


# Historical Overview of Geoheritage in France

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**Abstract:** In recent years, interest in geoheritage among scientists and the broader public alike seems to be growing. However, concern for geological heritage is relatively late, compared to that of living heritage. Actions for protections have long remained marginal. The increase in the number of views on this notion has gone along with a reflection on its meaning and a multiplication of the number of laws to accommodate situations and be able to take into account the diversity of possible cases. In this paper, after a historical review, we propose a synthesis of this notion of geoheritage, as it is currently underway in France. We support our point on specific examples, and especially those that have an echo at the international level: in stratigraphy, for example, with the list of stages based on French localities, as well as in petrography and mineralogy with the lithotypes or minerals whose name is linked to the territory. Finally, we deal with the legal aspects, which apply to objects (movable geoheritage), geosites, especially with recent developments because of these texts, and databases that govern the operation and current development of geoheritage.

**Keywords:** heritage; geology; historical; France; inventory; conservation; valorisation



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## 1. Introduction

This text has been requested as an introduction to a special issue of *Geosciences* dealing with geoheritage in France. We have tried to stay focused on this country.

Many groups claim to be based on heritage, be it architectural, literary, cinematographic, gastronomic, or cultural interests in general. The interest in geoheritage is not new, but the revival of interest is. In the years 1980–1990, a group of geoscientists and knowledgeable amateurs in France showed themselves to be sensitive to geological heritage. Some of them had gathered since 1982 under the name of the Natural Reserves of France (RNF). In this context, a ministerial commission called “Commission Bouchardeau” was set up to reflect on this subject. In 1991, international actors met in Digne, where the “Rights of the Memory of the Earth” were proclaimed under the aegis of UNESCO [1]. In 1997, the Muséum national d’Histoire naturelle co-organised a symposium on the subject at the Ministry of the Environment [2] and submitted a project for a “Plan pluriformation Patrimoine géologique national” (national geological heritage multi-formation plan) with the Ministry of Higher Education and Research, which was implemented in 1998. This mobilization of the actors in the field gave rise to a certain number of legislative advances.

In 2002, the ministry in charge of the environment promulgated a law called “Démocratie de proximité” (Local democracy), which established an obligation for the State to make an inventory of natural heritage, including geological heritage. This law gives a decisive impulse, and the inventory of the geological heritage was officially launched in 2007. As the law stipulates that the Muséum national d’Histoire naturelle is the scientific guarantor of the inventory, this establishment is even more strongly involved and launches, in co-edition, two collections of books related to geological heritage: “Geological heritage: stratotypes” and “Geological walks”.

The inventory was launched with the first results of various regional, national, and international symposiums in Digne-les-Bains (2008, 2012), Caen (2013), Toulouse (2015), etc. In 2018, a restitution symposium was co-organised in Chambéry by the Ministry in charge

of the environment, the National Museum of Natural History, and the University of Savoie Mont Blanc [3]. The first phase of the inventory has now been completed for the entire national territory and is available to the public on the INPN (Inventaire du Patrimoine Naturel) website.

## 2. Concept of Geoheritage in France

### 2.1. Background

The notion of heritage is integrated into the French culture [4]. The aspects of conservation and transmission are associated with it. Initially, the heritage approach is linked to human achievements (e.g., artistic works). One of the most demonstrative examples is the “tour de France” (not to be confused with the cycling event) undertaken by Prosper Mérimée between 1935 and 1941, following his appointment as Inspector General of Historic Monuments. This travel led him to classify historical monuments in France for the first time [5].

Created in 1837, the Commission des Monuments Historiques classified, in 1840, 943 monuments. The purpose is to have a list of buildings on which to intervene as a priority: the intention is above all administrative. The notion of authenticity and integrity that presides over the conservation of heritage, whether cultural or natural, will quickly change the meaning of the classification. This is what Mérimée suggested when he wrote: “*the repairers are perhaps as dangerous as the destroyers*”.

Paradoxically, the revolutionary period played a capital role, certainly in the mutilation or the destruction of the national heritage (the “vandalism” denounced by the abbot Grégoire), but also in a founding awareness. The destruction of the Bastille, ordered on 15 July 1789, was a key heritage object in the heritage policy that was then underway. On 9 December 1790, before the Constituent Assembly, the scholar-naturalist Aubin-Louis Millin de Grandmaison (1759–1818) presented a report entitled “*Antiquités Nationales ou recueil de monuments, pour servir à l’Histoire générale et particulière de l’Empire François, tels que tombeaux, inscriptions, statues, vitraux, fresques, etc.; tirés des abbâies, monastères, châteaux et autres lieux devenus domaines nationaux*” [6]. The cultural and natural heritages were, thus, defended by a man who demonstrated, without affirming it as such, that the heritage is a whole. Philippe Descola summarised this observation as follows: “*There is not a world of the social and a world of nature but a single world*” [7]. He specified elsewhere this ambiguity or this quasi paradox: “*At first sight, it seems that to distinguish what belongs to the nature and what belongs to the culture does not pose difficulty. Is natural what occurs independently of human action, what existed before man and what will exist after him . . . Is cultural what is produced by human action . . . Yet the distinction is not always so simple . . . Most of the objects in our environment, including ourselves, are in this in-between situation where they are both natural and cultural.*” [8].

In France, in nature, the first protected area was also protected for artistic reasons [9–11]. In fact, in the forest of Fontainebleau, the cutting of old trees and the replacement of oaks by conifers was postponed as early as 1836 under the influence of painters and naturalists. During the Second Empire, the empress was sensitive to the paintings of those who would come to be known as the Barbizon School (Jean-Baptiste Corot, 1796–1875, Jean-François Millet, 1814–1875, Jules Coignet, 1798–1860, etc.) (Figure 1), and the artists asked for her intercession. The first reserve was created by decree of Napoleon III in 1861 [12]. For the first time, the concern of “nature protection” under the aesthetic and landscape angle was associated with the forest management. This area of the Fontainebleau forest was classified as a biological reserve in 1953.

