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Editorial



Special issue: Time scaling issues in geoheritage studies

¹This virtual special issue is based on the presentations and discussions that took place at the International Geographic Union (IGU) Centennial Congress, held in Paris from July 18 to 22, 2022. The Congress was organized locally by the Comité National Français de Géographie (CNFG) around the theme “Time for Geographers.” Participants were invited to consider on how geography, which focuses primarily on terrestrial spatial issues, also deals with time. Among the 263 working sessions, the CNFG Geomorphological Heritage Commission, in partnership with the IGU Geoheritage Commission and with the support of the Working Group on Geomorphosites of the IAG (International Association of Geomorphologists) organized a session entitled “Time Scaling Issues in Geoheritage Studies”. The session was chaired and moderated by Claire Portal, and co-chaired by Fabien Hobléa and François Bétard, with the participation of Benjamin van Wyk de Vries and Dongying Wei. This special issue features six research papers based on the reflections of the session.

Participants were invited to examine questions of temporal scale, which are of fundamental importance in geoheritage studies, but whose various aspects are little considered in their own right. Indeed, it is the spatial dimension of geological and geomorphological sites (e.g., geosites in this editorial) that is more particularly studied; the complexity and interweaving of geoheritage spatialities (from outcrop to landscape) are the subject of numerous publications (for international journals, see among others the *International Journal of Geoheritage and Parks* and *Geoheritage*). While questions relating to temporal scales are explicitly developed in various studies (e.g., Reynard, 2009; Giusti & Calvet, 2010; Martini, Zhang, Gu, & Li, 2013; Bétard, Hobléa, & Portal, 2017; Coratza & Hobléa, 2018), these remain a minority in the profusion of publications on geoheritage. Most often, time and its scales seem to be integrated de facto. They rarely constitute a subject of reflection in their own right. As F. Hartog writes, referring to historians' practices, “time has become commonplace for the historian who has preserved or instrumentalized it. It is not considered because it is inconceivable, but because we do not think of it or, more simply, we do not think about it.” (Hartog, 2005, p. 7). However, temporal scales are a particular feature of environmental heritage: they interweave the temporalities of nature with those of culture, both historical and human. Theoretically, a geo-heritage element can tell its story from the creation of the planet to the present day, and into the future, depending on, for example, its evolution, its degree of vulnerability and, if they exist, the protection operations that have been put in place. The temporal aspect is therefore central to the selection of geosites, to the implementation of conservation and management measures, and to the production of interpretation tools. Thus, in order to understand the temporal dimension of geoheritage, two fields of study emerge, one more theoretical on the time of geoheritage taken in its broadest sense (including the geoheritage-making processes as a function of time), the other, more practical, on the time of geosites.

1. Geoheritage timescales

Time is a fundamental concept conceived as an “indefinite and homogeneous environment in which beings and things are situated, characterized by its dual nature of continuity and succession” (Centre National de Ressources Textuelles et Lexicales). Time is thus an uninterrupted movement whose duration is indeterminate and continuous, and which is marked by “instants that can be located in a chronological succession fixed in relation to a before, the past, and an after, the future” (ibid.). These temporal markers make change possible and comprehensible, and allow us to situate a story in time. Time then becomes measurable, and can be divided into delimited parts occupied by one or more events. We then speak of temporality as “the character of what is in time, of what belongs to time” (ibid.). More precisely, these last two points—succession and temporality—will interact

¹ Editor's Note: <https://www.sciencedirect.com/journal/international-journal-of-geoheritage-and-parks/special-issue/10K71ZR9NPG>.

