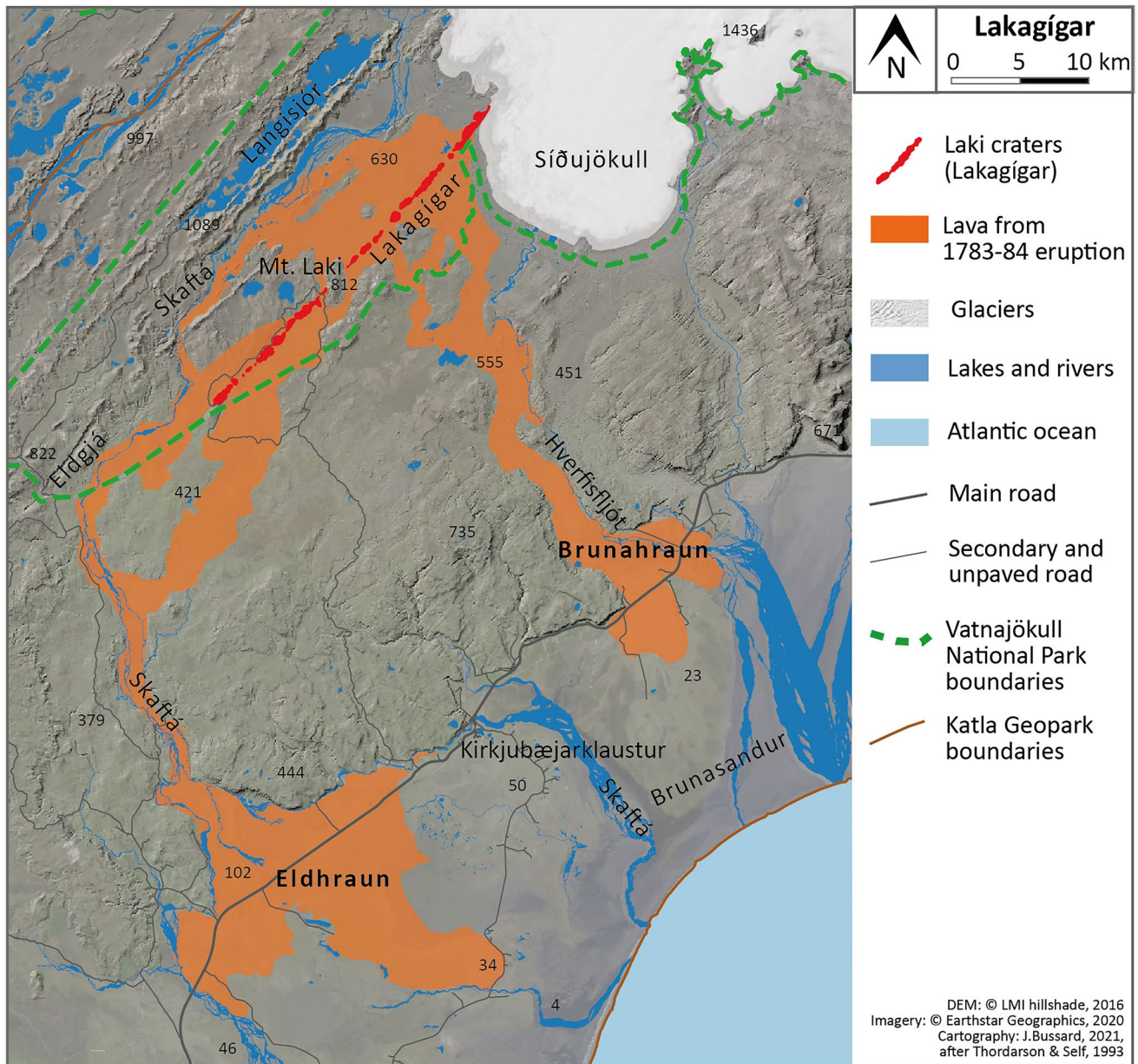


Fig. 5 Location of the Laki craters and lava flows from 1783 to 1784 eruption

is covered by mosses. The main road crosses the two lobes east and west of Kirkjubæjarklaustur village.

Skaftafell Glacier (in Icelandic: *Skaftafellsjökull*) is an active temperate outlet glacier (Fig. 6) flowing from Vatnajökull ice cap (Fig. 3). The accumulation zone is mainly in the Örefajökull volcano massif, Iceland's highest peak (2110 m ASL). Skaftafellsjökull tongue has a length of about 11 km and a relatively regular width of nearly 2 km. It is surrounded by steep slopes on both sides (U-shaped valley) until it reaches the lowlands, at an altitude of 100 m, where its proglacial margin meets the vast Skeiðarársandur, one of the largest active outwash plains in the world (Baldursson et al. 2018). At the end of the Little Ice Age