In 1887, a law was adopted “*for the conservation of monuments and objects of art of historical and artistic interest*”, eight years before the creation of the English *National Trust* (the *National Trust for Places of Historic Interest or Natural Beauty* (more commonly known as the *National Trust*) is a British not-for-profit organization whose purpose is to conserve and enhance monuments and sites of public interest. Established in 1895, the National Trust has become the largest such organization in Europe and the second largest private landowner in the United Kingdom after the Crown. The Trust manages over 300 monuments and 200 gardens

ranging from megalithic sites to manor houses of all periods. Its scope includes industrial buildings and collections. It owns 250,000 hectares of land and 1200 kilometres of coastline). The desire to protect remained motivated for a long time by aesthetic concerns, as shown by the numerous articles in the *Revue du Touring Club de France*, in particular, those of Edouard-Alfred Martel, who wrote in the May 1902 issue “*the Americans astonished the world [by the creation of their national parks], it is agreed, we will astonish them in our turn, when we can show them our Esterel National Park [ . . . ] I know of nothing more beautiful*” [9].



**Figure 1.** Painters on the Motif in the Forest of Fontainebleau by Jules Coignet (*Peintres sur le motif en forêt de Fontainebleau*), 1825. Oil on canvas. © Musée départemental de l’École de Barbizon, public domain.

These first sites can be considered from a natural, landscape, or even purely cultural point of view. The first law on sites (*law organising the protection of sites and natural monuments of an artistic nature of 21 April 1906*) will confirm this observation. It institutes in article 2 a commission by department to list “*the landed properties whose conservation can have, from the artistic or picturesque point of view, a general interest*”. This is a sensitive approach and not a scientific one. On 2 May 1930, a specific law (*Law No. 1930–05-02 having for object to reorganise the protection of the natural monuments and the sites of artistic, historical, scientific, legendary or picturesque character*) was promulgated. Its execution was entrusted to the Ministry of Fine Arts. One measure that still remains is how much of the vision is of the artistic order still in the 20th century.

The French approach for the protection of natural values will slowly start: 1912: the reserve of the Seven Islands, in particular, for the protection of birds, including the puffin; 1913: the national park of Pelvoux (while national parks did not exist in the French legislation); 1927: the reserve of Camargue; 1935: the reserve of Néouvielle. It was not until 1960 that the first law on national parks was promulgated.

In 1913, Édouard-Albert Martel defined what a national park should be [13]: “A territorial reserve, with precise limits, within which an appropriate legal provision preserves and protects -against any destruction, deterioration or disfiguration due to mankind- the natural components, fauna, flora, picturesque sites, and geological or hydrological features [ . . . ]. A national park must therefore meet the following objectives:

- to preserve, from a scientific point of view, the fauna, the flora, the topography, the hydrography, the geology;
- to maintain, for the artists, the aspect of the landscapes in an absolutely inviolate natural state;
- to ensure convenience of access and stay, while preventing that the purely tourist requirements, as for the comfort, the distractions and the sports, lead to untoward modifications”.

This time the scientific aspect was clearly exposed. Legislative proposals were discussed in 1914, but the war interrupted the process, which was certainly resumed afterwards, but again interrupted by the Second World War.

The natural heritage was taken into account in the law of 1960 (Law No. 60-708 of 22 July 1960) on national parks, since Article 1 states: *“The territory of all or part of one or more municipalities may be classified by decree in the Council of State as a “national park” when the conservation of the fauna, flora, soil, subsoil, atmosphere, water, and, in general, a natural environment is of special interest and it is important to preserve this environment against any effect of natural degradation and to remove it from any artificial intervention likely to alter its appearance, composition and evolution. The territory delimited by the decree can extend to the maritime public domain.”* However, the idea of natural heritage did not really emerge in France until the law of 1976 (Law No. 76-629 of 10 July 1976, relative to the protection of nature), which officially established the concept of nature reserve. In France, for decades, the priority was clearly put on biological heritage (see [14] for comprehensive synthesis of the regulatory tools in France).

## 2.2. What Is Heritage?

UNESCO [15] defines heritage as follows: *“Heritage is the legacy of the past that we enjoy today and pass on to future generations. Our cultural and natural heritage are two irreplaceable sources of life and inspiration. Several key notions can be read very well: the necessary links between the past, the present and the future; the existence of a unique and two-headed concept at the same time; the obligation of creative dynamics prohibiting contemplative immobilism”*.

In any society, since prehistory, the sense of the sacred intervenes by invitation to treat certain objects, certain places, certain material goods as escaping the law of the immediate utility. These elements, which *“have escaped obsolescence and destruction are endowed with a particular prestige, arouse a passionate attachment, even a true cult”* [4]. *“For about thirty years the notion of heritage has not ceased to widen and to take importance. Everything or almost everything is now likely to come out of it”*, according to [16]. For the economist Marc Guillaume [17], *“a new form of passion for the past seems to seize the industrial societies of the West. Everything becomes heritage: architecture, cities, landscape, industrial buildings, ecological balances, the genetic code. The theme arouses a rather large consensus, because it flatters various nationalist or regionalist attitudes. Playing on a certain ecological sensitivity, it appears in any case as a reasonable counterpoint to the threats and uncertainties of the future”*.