to provide a framework for reflection in this first section. Theoretically, the aim is to question the temporalities specific to geoheritage, and in particular those of its scientific and institutional construction—from the knowledge of legacies to the modalities of heritage recognition. In other words, the temporal dimension of the heritage-making process (e.g., Bétard, 2017; Di Méo, 2008; Portal, 2010)—identifying the milestones that mark the transition from geodiversity to geoheritage—is explored in greater detail. Abiotic nature became part of the heritage field in the 1990s, at a time when this last was expanding rapidly and the historicity of natural elements had been thickening since the late 1960s. How is it that geoheritage, which holds one of the planet's oldest heritages, is one of the last of humanity's common goods to enter the heritage sphere? What were the triggers? What temporal trends (thresholds, continuity, duration) characterize the process of geoheritage institutional recognition? The literature on the modalities of geoconservation in different countries clearly shows that major international events such as the Declaration of the Rights of the Memory of the Earth in 1991, the constitution of the Global Geoparks Network in 2004, and its integration into a UNESCO program in 2015, and mark out the international temporal arrow, but that significant shifts exist at national scales (Bétard et al., 2023; Brocx & Semeniuk, 2007; Burek & Prosser, 2008). What's more, perceptions of historical time differ from one civilization to another: the linear, written history of the West is not the same as the cyclical or oral history of other cultures. "The diversity of heritage can be approached as the expression of the diversity of time in the history of cultures," wrote (Hartog, 2005, p. 8), qualifying the notion of "regime of historicity." According to Hartog, it can be understood in two ways: "in a restricted sense, as the way in which a society considers its past and deals with it. In a broader sense, [as] a method of self-awareness in a human community (...). More precisely, the concept provides an instrument for comparing different types of history (...) [to] highlight methods of relating to time" (Hartog, 2005, p. 8). This involves our representation of the past, present and future, and the way we have thought about history and time (Hartog, Chaouad, & Verzeroli, 2013).

Genetically, the notion of geodiversity is rooted in cosmogonic and cosmological temporalities, in human history and in aesthetic and landscape representations; the patrimonialization of elements that make up geodiversity involves temporalities associated with the actions of institutions that set up inventory, assessment, protection and enhancement procedures. Thus conceived in these multiple dimensions, the time of geoheritage requires the researcher to take a broad thematic approach in order to reconstitute its temporalities and trace its trajectory, whatever the spatial scale of analysis. Addressing the time of geoheritage-making process ultimately implies reflecting on its chronogenesis, "the recounting of scattered elements through the creation of a discourse characterized by an accumulation of signs and elements that allow us to think about and represent the time-image linearly" (Héritier, 2013, p. 7–8). As mentioned above, in the case of geoheritage, this storytelling goes beyond human temporalities, depending on the spaces studied, and is part of a multi-temporal and often multi-patrimonial dimension. As Héritier (2013) points out, heritage chronogenesis, like all forms of narrative, has three dimensions: retrospective, introspective and prospective-projective. This proposed reading applies to geoheritage chronogenesis:

- The first is retrospective, and "enables a society to draw on elements inherited from the past, to look back to past times to grasp certain forms, places or objects that have acquired symbolic status" (ibid., p. 5). For geoheritage, this means geological and geomorphological elements and paleoenvironmental archives associated with the sphere of life (paleobiodiversity), climate (including paleoclimates), and the broad cultural sphere (archaeological, industrial, mythological, historical, etc.).
- The second is introspective, "insofar as the construction of heritage questions the present in relation to the past" (ibid.). In the field of geoheritage, as with other types of heritages, this relationship is essentially inscribed in scientific discourse and in methods of interpretation and mediation.
- The third is prospective (or projective), "suggesting that through the modalities of heritage composition (...), heritage carries a societal project or purpose (which may be aesthetic, political or social)" (ibid., p. 6). In this context, the criteria for inventorying and selecting geosites, and the tools for protecting, promoting and labelling them, are important markers of this relationship with time: they bear witness to geoheritage temporal complexity through the "humanity/nature" relationship.

2. Geosite timescales

The title of the thematic session "Time Scaling Issues in Geoheritage Studies" suggests that, like spatial scales, the time of geoheritage can be plural: "as a palimpsest, the geo-morpho-site needs to be deciphered, even decrypted, in all its complexity, which is not only spatial, but also temporal" (Giusti & Calvet, 2010, p. 233). Through the selection criteria defined, geosites constitute a "practical" application of the modalities of geoheritage recognition. For geomorphosites, the integration of cultural criteria, even if secondary, is a determining factor in heritage consideration: it shows a predominance of certain aspects over others, and therefore the prioritization of certain temporalities. Finally, three temporalities, often successive, are involved in these practices. For each of them, the time factor takes on two dimensions:

- a. That of the "natural" temporalities of the geosite, intrinsic, genetic, of a geological, geomorphological or even ecosystemic nature;
- b. That of historical and cultural temporalities, associated with the different generations of people who have been and still are interested in the site and act upon it, either in relation to ancient practices and uses that are often bygone, or in the modern consideration and use of the place that has joined the heritage sphere as a geosite. This modern use of a geodiversity hotspot like a geosite brings into play and interrelates the approaches and viewpoints of scientific experts, managers, mediators and interpreters, as well as institutions, thus writing a new chapter in the narrative characterizing the temporal trajectory of the geosite as a place of diachronic nature/society interactions.