(LIA), Skaftafellsjökull was coalescing with its neighbouring Svínafellsjökull. Today, the glacier front is nearly 2.5 km from the LIA terminal moraine and finishes its course in a small proglacial lake (Guðmundsson et al. 2020). Within the limits of the LIA end moraines, almost untouched moraine and glaciofluvial deposits are valuable evidence of the dynamics of glacier retreat. A dense network of sawtooth-shaped (or hairpin-shaped) push moraines is particularly developed at the front of Skaftafell Glacier and provides a textbook example of such landforms (Evans et al. 2017). The entire glacier and part of the proglacial margin have been included since 1967 in the Skaftafell National Park (Ives 2007), which became part of the larger Vatnajökull

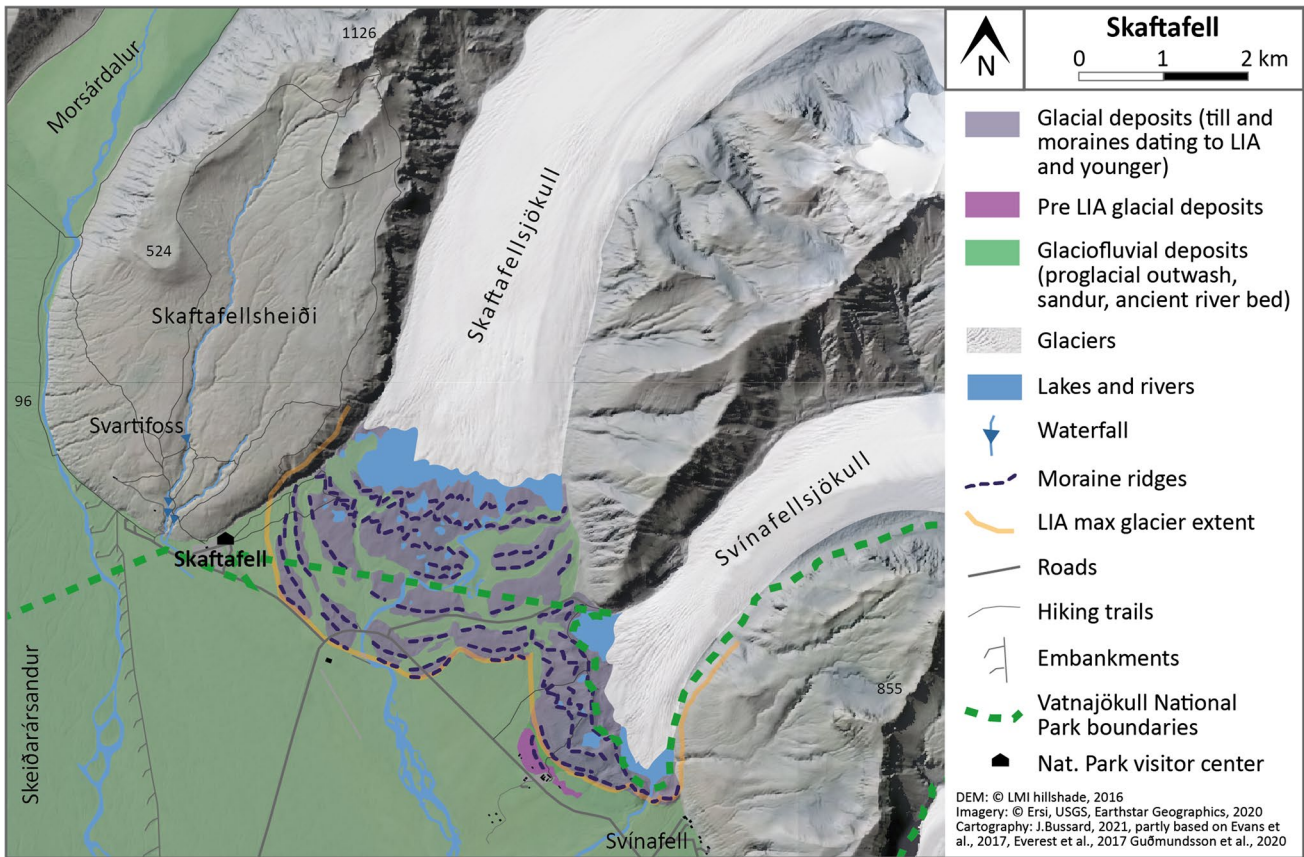


Fig. 6 Simplified geomorphological map of Skaftafell and Svínafell glaciers area

National Park in 2008 and was included in the UNESCO World Heritage List in 2019. Most of the LIA moraines are outside the park’s boundaries. The National Park’s visitor centre is close to the main road and accessible all year. Recently, the numbers of visitors in Skaftafell increased very rapidly from 183,000 in 2010 to 736,000 in 2017 and the proportion of visitors travelling in summer (June, July and August) diminished simultaneously, from 77% in 2010 to only 47% in 2017 (Þórhallsdóttir and Ólafsson 2018). Svartifoss, a waterfall surrounded by basalt columns at a walking distance from Skaftafell, is also a goal of excursion.