In the name of heritage, a new system of community values is disturbing the economic order of the free market. Between the World Trade Organisation (WTO) and UNESCO, a veritable “heritage war” has been waged, in which France, because of its tradition and its interests in the cultural economy, has played a leading role in defending the “cultural exception”. When first isolated, it was joined by Japan and Canada, then by all the countries that fear “cultural imperialism”. It is now a question of reconciling the protection of heritage and economic protectionism, a difficult, if not impossible, mission, especially when this heritage is a commercial sector.

The concept of natural heritage recognises that elements of nature are part of the commons. The concept of heritage is the result of external confrontations. It incorporates possible threats to an object or a site, to a community, to an economic project, or to the use of a resource. Therefore, heritage should not be decreed by an authority, but pushed, claimed as such by a community or a State that is its legal depository.

In Roman law, the *pater familias* was the only person with authority. Today, a patrimonial asset is necessarily a shared asset. As a trustee of a patrimony, a person no longer acts in his own name, but in that of his family, his lineage, his company, or his community.

The most common definition applicable to all kinds of heritage, tangible or intangible, symbolically “is that which each of us inherits from our forebears and that we wish to bequeath to our descendants”, as the French saying goes. The necessarily collective dimension of the heritage appeared clearly with the explicit recognition, in the XIXth century, of the “legal persons”: the joint stock companies and the associations. The legal recognition of the “legal person” as a subject of law is paradoxical: the legal person does not exist physically, except through the group of individuals who compose and represent it: it is a legal fiction. However, it is a question of giving it the same rights as those of a “natural person”, in particular, the right of ownership and the moral right (i.e., the right to take legal action or the right of authorship). Thus, not only is heritage necessarily a collective good, but, moreover, it is thanks to it that a community can exist beyond its territory and throughout generations.

The notion of ownership of tangible property that is moderated by the collective dimension of an intangible property. It can belong to a private individual, provided that he leaves his rights to the community. Monuments and works of art have always, in troubled times, been subjected to the fate of the symbols they convey. This was the case during the revolution: statues were broken if they were crowned, and monuments were destroyed if they were lily-white. In destroying the Buddhas of Bamiyan, Afghanistan, the Taliban claimed the ‘political’ right to the Buddhas as the legitimate owners, since they were the leaders of the country. They also claimed the “moral” right to them because the Buddhas, were, in their view, a heresy as a human representation. This touches on another aspect of heritage, which is the recognition of other cultures according to varying scales of time and space.

It is because there were so many abuses in France, in the year II (1793–1794), that the “instruction on the way to inventory and conserve” was addressed to the administrators of the Republic concerning the buildings and works of art. It was clearly stated: “you are only the custodians of a property of which the great family has the right to demand an account”. The time had come to define an intangible national domain. The notion of patrimony, of inalienable fundamental assets, was then extended for the first time in France [4]. Thus, in France, the notion of heritage was enriched under the Revolution. Two new approaches appeared as a result of these circumstances: the inventory and the museum. It was precisely at this time that the Museum of Natural History was born (Created by decree on June 10, 1793, it became the National Museum of Natural History), which went from private property to national property.

If it is legally recognised, this symbolic value is imposed on the owner: this is how protection, with the classification or inscription of a site, a building, or an object, as belonging to the heritage, has, as a consequence, a certain number of constraints, in particular, the prohibition to destroy it or to modify it without the agreement of the State. The claim of a common heritage helps to recognise oneself. Once recognised as having official status, heritage assets must be administered by a community that has custody and responsibility for them. In a free country, it is difficult to hierarchise heritage in an authoritarian way, in order to sort out the good and the bad that suits everyone. Heritage cannot be decreed, on the contrary, as André Malraux said, “*it must be conquered*”.

Heritage value can, thus, be given to objects that, for those who do not share them, have none. The heritage quality is sometimes granted only for the benefit of antiquity: the shards of ancient pottery are collected in a religious way, while the broken pots of today are thrown away. However, it is true that the testimonial value is also added to the antiquity. The Roman signed shards are very important to understand, for example, for the functioning of ancient trade, but they exist in hundreds of thousands of copies: it is not their rarity that makes them heritage, it is that they are the witnesses of past ways of life that, with other witnesses, inform us about the human societies that preceded us. Of course,

the rarity also confers a heritage value. The classification of the city of Le Havre, as a world heritage site and a model of reasoned architecture, shows how the notion of “heritage” can evolve and is eminently relative. The slag heaps of the North, of which several generations were almost ashamed because they seemed to spoil the landscape, registered as world heritage since July 2012, are another example.

Measures that trivialise heritage find their most recent expression in the law on Solidarity and Urban Renewal (SRU) of 27 March 2001. The notion of “renewal” recognises that heritage has a kind of dynamic. It is almost paradoxical to point out that heritage exists through dynamics, whereas conservation can be considered a static act. It also affirms the need to break with the principle of development at all costs, which can appear as a headlong rush that puts “heritage” at risk. The emergence of the concept of “sustainable development” comes from this point of view. The notion of heritage is, therefore, known to all, but its definition is vast and complex. In the broadest sense, the term covers all the legacies of a given civilization’s past, whether material or immaterial, movable or immovable, as well as the philosophical and historical vision that stems from it. It is a question of transmitting to future generations what the past has passed on to us. To exist as such, a given heritage must belong to a current society and be visible to others.

The notion of heritage encompasses all the elements of a society: songs, dances, pharmacopoeia, furniture, usual and cult objects, ornaments, and architecture. Heritage also integrates beliefs (cosmogonies and religions), as well as the way of organizing the territory and managing its resources (agriculture, developed natural spaces, and politics). We can see that the notion of heritage can, thus, be defined by the whole of the cultural, social, and environmental data that people have elaborated and bequeathed. This notion was further expanded in 2011, when a report by the environmental lawyer Arnaud Gossement to the Minister of the Environment proposed, in paragraph No. 10, “to qualify mining resources as common heritage from the first article of the mining code “in accordance with the provisions of the Charter of the Environment and the Environment Code” [18]. By mineral resources, he meant mineral and energy resources. Gossement underlines that the Charter of the Environment, backed by the Constitution, specified: “that the environment is the common heritage of human beings”. The common heritage is, therefore, not only linked to French citizens, but to “human beings”, demonstrating the transnational vocation of this notion.