2.1. Time for research

The geoscientific characterization of a geosite involves a process of chronological calibration (dating) and genetic reconstitution (a), a process itself dependent on its own temporalities (b):

- a. When it comes to the geological and geomorphological nature of a geosite, age and time scales can be extremely broad and intertwined. Inherited geosites, which are sometimes more static, may have a very ancient geology and be subject to recent processes; “active” geosites, which are subject to current dynamics, do not exclude ancient heritages.
- b. Research time may be constrained, both in terms of duration and feasibility, leading to the adoption of adapted investigation strategies depending on the quantity and quality of existing documentation, the need for complementary or innovative research, financial issues, accessibility to the geosite, and so on. These temporalities are also valid for research carried out on ecological, archaeological, historical and cultural, aesthetic and other criteria. Thus, beyond temporal aspects *stricto sensu*, the holistic consideration of a geosite—and therefore of temporalities that can be very broad—raises the question of its documentation: if it relies on geoscientific data and environmental archives for geological and geomorphological issues, it must also integrate human archives, in order to feed the geohistorical knowledge of the geosite.

2.2. Time for geoconservation

The conservation actions implemented on a geosite depend on the results of scientific research. They are decisive when the integrity of the geosite is threatened.

- a. Temporal reconstruction of the evolution of a geosite (via satellite imagery, sedimentological studies, palynology, etc.) is essential in order to understand the dynamics specific to geosites and their evolution. In a context of global change and human actions that are sometimes detrimental to the preservation of a site, these elements are essential for adapting effective geoconservation strategies.
- b. In this context, the geoscientific sphere communicates to legislators and managers the need to set up conservation tools more or less rapidly: this is the time of “institutional” geoconservation, more or less long, which can, in some cases, exceed the urgency of preservation based on scientific criteria.

2.3. Time to promote geoheritage

The popularization of the results of scientific studies implies an in-depth reflection on time:

- a. The staging of genesis and dynamics of a geosite involves a number of didactic choices: which stages to focus on, how to show them, and how to present them? While digital tools (3D, dynamism) enable sometimes spectacular staging, they are no substitute for upstream reflection on content, the form of scientific information and the target audience (Ambert & Cayla, 2020; Martini et al., 2013; Migoń, Duszyński, Jancewicz, & Różycka, 2019; Sellier, 2009).
- b. The implementation of the means and tools themselves, e.g., their physical and intellectual accessibility, depends on the timeframes associated with funding arrangements, *media* production and so on. Experience shows that the time devoted to the crucial stage of final scientific validation of the contents and of the system for promoting a geosite (the scientific “ready for press”) is most often underestimated and compressed, even forgotten or is an “adjustment variable” in the timing of product manufacture.

The interweaving of these temporalities makes geosites spaces of memory (or “inscribed memory”) that record, through their spatial inscription, actions of transformation and development of the Earth, in other words, the temporally situated expression of evolving relationships between human societies and their environment. These are transmitted by “physical and concrete presences,” e.g., visible, whose content can be rapidly modified (Durand-Dastès, 1990, 2001). This is particularly true for geosites which are part of dynamic environments (coastal, mountain, hydrological, volcanic, etc.) or in areas subject to major anthropogenic modifications (e.g., urbanization). In the case of geoheritage and geosites, these explanatory approaches are part of a heuristic and multi-disciplinary dimension, at the junction with institutional players. The study of geoheritage temporalities is thus vast and complex. The six papers in this thematic issue illustrate different forms of temporality associated with geoheritage and geosites, without being exhaustive or covering all the aspects discussed above.

3. Presentation of the thematic issue

Thus, despite the diversity and specificity of the geoheritages studied in this special issue, there are two points in common between the different papers: the first shows the authors’ desire to take into account the cultural aspects of geosites, whether intrinsic (e.g., geoarcheosite, “hypergeosite,” geocultural site) or documentary (ancient and contemporary documentation); the second point places the methods of evaluating geosites at the heart of the reflections on the times of geo-heritages. These methods, whether quantitative or not, are strongly based on the cultural criteria mentioned above; they even go beyond the mere aspects of classification to evoke the anchoring of representations—genetically cultural—and the need to transmit the scientific knowledge of geosites that are evolving in a context of global change. The six papers are presented below in alphabetical order.