Breiðamerkurjökull is another outlet glacier (Fig. 7) formed by the coalescence of four tongues flowing from Vatnajökull ice cap (Fig. 3). A part of its wide front (more than 12 km wide) ends in a proglacial lake called Jökulsárlón, which fills a depression almost 300 m deep (Björnsson 1996). Jökulsárlón is connected to the Atlantic Ocean by a narrow 700 m long channel. At high tide, the relatively warm and salty sea water flows into the lake, giving Jökulsárlón the characteristics of a coastal lagoon (Harris 1976). Numerous icebergs detached from the glacier are constantly moving because of the currents generated by the significant variations in temperature and salinity inside the lake (Voytenko et al. 2015). A parking lot alongside the main road and near the bridge over the Jökulsá

River provides easy all year access to the shore of Jökulsárlón for an estimated 770,000 visitors in 2017 (Þórhallsdóttir and Ólafsson 2018). The vast proglacial margin partly filled by the lake can be separated into two distinct entities: the part outside the LIA end moraines, which ends in the ocean, is a sandur which bears the marks of many ancient river beds. The part inside the LIA end moraines consists of a large variety of landforms such as moraine ridges, push moraines, fluted moraine deposits, eskers, kames and kettles, small sandurs, active or former glacial outwash channels and proglacial lakes. This high variety of landforms has been widely studied and provides a striking example of temperate glacial geomorphology (Price 1969; Evans and Twigg 2002; Evans 2016). Since 2017, all the area is included in the Vatnajökull National Park.

Results

Heritage Value of Geomorphological Landscape

The results of the evaluation of the heritage value from a geomorphological perspective are summarized in Tables 1, 2, 3 and 4. The scientific value is very high for the four

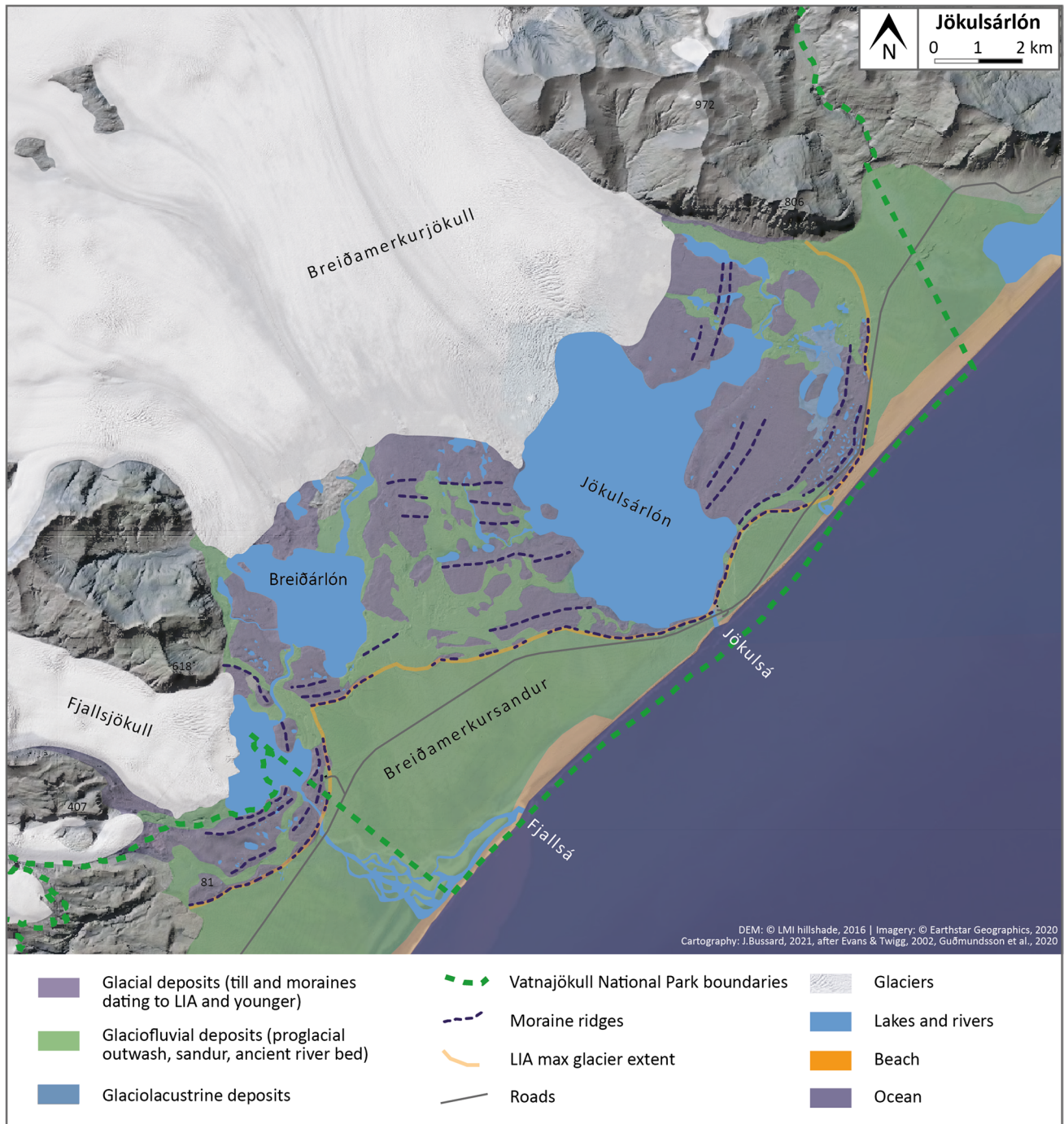


Fig. 7 Simplified geomorphological map of Breiðamerkursandur and Jökulsárlón area