### 2.2.1. From the Simple Object to the Conjunction of Values

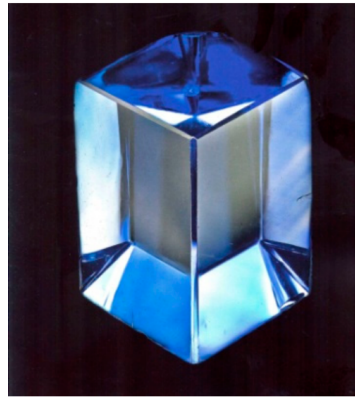
Some objects, in themselves, do not deserve to be classified as heritage, but loaded with additional information, they obtain this status.

The court of the king of France had many jewels. The stones were sometimes mounted on crowns, brooches, rings, etc., and sometimes they were isolated between two sets of jewels waiting to be mounted on other jewels. During the French Revolution, the jewels were sold as national property.

The French National Museum of Natural History was created by decree of the Convention, and Daubenton (Louis Jean-Marie D’Aubenton, known as Daubenton, 1716–1799) was put in charge of the Gallery of Mineralogy. During the sale of crown jewels, he managed to convince the revolutionaries that the unmounted stones were not jewels, but natural history gems, and should, therefore, be deposited them in the mineralogy collections of the new museum. Since then, this institution has been the depository of the gems of the French crown. These objects are, therefore, the property of the nation and belong to the national heritage, not only because they are beautiful, but also because they are part of a history, not so commonplace, and part of a whole. Their beauty alone is not enough to make them heritage objects; otherwise, all jewellery would be heritage. Only the conjunction of values makes it a heritage object.

Among the objects in the mineralogy collection is the large sapphire brought from Sri Lanka (Figure 2). It is the first sapphire from the crown jewels kept in the museum. It was stolen in 1792 during the ransacking of the storage room by thieves, but was recovered shortly afterwards. In 1796, it was chosen by Daubenton to enrich the collections.

Its rhomboid faceting is unique in the world, and it was of Indo-Mongolian origin. Its patrimonial character comes from a set of values: the uniqueness of its size (faceting), ownership of the crown, and its history. Its beauty, size, or commercial value are not the only criteria.



**Figure 2.** Large sapphire of Louis XIV, offered to the Sun King in 1669.  $38 \times 29 \times 28$  mm. Mineralogy Gallery. MNHN (MNHN-MIN-a.67) © F. Farges.

The “dream stones” (Dali Shi, which means the stone of Dali, Yunnan, China, where they are so abundant that the word marble is also called Dalishi) are another example of objects whose real aesthetic quality is not enough to make them a heritage object. However, when such objects are not isolated, but belong to a collection of dozens of pieces deposited in a museum (Figure 3), their status changes in legal terms, for the word collection has a particular legal status, which is very specific and concerns the spirit of the collection, its integrity (it cannot be dispersed), as well as its place. The collection, in fact, is referred to by the device of the code of the heritage, which subjects, in particular, the export of certain cultural goods to the obtaining of a certificate, as well as the decree of application of 29 January 1993, which defines the collection as “*a whole of objects, works and documents whose various elements cannot be dissociated without undermining its coherence and whose value is higher than the sum of the individual values of the elements which compose it*”.



**Figure 3.** Quartz from Uruguay, Mineralogy Gallery, MNHN, Paris. Dation (A dation is not a donation because there is a counterpart, notably in terms of payment of inheritance tax) of Roger Caillois. © Camille Gévaudan, CC BY-SA 4.0.

If, in addition, this collection was assembled by a famous person, such as Roger Caillois (1913–1978), known for his literary works and for his passion for stones and the poems he dedicated to his “pierres de rêve” (dream stones) (i.e., *Pierres* in 1966 and *L'Écriture des pierres* in 1970), then the collection can really be considered as patrimonial.

### 2.2.2. What's at Stake?

The interest of wanting to find, preserve, and exhibit a heritage is above all to enrich our knowledge of universal history. If the stakes are different, according to our origins, our ambitions, heritage, and culture remain at the heart of the notion of identity. Despite this apparent homogeneity, it is advisable to go beyond the simple comparison between our heritages. It is necessary to preserve, first of all, what is likely to mobilise public opinion, i.e., what we do not wish to see disappear. Without this investment of the populations, the heritage would be similar to folklore, having an especially economic interest. Heritage, thus, allows people to situate themselves in an era, a time, or even a space. It then confers distinctive characteristics on territories, on the basis of the constitution of collective identities.

The double phenomenon of the multiplication of authorities that deal with heritage and the extension of the symbolic field of heritage objects is not typically French. This itch to expand the field of heritage is worldwide and is sometimes used to assert an identity (the Eiffel Tower), even if it means destroying what does not seem to correspond to the desired, imposed identity: it is for this reason that the Buddhas of Bâmiyân (Afghanistan) were destroyed in 2001, just as the certain buildings of Timbuktu (Mali) were destroyed in 2012.