T. Ben Fraj, E. Reynard, A. G. Messedi and H. Ben Ouezdou focus specifically on the importance of interweaving the temporal aspects of geosites with a cultural dimension: these indeed combine high geoscientific and cultural values and are particularly suited to interpreting and promoting both cultural and natural heritage. The authors base their proposal on previous geoheritage inventories and analyze seven geocultural sites in the Dahar (south-eastern Tunisia) from the point of view of temporal interrelations. A specific four-stage methodology is proposed: (i) a synthesis of the site's components in text form; (ii) a summary table constructed according to a temporal scale made up of six periods (geological, geomorphological, prehistoric, historical, present and future); (iii) a graphic representation of the interweaving of these temporal scales; (iv) a cartographic representation of the results of the analysis. The proposed approach shows that the criteria used can serve both as an analytical grid for the inventory, selection and evaluation of geocultural sites, and as a framework for thinking about the interpretation and management of these sites.

J. Bussard and E. Reynard take up a topical reflection concerning glacial geosites and their rapid contemporary evolution: how are the geoheritage values associated with the presence of glaciers to be considered if they have disappeared or are only relict? The authors focus on the Great Aletsch Glacier and the upper Lauterbrunnen valley (Swiss Alps, UNESCO World Heritage Site 2001). They describe the evolution of the glacial landscape using a past-present-future framework, thus projecting the temporal issues of glacial geosites into their post-glacial future. Ultimately, the forms to be protected will be the legacies of landscapes that have disappeared but are recent (e.g., moraine ridges); the actions taken to enhance them will also have to be modified. The authors propose that the aesthetic codes of the white glacier landscape should evolve towards informed geotourism, where the public is offered a range of elements to understand the evolution of the landscape.

F. Hobléa's paper questions and explores the plurality of temporal dimensions of geo(morpho)sites, proposing to assign them designations as well as metrics enabling their quantification. The concept of geotemporality is thus proposed and developed, articulating the time of the Earth and the time of humans. Some tracks and examples of concrete application of this concept and its associated ontology are presented both in terms of methodologies for inventorying and evaluating geosites and in the operational fields of geoconservation studies or concepts of geoeucational and geotouristic interpretation of sites and objects. This exploratory work thus aims to bring out the temporal value of geosites as a heritage value in its own right, which could constitute a third pillar of geoheritage values alongside the two registers of values (geoscientific and additional) that have been in force up to now.

F. Huguet highlights the Matterhorn's great wealth of memories, helping to make this famous mountain a "Hyper Geosite" in [Hobléa's \(2018\)](#) sense. Earth time and human time meet here at the summit, merging in a present and near future with cataclysmic allure, symbolized by the destabilization of the walls due to the rise of the permafrost limit under the effect of anthropogenic global warming. These changes are already evident, making this mountain more dangerous to climb, while it was, in the 19th century, the scene of one of the most famous tragedies in the history of mountaineering.

T. Piau, F. Bétard and F. Dugast present the results of their study of 19 geoarcheosites in the middle Eure valley (Paris Basin, France). Archaeological aspects, traditionally associated with geomorphosites in "additional criteria," are given equal weight with geo(morpho)logical facts. In this case, geosites take on a temporal dimension rooted in human history, which the geoscientific aspects illuminate (and vice versa). The authors propose a quantitative assessment method specific to these geoarcheosites that can be applied to other sites with different spatial and temporal invoices. This article also highlights the question of the researcher's view of the geosite, what constitutes its specific features and the importance given to one or more criteria. The temporal perception of the geosite will then be directed towards these primordial data, without losing its geopatrimonial identification: the authors show that geoarcheosites are particularly important for understanding past interactions between society and the environment on the recent geological scale of the Quaternary and human history.

C. Portal focuses on the cultural sphere of geoheritage, using photography to understand the role it has played in the understanding of geodiversity and the recognition of geoheritage. Drawing on a corpus of images from works on the history of photography, she shows that photography enriches reflections on the temporal scales of geoheritage in two main ways: the first concerns the element photographed, e.g., the subject of the image, which is often taken as a "reference state" and therefore to be protected "as is," notably when creating protected natural areas; the second is linked to the photographic object itself, whose heuristic dimensions (e.g., historical and technical evolutions of the photographic tool, issues associated with the production, conservation and dissemination of the object) are interwoven with the temporal history of geoheritage and geosites.

CRedit authorship contribution statement

Claire Portal: Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **François Bétard:** Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Fabien Hobléa:** Conceptualization, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

Claire Portal, François Bétard, and Fabien Hobléa are the guest editors of "Specila issue: Time scaling issues in geoheritage studies," and were not involved in the editorial review or the decision-making process to publish this paper. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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