sites, ranging from 0.81 to 0.94 (the maximum possible score is 1). The highest score is for the representativeness of geomorphological processes and landforms: all sites can be considered textbook examples for their characteristics. Three sites are rare at a national and global scale, Skaftafell being a bit more common. The paleogeographic

interest is high for all sites: proglacial landforms in Skaftafell and Breiðamerkursandur provide valuable information on past glacier extent and dynamics and volcanic deposits (tephra, lava flows) provide the same for characterizing eruptions that occurred in Landmannalaugar and Laki. Integrity does not reach the maximum score

Table 1 Evaluation of the heritage value of the Torfajökull caldera in the vicinity of Landmannalaugar

Torfajökull caldera in the vicinity of Landmannalaugar		
Scientific value		0.94
<i>Integrity</i>	Near Landmannalaugar, tourism-related facilities (access roads, parking lots, campsite, mountain hut, hiking trails) have a noticeable impact, especially the access road through the Námshraun lava flow. Elsewhere, despite the fragility of some forms such as hot springs, impacts of tourism are low. There is no industrial exploitation of the hydroelectric potential or geothermal heat (area located in the Fjallabak nature reserve since 1979)	0.75
<i>Representativeness</i>	Very representative of the geothermal formations visible in Iceland (fumaroles, boiling pits, mud pools, hot water springs), the geothermal alteration of rhyolite and post-glacial volcanic activity, with the presence of numerous lava flows. It also illustrates the impact of periglacial processes and river erosion on rhyolite slopes, which are very sensitive to frost weathering	1.00
<i>Rarity</i>	The diversity of landforms and processes in a small area makes the Landmannalaugar region very rare. Light coloured rhyolite outcrops and obsidian lava flows are a rarity in Iceland and make it possible to study the generation of continental silicic crust within an oceanic basaltic crust. It is also the largest and most powerful geothermal area in the country. The landforms related to subglacial volcanic eruptions (pillow-lavas, tuya, tindar) are frequent in Iceland but rare at a global scale	1.00
<i>Paleogeographic interest</i>	The succession of volcanic eruptions offers an interesting possibility to date the main stages in the development of the current landscape	1.00
Additional values		
<i>Aesthetic value</i>	Exceptional diversity of colours, contrasts and landforms. The aesthetic value is particularly high	
<i>Cultural value</i>	Summer tourism destination developed since the construction of the mountain hut close to the hot springs in 1951, but little cultural value	

Table 2 Evaluation of the heritage value of the Laki craters and Skaftáreldahraun lava flow

Laki craters and Skaftáreldahraun lava flow		
Scientific value		0.94
<i>Integrity</i>	Except the imprints of some hiking paths, the craters are intact and well protected (Vatnajökull National Park). Most of the lava fields are in remote places and intact as well. The main road crosses the lava fields. That causes occasional damage to vegetation and lava integrity close to the road	1.00
<i>Representativeness</i>	Laki craters and related lava flows are representative of effusive eruptions along fissures	1.00
<i>Rarity</i>	Basaltic lava fields are frequent in Iceland, but the huge dimensions of the 1783–1784 eruption lava are rare. The existence of 140 cones and craters lined up over a length of 27 km is unique in the country	1.00
<i>Paleogeographic interest</i>	Dimensions, structures and composition of the lava fields and craters allow understanding the features of the Laki eruption	0.75
Additional values		
<i>Aesthetic value</i>	Cones and craters have a high aesthetic value as they provide an impressive topographic contrast with the surroundings. The lava fields are very large and can be better appreciated from a high view point outside the lava surface	
<i>Cultural value</i>	Volcanic eruptions are part of the history of the country. Laki eruption had particularly disastrous consequences for people in Iceland and in continental Europe (due to sulphur dioxide emissions). The “Skaftá Fires” are an important part of local culture and history	

because of the impact of some infrastructure, mainly roads and tracks, in specific locations. However, most sites, all located in protected areas, are intact.