*There are two things in a building: its use and its beauty.*

*Its use belongs to the owner, its beauty to everyone,*

*to you, to me, to all of us.*

*Therefore, to destroy it is to exceed its right.*

Victor Hugo (Hugo V. (1832)—Guerre aux démolisseurs. *Revue des Deux Mondes*, March 1832, Initial Period, volume 5, p. 621)

### 2.3. Natural Heritage

If all nature is heritage and it becomes difficult to identify and to question the existence of a natural heritage, one can wonder if, finally, its field and its objects do not concern them, i.e., from a cultural point of view: is it not a question of a creation where the human is not the creator, but of which he defines the values? Charles Baudelaire writes in “*Aesthetic Curiosities*” (1868) [19]: “*If such an assembly of trees, mountain, waters and houses that we call a landscape is beautiful, it is not by itself but by me*”.

A heritage, heritages? This is not a simple question, and there are many examples that keep the debate going.

In “*Phenomenology of the perception*” (1944), Maurice Merleau-Ponty [20] suggested that it is the reality of what human beings are which contains the imbrication of nature–culture: “*It is impossible to superimpose in the man a first layer of behaviors that one would call “natural” and a cultural or spiritual world manufactured. All is manufactured and all is natural in the man, as one will want to say, in the sense that it is not a word, not a behavior which does not owe something to the simply biological being—and which at the same time does not escape from the simplicity of the animal life, does not divert from their sense the vital conducts, by a kind of escape and by a genius of the equivocation which could be used to define the man.* Philippe Descola [21] pointed out that it is our Western society and behaviors that cut off from the fusional relation between nature and culture: “*Where does nature stop and where does culture begin when I take a meal, when I identify an animal by its name or when I look for the tracing of the constellations in the sky?*”

Many so-called primitive societies invite us to such an overtaking, they who have never thought that the borders of humanity stopped at the doors of the human species,



they who do not hesitate to invite in the concert of their social life the most modest plants, the most insignificant animals.”

In a shocking phrase of which he has the secret, Edgar Morin [22] likes to say, “*Human is a cultural being by nature because he is a natural being by culture.*” Although the conviction that there is only one heritage world seems to prevail from an intellectual point of view, the fact is that, on a practical level (scientific approaches, legal frameworks . . . ), the separation into two parts remains the rule. This was the case for the World Heritage Convention. Criteria that can justify the outstanding universal value of a site being nominated to the World Heritage List were first separated into 6 cultural and 4 natural criteria, and then it was decided to merge the list of criteria into a single list of 10. This was the case for the World Heritage Convention.

This is a laudable effort to encourage a global vision, but it is also an artifice because the arguments continue to be made with the six criteria on one side and the four on the other. The most striking example is a criterion (vii) that relates to aesthetic values of natural phenomena and is considered as a criterion qualifying natural properties, whereas the aesthetic value is not considered by a specific criterion for cultural properties.

According to the Convention Concerning the Protection of the World Cultural and Natural Heritage [15], adopted by the General Conference at its seventeenth session, held in Paris on 16 November 1972, in its Article 2, UNESCO specified that “*the following shall be considered as natural heritage*”:

- Natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view;
- Geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation;
- Natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty”.

It should be noted that the “bio” components are subordinated here to “natural monuments” and “geological or physiographical formations”. It is, therefore, out of the question to deal with biodiversity alone for UNESCO, without first putting it in its context, unlike what France does.

This remark is all the stronger because it is contrary to the French conception of nature, which has, until now, been too often limited to living elements (fauna and flora), habitats, and natural environments. Geological and mineral elements (non-living elements) were not, or hardly, considered. However, the link between geosystems and ecosystems is obvious. However, unlike biological species, geological objects do not reproduce, and the deterioration of even a local site leads to its permanent loss. The geological heritage, therefore, includes the past of the Earth. It underlines, perhaps more than any other heritage, the notion of time. The General Conference of UNESCO has, indeed, noted that the natural heritage was more and more threatened with destruction, not only by the traditional causes of degradation, but also by the evolution of social and economic life, which aggravates them by the even more formidable phenomena of alteration or destruction. It also noted that (1) the degradation or disappearance of a natural heritage property constituted a harmful impoverishment of the heritage of all the peoples of the world; (2) the protection of this heritage at the national level often remains incomplete because of the magnitude of the means required and the inadequacy of the economic, scientific, and technical resources of the country on whose territory the property to be safeguarded is situated. It recalls that the Constitution of the Organisation provides that it will assist in maintaining, advancing, and diffusing knowledge by assuring the conservation and protection of the world’s heritage. It considers that certain properties of natural heritage are of exceptional interest, which necessitates their preservation as part of the world heritage of humanity as a whole. It is then incumbent upon the international community as a whole to participate in the protection of the natural heritage of outstanding

universal value by granting collective assistance, which, without substituting for the action of the State, will effectively complement it. It concludes by recalling that it is essential to adopt, for this purpose, new treaty provisions establishing an effective system of collective protection of the natural heritage organised on a permanent basis and according to scientific and modern methods, as a result of which, the above-mentioned convention was adopted.

A World Heritage List, or heritage of humanity, is established by the ad hoc committee of UNESCO. The purpose of the program is to catalogue, name, and conserve these properties. At the conclusion of the 42nd session of the World Heritage Committee, held in Manama, Bahrain in 2018, there were 1092 properties inscribed on the list, spread across 167 states parties. Currently, Italy has the most sites included in the list of World Heritage Sites (54 sites).

#### 2.4. Geological Heritage

In this volume, we use the term geology in its broadest sense (from the Greek *geo-logos*: discourse on the Earth). This term includes sedimentology, palaeontology, mineralogy, tectonics, geomorphology, landscapes, etc.