Topographic variety and contrasts of colour provide a very high aesthetic value to all four sites. The diversity of landforms and colours is particularly striking in the Torfajökull caldera. The presence of blue and white icebergs in the vast Jökulsárlón Lake and spectacular surrounding glaciers is also of great interest from an aesthetic point of view. As glacier expansion and volcanic eruptions had substantial

impacts on the life of local people (volcanoes are still a very noticeable threat), some landforms can be considered part of the local history and identity. The cultural importance of Laki craters and lava fields, which reminds one of the darkest episodes in Icelandic history, is particularly significant. Glaciers in the southern part of Vatnajökull have been the subject of remarkable glaciological studies since an early period and observations from local farmers were valuable for the understanding of their movements and dynamics. Finally, we choose not to assess the ecological value, but

Table 3 Evaluation of the heritage value of the Skaftafell Glacier and its proglacial margin

Skaftafell Glacier and its proglacial margin		
Scientific value		0.81
<i>Integrity</i>	Inside the Vatnajökull National Park (VNP) boundaries, the proglacial margin and the numerous moraine deposits are intact, with the exception of some foot paths. Outside VNP, the main road and access roads to Skaftafell and to Svínafell Glacier cross the proglacial margin and parts of the LIA end moraines	0.75
<i>Representativeness</i>	Very representative of active temperate glacial systems	1.00
<i>Rarity</i>	This type of glacier and proglacial margin is common in Iceland and particularly along the southern part of Vatnajökull, but is much rarer at a global scale	0.50
<i>Paleogeographic interest</i>	Moraine and glaciofluvial deposits give information on past glacier extent and dynamics. Tephrochronology helps to date deposits older than LIA. For example, a tephra cover shows that the outermost moraine crest of Svínafellsjökull (called Stóralda) is older than the AD 1362 Öraefajökull eruption (Pórarinnsson 1956; Gudmundsson 1998; Everest et al. 2017)	1.00
Additional values		
<i>Aesthetic value</i>	The U-shaped valley filled by the glacier is spectacular and has lots of colour and topographic contrasts. The proglacial margin is mostly greyish and greenish with a relatively smooth topography. In itself, the proglacial margin does not have a high aesthetic value	
<i>Cultural value</i>	Local farmers of the Skaftafell area are used to live very close to the glaciers. At the end of LIA, glaciers and jökulhlaups were threatening arable land and farms (Ives 2007). On many occasions, local knowledge and observation about glaciers helped scientists in the understanding of glacier dynamics (Björnsson 2017). Glaciers are an important part of the local cultural heritage and identity (Jackson 2019)	

the presence of rare species in geothermal formations (thermophilic species) in the Torfajökull caldera and pioneer plants in the recently deglaciated lands in Skaftafell and Breiðamerkursandur might be mentioned.

Heritage Value from Stakeholders' Perspective

The results of the interviews are summarized in this chapter. Quotations from respondents working in the tourism sector are indicated with the numbers T1–T4, in protected areas and geopark P1–P6, and in local municipalities M1 and M2.

Geoscientific Value

The high geoscientific value of the four geomorphological landscapes was mentioned by several respondents who described their specific characteristics of geoscientific interest. For instance, the scientific interest of the Laki craters was pointed out by a representative of the regional tourism office: “This is our attraction. [...] The Atlantic ridge is going through here and it is one of the few places where you can, on the ground, be on this tectonic plate boundary. Iceland is a very special place and there are a lot of places that have some nice scientific explanations” (T3). From the point of view of Vatnajökull National Park managers, glacier landscapes around Skaftafell are part of the area's identity and need to be protected: “We have the big big glaciers that are like crowning over us [...], we can see in our immediate landscape that all our surroundings are carved out by the glaciers [...], and that's what makes us special, I would say” (P3). “It is very important for us to protect the glacier

moraines and everything that reminds us how the glacier is retreating” (P2). For the Torfajökull caldera, which is a candidate for integration in the UNESCO World Heritage List (<https://whc.unesco.org/en/tentativelists/58177/>), the manager of Fjallabak Nature Reserve referred to the description provided by the Ministry of Education, Science and Culture of Iceland to UNESCO to justify its “outstanding universal value”. The application is based on criteria *vii* (exceptional beauty) and *viii* (significant geological and geomorphological features). “Well, it's a long list [of heritage values]! Because it is a very unique volcanic area” (P4).

Some respondents did not mention the geoscientific value directly, but when we raised the issue of site management, the protection of features related to the geoscientific value was discussed in many cases. The impacts of off-road traffic, including motorized off-road driving, but also the impacts of hikers, bikers and horse riders, were identified as the main threats to the integrity of fragile landforms, such as moraines, craters, lava fields and geothermal formations (P1, P2, P4, M1, M2). In Breiðamerkursandur, recently deglaciated land was considered by some respondents (P2, M1) to be the most fragile area because the land is not consolidated. In the Torfajökull caldera, geothermal areas were described as the most sensitive areas, where strict conservation measures need to be in place (P4).

Aesthetic Value

The high aesthetic value was mentioned by several respondents, especially the beauty of Jökulsárlón Lake and its blue and white icebergs (T1, M1), the mountainous glacier

Table 4 Evaluation of the heritage value of the Breiðamerkur Glacier and its proglacial margin

Breiðamerkur Glacier and its proglacial margin, including Jökulsárlón proglacial lake		
Scientific value		0.94
<i>Integrity</i>	The vast proglacial margin is very well preserved, except the area around Jökulsárlón parking lot, a few tracks used to access the glacier front from the main road and a section of 2 km of the main road which crosses the LIA frontal moraine east of Jökulsárlón	0.75
<i>Representativeness</i>	Very representative of active temperate glacial systems, including areas of glacial deposits composed of moraine crests and push moraines, areas of incised and terraced glaciofluvial deposits and areas of subglacial landforms such as drumlins, fluted moraines and eskers (Evans and Twigg 2002)	1.00
<i>Rarity</i>	The dynamics of Jökulsárlón, allowing the study of the impact of salted water on glacier melt, is very rare at a national scale. The spectacular dimensions of the glacier and its proglacial margin are also very rare. Even if larger examples exist in Iceland, the assemblage of multiple and well-developed glacial landforms seen in Breiðamerkursandur is unique	1.00
<i>Paleogeographic interest</i>	Moraine and glaciofluvial deposits provide information on past glacier extent and dynamics. With empirical observation below Breiðamerkursjökull, Boulton and Hindmarsh (1987) were the first to show that downstream displacement of a glacier is due not only to basal sliding and ice deformation, but also to deformation of the bed under the glacier (Evans 2016)	1.00
Additional values		
<i>Aesthetic value</i>	The aesthetic value is very high, thanks to the presence of a blue lake surrounded by a pronounced topography, from the green and grey plains to the highest peak in the country, covered by huge white coloured glaciers. Blue and white icebergs moving on the lake surface reinforce the particularity of this landscape	
<i>Cultural value</i>	Glaciers are an important part of the local cultural heritage and identity (Jackson 2019). Breiðamerkursjökull proglacial margin has also been a major scientific study site that has led to significant development in the understanding of glaciology and glacial geomorphology (Evans 2016; Björnsson 2017)	

landscapes (P3) and the lava fields (P5, M2). Glacier landscapes were for example qualified as “dramatic landscapes of pure beauty” (T1) and the panoramic view from the Kristínartindar, a peak overlooking Skaftafell Glacier, as “unique” and “the most spectacular” (P3). The aesthetic value and the intact natural landscapes are also considered a major resource for tourism, as the manager of a tourism agency said: “For Jökulsárlón, where my company is, the nature is what we are selling, and we have to be careful that the nature is saleable, that we can sell it. So, we have to keep it as clean, as original as possible” (T4). Another example is that of the regional tourism marketing office, which places great emphasis on scenic natural landscapes in its marketing: “Of course, we show pictures of the landscapes we have, of specific places, but also of kinds of landscapes like lava fields and black sand beaches. So, we are trying to make some impressions on people, this ‘waouh!’ impression” (T3). Several interviewees noted that the mass tourism practices that have developed since 2010, especially sightseeing tours, are very much focused on the aesthetic character of tourist places: “Instagram tourists” (M1) go around the island as quickly as possible to see as many sites as possible and post photos on social media. They travel too fast to take advantage of the experiences related to cultural and natural heritage (M1, M2, T3, P3).

However, for some tourists, the motivation for visiting the region is not only related to the appreciation of the aesthetic value of landscapes, but also to the willingness of

“experiencing nature”. Seeing the ice, touching the ice or walking on the ice are seen by different respondents (T1, M1, P2, P3) as major tourists’ motivations for visiting the area, with other reasons such as being in nature, hiking, seeing volcanoes and bathing in hot pools.

Cultural Value

Another element noted by various respondents is the high cultural value. Several stakeholders (P1, M2, T3) mentioned that volcanic eruptions are part of Icelandic culture and local identity: “All the people in Iceland have heard about the big eruption in 1783 [...] and they like to hear the story of the reverend who stopped the lava flow and everything [...] because it is just part of our culture” (P1). Laki craters and lava flows are in that sense a remarkable reminder of how volcanism affected people’s lives. “The eruption has affected this area so much and we have it all around us, we see it in the lava fields. [...] I think it’s very very important to protect the area so we can keep on telling the story [...], give people chance to see it, also because it’s beautiful” (M2).

According to the respondents, considering craters and lava fields as part of the cultural heritage is recent: “I don’t think that people in the old times have seen any beauty in craters like these. For them it symbolized just death, you know, something terrible” (P1). The same observation applies also to glaciers, especially around Vatnajökull outlet glaciers. A local guide (T1) originated from Skaftafell region and a

park manager (P2) explained that for previous generations, glaciers were representing a hazard and their current retreat sounds like good news. “For example, my husband’s grandma, she was like ‘are you crazy going up to the glacier?! Do you know how dangerous that is?’, because when she was growing up very close to the glacier, it was really dangerous and you didn’t go to the glacier unless you really needed to” (P2). Jackson (2019) observed the same by interviewing local people in the area. Today, for younger generations and for visitors, the feeling is the opposite, with Icelandic glaciers and especially the Breiðamerkurjökull being “a huge evidence of what is happening to our climate” (T1).