Geology must be considered in the context of its relationship with the other objects of nature, culture, and history, with which it is in permanent interaction. People wish to understand the socio-economic, natural, or geographical contexts in which they live. Therefore, the geological approach is necessary. Indeed, the history of humanity, animals, and plants is perfectly linked to the history of the Earth and the presence of water in its various forms. Landscapes, agriculture, and human settlements are dependent on the nature of the soil (ground and subsoil). In current practices, the local becomes global, and the effects of geology on the environment also become global (natural resources, energy, water, etc.), as well as natural, hazards, pollution, and climate change. An illustration is the local alteration of basalts, which consumes a lot of CO<sub>2</sub> and influences the climate on a global scale.

What we call geoheritage can be defined, following [23–25], as “*Globally, nationally, state-wide, to local features of geology, such as its igneous, metamorphic, sedimentary, stratigraphic, structural, geochemical, mineralogic, palaeontologic, geomorphic, pedologic, and hydrologic attributes, at all scales, that are intrinsically important sites, or culturally important sites, that offer information or insights into the formation or evolution of the Earth, or into the history of science, or that can be used for research, teaching, or reference*”.

Geoheritage concerns objects of all sizes (from landscape to mineral size) that are, therefore, intrinsically (by their own value) or extrinsically important, by the way we look at them, i.e., culturally. It offers information or allows for the understanding of elements related to the formation or evolution of the Earth and to the history of science, which can be used for research or as a reference or for educational purposes [26,27].

Geoheritage concerns both the objects removed from their sites (geoheritage *ex situ*) and the sites themselves (geoheritage *in situ*) that are related to the earth sciences and of remarkable interest for the memory of the Earth (Figure 4). In addition to the rich geological sites (*in situ* objects), museums and universities house several million objects (*ex situ* heritage), represented by rocks, fossils, minerals, and drill cores associated with their documentation (without which these objects lose their scientific value), which are also geological heritage [28].

Some objects are heritage in their own right, such as highly fossiliferous blocks, such as the ammonite slab in the Haute-Provence Geological Reserve (Figure 4) or the orthoceran plates from southern Morocco (Figure 5).

In Morocco, the preparation of fossils and their trade is very developed in some regions, and many are acquired for scientific research and are found in Moroccan museums or around the world. Some geological objects are also sold in local stores as handicrafts or decorative items displaying beautiful fossils (e.g., in Erfoud town, as well as in other towns). Many geologists recognise some pieces as artefacts (made of several pieces of different organisms), and artisans produce beautiful, but artificial, objects. These pieces can

be sold, and they help the local economy and are not a danger to the geological heritage of the area. It is only necessary to ensure that these pieces are not sold as objects of authentic nature. The buyer should also be careful, even if sometimes artisans announce the colour on their points of sale by frankly displaying “fossil manufacture” (Figure 5).

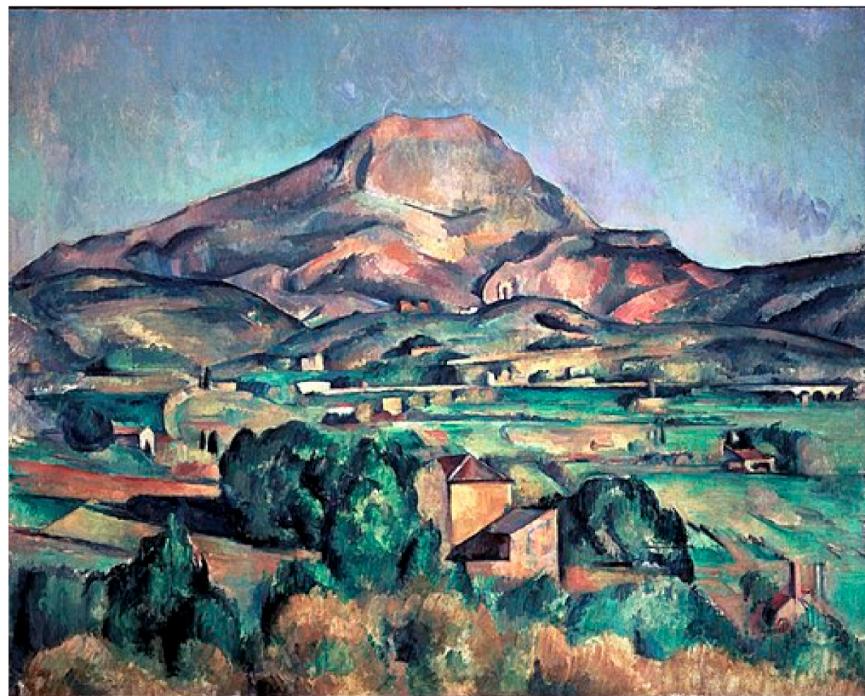


**Figure 4.** The ammonite slab of Digne-les-Bains, one of the 18 sites classified as a national nature reserve of the Réserve Naturelle de Haute-Provence, presents more than 1500 ammonites of the Sinemurian, most of which are *Coroniceras multicostratum*. Some of them reach 70 cm in diameter. This site recently redeveloped. It is considered of high value and is an internationally renowned geoh heritage site. © M. Guiomar.



**Figure 5.** The wall of this artisanal centre clearly announces what they do: “Fabrication des fossiles” (manufacture of fossils). One cannot blame them for selling “fakes”, it is written! (Erfoud, 2008, South Morocco). © P. De Wever.