Multiple Values of the Landscape as a Whole

Regarding landscape management issues, for most respondents, the distinction between different types of values is not very clear. Rather, the landscape seems to form a whole characterized by a set of different values that are combined. Thus, landscape management seems to respond to several parallel objectives: to ensure the protection of the beauty of the landscape, in particular by ensuring that it remains as untouched as possible, to protect specific landforms such as moraines, lava flows and craters, and to provide access for visitors to enjoy and experience the beautiful landscape and the outdoor activities. The diverse management measures in force or proposed are of two types: (1) land use planning and infrastructure development, particularly regarding tourism activities and (2) tourism management and education. In the Vatnajökull National Park, in the Fjallabak Nature Reserve and on the Eldhraun lava flow, the hiking trails and footpaths networks have been improved in order to limit the dispersion of visitors away from the marked roads and paths. This measure makes it possible to limit damage to fragile landforms such as craters or geothermal formations, but also to limit the visual impact of new trails, larger tracks, etc. (P2, P4, M1). Different managers of protected areas suggested other measures that could be adapted to specific sites, such as a limitation of motorized access, an interdiction of visits without a guide, a limitation of the number of visitors or travel agencies, or the definition of sensitive areas where access should be limited.

The management objectives for accessible or for less accessible sites are different. The long and difficult unpaved track leading to the Laki craters, and to some extent the dirt road leading to Landmannalaugar, drastically limit the number of visitors and reduce the length of the tourist season to few summer months. Consequently, the poor access conditions ensure a passive conservation (P1, M2). For these sites, management objectives tend to minimize the development of large infrastructure and their visual impact in order to keep nature and landscape as intact as possible. Conversely, the proglacial margins of the Skaftafell and Breiðamerkur

Glaciers are very easily accessible, being directly on the main road, which is open all year. According to the interviewees, there is a need to develop tourism infrastructure (T2, T3, T4, M1, P2, P3, P4) adapted to the hundreds of thousands of tourists who visit the glacial sites every year (except in 2020). All interviewees agreed that the existing infrastructure on the shores of Lake Jökulsárlón is by far insufficient — “Even the toilets are terrible!” (M1) — and that the country was not prepared for such an increase in the number of tourists during the last 10 years. “In 2010, after the volcano eruption, we were put on the world map. I think there is no TV station in the world that didn’t talk about the eruption. All of a sudden Iceland became a hot spot and we had a huge number increase every year. [...] We were not ready for that, we didn’t have the infrastructure ready, we didn’t have any planning ready” (T2). In Jökulsárlón, poor visit conditions (T2, T4, M1) and difficulties in managing traffic can have a negative impact on the landscape and damage landforms. The objectives of the measures envisaged in a new management plan in preparation (by Vatnajökull National Park) are therefore to improve visit conditions, to keep the landscape as intact as possible and to avoid degradations due to the increasing number of visitors.

To a majority of respondents, the multiple interests (scientific, aesthetic, cultural) need to be better promoted through the development of educational activities (P1, P2, P3, P4, P5, P6, M2, T3). A park manager explains that to avoid damages on sensitive landforms, “Most of the work is just to talk to people, let them know how fragile it is, because it doesn’t look like that” (P1). The same discourse was observed in the regional tourism office: “We need to make people aware of the importance of nature, because if people know more about the nature, more about how important it is or how rare it is, it’s obvious that people will respect the nature more and they will not damage it or walk outside of the path, etc.” (T3). In 2020, Vatnajökull National Park was planning to build a new visitor centre in Breiðamerkursandur which, besides improved catering and souvenir shopping services, would allow for increased information and awareness among visitors about the characteristics of the site. The National Park has also recently initiated projects to inform visitors about glacial processes and morphology, as well as past and future changes in the glacial landscape under the influence of climate change, through an educational website (project “melting glaciers”) and the implementation of interpretive trails.

Discussion

The assessment of the heritage value showed that all four geomorphological landscapes have a high geoscientific value, related to their rarity, representativeness and paleogeographic

interest. With only little impacts of human activities, these sites are almost intact. The geoscientific value was the main reason to justify the integration of Vatnajökull National Park in the UNESCO World Heritage List in 2019, as the nomination (Baldursson et al. 2018) and the decision of the UNESCO World Heritage Committee (decision code: 43 COM 8B.8) clearly indicate. The Icelandic Act on Vatnajökull National Park entered into force in 2007 also stipulates that the protection of “landslag, lífríki, jarðmyndanir og menningarminjar” [landscapes, ecosystems, geological formations and cultural monuments] (art. 2, al. 1) is a purpose of establishing the park. The inscription of “Torfajökull Volcanic System / Fjallabak Nature Reserve” on the UNESCO Tentative List by the Government of Iceland in 2013 is also based on the geoscientific value (selection criterion *viii*) and on the exceptional natural beauty (criterion *vii*) of the site related to the colorful landscapes formed by geothermal alteration and to “remarkably diverse landforms resulting from a combination of volcanic, geothermal, glacial and fluvial processes” (Icelandic Ministry of Education, Science and Culture 2013). From an institutional point of view, the geoscientific value of the study sites is therefore clearly recognized. By consequence, it is not surprising that managers of Vatnajökull National Park and Fjallabak Nature Reserve consider the geoscientific value as an important feature that must be protected in their areas of operation, even though the term “geoscientific value” is never used as such by the interviewees.