Some landscapes are interesting in their own right, but do not merit registration as geo-heritage if considered alone. However, if they are associated with other criteria, their level of interest increases. This is the case, for example, of the Sainte-Victoire massif (Provence, France; Figure 6). This mountain exposes a Provençal thrust front in an educational way. Its southern foothills still bear the remains of Gallic Celto-Ligurian oppidums, and its western foot consists of Cretaceous red earth, rich in dinosaur eggs. In addition, Sainte-Victoire has been painted over and over again, by Pablo Picasso, Vassily Kandisky, and in particular, by Paul Cézanne, who represented it in about sixty paintings and who wrote about it: *“As I was telling you this morning, I need to know the geology, how Sainte-Victoire is rooted, the geological color of the land, all that moves me, makes me better”* (remarks reported by Joachim Gasquet, Doran, 1978 (letter to his friend, the poet Joachim Gasquet (according to [19,29])). The conjunction of these five criteria unquestionably confers a patrimonial value to this site, which is moreover classified for its picturesque and artistic character under the law of 2 May 1930 and is labelled “Grand Site de France”. In addition, the geology of the site and its geographical location gives it a remarkable ecological interest, which has led to its designation as a Natura 2000 site. The standard data form sent by the French government to the European Commission gives the following brief description of the site: “Supra-Jurassic limestone massif, standing on a base formed by the Cengle plateau. The adret presents a succession of rocky escarpments, while the ubac, less abrupt, is dug by deep valleys. The Sainte-Victoire mountain is a biogeographical limit with meso-Mediterranean vegetation on the adret side (cliff and scree groups) and euro-Mediterranean groups on the ubac side (Genêt de Lobel moors). The flora, of orophilic affinity, presents rare elements for France. The karstic zones, the open environments, and the old forests constitute complex of habitats favourable to chiropterans. A vast continuous forest territory allows for the consideration of a functional entity of the greatest interest.



**Figure 6.** Mont Sainte-Victoire (“La Montagne Sainte-Victoire”), painting by Paul Cézanne (1839–1906). © Barnes Foundation, public domain.

A geosite is understood as a geologically exceptional, geographically limited place containing one or more geological features. These features have a specific value of scientific, educational, cultural, or tourist interest [30]. Geosites are generally selected on the basis of expert opinion from those with knowledge of the site.

Geoheritage is essentially a part of the world's heritage, in that it represents the only record of the entire evolution of our planet. This is recorded in a multitude of forms and, similar to a jigsaw puzzle, these pieces only make sense when they are assembled coherently and viewed together. However, only a limited number of pieces are accessible to human observation.

The term geological heritage is defined with the notion of a remarkable geological object, which emerges from its scientific, educational interest, its rarity, its exemplarity, its representativeness, its historical value, its exceptional state of conservation, its aesthetic quality, etc.

The most remarkable geological objects, regardless of their size, should benefit from in situ or ex situ conservation and protection. Nowadays, the protection of heritage must be understood as a dynamic process, rather than deposited under a protective exhibition dome. That is to say, a valorisation with a "faire-savoir" (know-how) allows us to see, to understand, and to study. The conservation of geodiversity is an objective in its general sense because many threats must be considered, such as the unrestrained collection of fossils, coastal erosion, excavations, filling of quarries, uncontrolled development of vegetation, urban extensions, land use planning, etc.

The concept of geoconservation (conservation of geodiversity) is quite recent in most countries, although France has had a general framework for the protection of natural sites since 1836 (see above) and, more specifically, for "natural monuments" in 1930. The first national parks were created in France in 1963 (Vanoise, Port-Cros), the first voluntary nature reserve was created in 1980 (Montredon Reserve, Hérault), and the first geological nature reserves in 1982 (Saucats and La Brède).

For nearly thirty years, the priority has clearly been on biological heritage. For a long time, the protection of nature was understood as the protection of living things (flowers, birds, insects, butterflies, etc.). As we have seen, however, several geological nature reserves have been created since 1982, and the mobilization of part of the geological community has succeeded in highlighting the need for protection and led, in 1994, to the publication of the "International Declaration of the Rights of the Memory of the Earth", following the international meeting in Digne-les-Bains in 1991 (See [1]).

### 3. French Geoheritage

The French metropolitan territory covers ca. 550,000 km<sup>2</sup> and a little more than 675,000 km<sup>2</sup> for the national territory, including the overseas elements (excluding maritime areas under French jurisdiction). These include South America (French Guiana), the Atlantic Ocean (West Indies: Guadeloupe, Martinique, Saint-Martin, Saint-Barthélemy, and Saint-Pierre-et-Miquelon), the Pacific Ocean (French Polynesia, New Caledonia, Wallis, and Futuna and Clipperton); the Indian Ocean (Reunion Island, Mayotte, the Spars Islands, Crozet Island, the Kerguelen Islands, and Saint-Paul and Amsterdam Islands), as well as the Antarctic (Terre Adélie). This scattering suggests a great diversity of geological settings and of various administrative statuses (regions and départements, collectivities, territories).

The geodiversity of a country can be seen, for a first approach, by its geological map. Nevertheless, detailed maps, geological or otherwise, can also show the geological richness by the detail of their contours.

#### 3.1. The First Geological Maps

The first geological maps showing a global vision of geology were the result of an inventory of the mineral resources of France. The result was first a geographical map with symbols. This map, signed by Jean-Étienne Guettard, Antoine-Laurent Lavoisier, and Antoine-Grimald Monnet, was completed in 1767 and published in 1780. It was preceded by a real geological map with contours, drawn by Jean-Étienne Guettard, a naturalist supported by the Duke of Orléans. Guettard [31] presented his synthesis under the name of "*Carte minéralogique sur la nature du terrain d'une portion de l'Europe*" in 1746 (Figure 7). This map was not very precise in its geological contours, but it clearly showed the continuity of

the contours of the different units on both sides of the English Channel. The geology of the English Channel was not known at that time. There was, thus, an abstraction, an intellectual construction, a model, which are the characteristics of a scientific novelty. A geological map is a model. In this document, the author “proposed to show by this map that there is a certain regularity in the distribution that has been made of stones, metals & most other fossils”. He recognises three concentric bands: the “sandy” band in the centre, which corresponds roughly to the Cenozoic, the “marly” band, shaded on the map, which corresponds to the Mesozoic, and the “shaly” band for the older terrains, most of which are Palaeozoic.