However, the interviews showed that protected area managers are not the only ones with this opinion. Indeed, stakeholders of the tourism sector and representatives of local authorities are aware, to some extent, of the value of geomorphological heritage. This explains why, in 2010, local stakeholders decided to establish Katla Geopark, with financial support from three municipalities, with the objective of promoting tourism activities based on local geoheritage and supporting regional development. We argue that the efforts undertaken for protecting and labelling geomorphological heritage are perceived very positively by tourism service providers and by tourism offices because they constitute a valuable territorial resource (Bétard et al. 2017). A preserved nature with interesting geomorphosites has indeed a great value for local tourism economy. According to some respondents, the aim of the creation of Katla Geopark was mainly to develop new tourism offers. Similarly, Vatnajökull National Park has the objective, written in the law, to strengthen economic activities in the vicinity of the park (Act on Vatnajökull National Park, art. 2, al. 4). This process of using geomorphological heritage for tourism purposes and economic activities shows a shift from conservation to a more economic approach that may possibly increase “tensions between the imperatives of geoheritage conservation on the one hand and the challenges of territorial development on the other” (Poiraud and Dandurand 2017).

The high aesthetic value was often mentioned by all types of stakeholders. This supports the hypothesis of Hobléa et al. (2017) that additional values — in particular the aesthetic value — play a primary role in the use of geomorphological landscapes as territorial resources for tourism. The predominance of aesthetic aspects may cause two types of issues (Reynard 2021): (1) geomorphosites with a high geoscientific value but that are less scenic (for example a moraine ridge), less spectacular or considered as “ordinary” landscape may be ignored (Portal 2013) and (2) the aesthetic value of geomorphosites may mask their geoscientific interest (Cayla et al. 2012). However, local stakeholders are, to some extent, aware of the geoscientific interest of the study sites, and they give importance to their cultural value. This allows us to consider that the geoscientific, the cultural value and the aesthetic values are all taken into account by local stakeholders, and that less aesthetic geomorphosites are probably not ignored.

Finally, from a methodological point of view, we believe that a broad approach, with the use of the concept of geomorphological landscape, is very useful for discussing issues of geoheritage management in a tourism context. Indeed, the question of the spatial scale and related complexity (selection of specific scales, nested scales) can be simplified by considering the landscape as a scale of analysis. Because the area considered is the same, this allows comparing data obtained with different methods (geomorphological landscape assessment method and qualitative interviews). Besides, in the case of the four geomorphological landscapes studied in Iceland, the cultural and aesthetic values are related to a whole landscape (glacier landscape or volcanic landscape) and not to specific smaller landforms. Consequently, the scale of the geomorphological landscape is well adapted.

Conclusion

The evaluation of the heritage value of four geomorphological landscapes in Southern Iceland has shown that their geoscientific, aesthetic and cultural values are particularly high. Indeed, thanks to their rarity, representativeness, integrity and paleogeographic interest, all four sites have a geoscientific value ranging from 0.81 to 0.94 (the maximum possible score is 1). They also constitute spectacular and beautiful landscapes and have acquired a relevant cultural value because of the major impacts that volcanic eruptions and glaciers advances had (and occasionally still have) on the local population. Not surprisingly, the heritage awareness of managers of protected areas (Vatnajökull National Park, Fjallabak Nature Reserve and Katla Geopark) that include these geomorphological landscapes is high. The interviews also show that other types

of stakeholders, such as tourism services providers, tourism promoters and representatives of local authorities, are also aware, to some extent, of the high geoscientific value. The establishment of Katla Geopark in 2010, the extension of Vatnajökull National Park to Breiðamerkursandur and Jökulsárlón in 2017 and the inscription of the park on the UNESCO World Heritage List in 2019 are evidence of a process of heritage making. The societal and institutional recognition of the heritage value of these geomorphological landscapes is closely linked to their use as territorial resources for tourism, with the risks that the aesthetic aspects tend to mask the geoscientific value and that a more economic approach increases tensions between conservation and tourism development. The lack of appropriate management plans and infrastructure in several tourist sites, particularly in the most accessible ones, due to the rapid increase of tourism activity since 2010, was pointed out by the majority of stakeholders as a major issue to ensure that tourism is compatible with landscape and nature conservation. The ongoing elaboration of several management plans for protected areas and tourist sites will reveal the extent to which the heritage values of geomorphological landscapes are actually taken into account in relation to other interests and uses.

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