**Figure 7.** “Mineralogical map on the nature of the soil of a portion of Europe” by Jean-Étienne Guettard. Map published in 1746 [31]. The great novelty of this publication is the continuity of the layers on each side of the Channel, then completely unknown at the time. The author has differentiated the three sandy, marly, and schistose bands that correspond roughly to the Cenozoic, Mesozoic, and Palaeozoic.

Although that the first coloured geological map of a whole country and of a single country ever drawn was William Smith’s 1815 map [32], it was far from the first geological map. Indeed, as Cecil J. Schneer, Professor of Geology and History of Science at the University of New Hampshire, makes clear: “But the great map he [Smith] published in 1815 was neither the first geological map of the nineteenth century, nor the first to show an order in the layers using the order imposed by the fossils they contain. Smith’s Parisian rivals, Georges Cuvier and Alexandre Brongniart [33], had published such a geognostic map of the Paris Basin in 1808, seven years before Smith’s map, and republished it in 1811 and again in 1822” [34] (In fact, the publication in 1808 (whose title is identical to that of 1811) does not include a map).

Other maps were also produced earlier, such as Guettard’s map (1746), covering a part of Europe and in black and white. That of Jean-Baptiste Julien d’Omalius d’Halloy [35] covered part of France (1816), then all of France and part of Belgium (this country did not exist yet), Germany, Switzerland, and Italy (1822). The idea of representing geological information on a map dates back to 1684, when Martin Lister discussed it. From the beginning of the XIXth century, the progress in cartography correctly detailed the contours, and the colours used are those we know. Indeed, after Guettard’s map, it seems that colours appeared on maps in Germany around 1770 [36,37].

### 3.2. Some Testimonies of the French Geoheritage

The geodiversity in France is quite remarkable. The main geological objects and sites are well-represented: ancient massifs (Armorican Massif, Ardennes, Massif Central, Saint-Pierre-et-Miquelon), and more recently, folded mountain belts (Alps, Pyrenees, Caledonian Alps), island arcs (West Indies), hot spots (Reunion Island), large igneous provinces (Kerguelen), large sedimentary basins (Parisian, Aquitanian and South-Eastern basins), smf grabens (Alsace, Limagne). The territory is also the witness of a history that extends over 2 billion years. Geological phenomena, such as volcanism (recent and ancient), mid-oceanic rift or intra-plate, distensive or compressive properties, metamorphism, erosion, transport, and depositional mechanisms, are well-represented. All types of rocks are present (those formed at depth, volcanic, metamorphic, sedimentary, etc.).

Among the heritage sites and objects, one could cite paleontological deposits of exceptional conservation (*Lagerstätten*) or those that are exceptionally rich, such as the so-called ammonite slab (Réserve naturelle de Haute-Provence; Figure 4), the dinosaur egg deposits (Réserve naturelle de la Sainte Victoire; Figure 6), or the dinosaur tracks of the Jura (in Loule or Plagne), the pterosaur tracks of Crayssac (Lot), etc. Examples are very numerous, and we cannot quote them all.

Many international references are from the national territory. Names of rocks, minerals, or stages from the geological time scale relate to their territory of origin, or to a Frenchman, often a geologist. Sometimes, it is the time scale (stratotype names) that bears the trace. An exhaustive list of these names was published by De Wever et al. [38]. Even if tomorrow the discontinuous representation of time is replaced by a continuous representation, based on the degree of evolution of taxa and on precise radio-chronometry, one will continue to have recourse to the concrete references that are the stratotypes. They, thus, remain a concrete heritage reference, since they express discontinuities, regarding periods, on a global scale. It is not only the fossils and rocks extracted from the stratigraphic successions that represent the significant record, but the land sections themselves, i.e., the cliffs and the landscapes that carry them. The protection of these sites is the only way to guarantee the perfect scientific integrity of these reference objects.

The outcrops of the ground layers, which correspond to these international time standards, therefore, deserve to become protected sites because they belong to the international scientific heritage.

Of the approximately 40 stratotypes in France, only a dozen are currently protected (Figure 8). Contrary to other protected stratotypes, the Barremian stratotype and the Bathonian boundary stratotype (GSSP) have not given rise to the creation of a National Nature Reserve (RNN), but they are part of the protection perimeter of the Haute-Provence Geological Reserve, created by prefectural order in 1989. It can be noted that this protection status was a positive argument in favour of the selection of the locality of the Bès ravine for the GSSP.

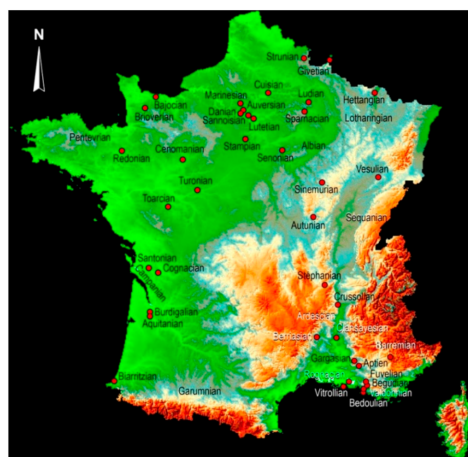


Figure 8. Location of stratotypes in France with their names.

#### 4. How to Protect?

The World Heritage Convention (<https://whc.unesco.org>, accessed on 15 June 2022) is characterised by two aspects. First, it recognises both cultural and natural heritage. Second, it provides a global mechanism for identifying (and protecting) important geological sites. This convention promotes, at the global level, a wide spectrum of sites: from sites of a few hectares to large landscape areas. There is, thus, great potential for developing new ideas and new ways to enhance major geological sites, linking them with other cultural or natural interests.

To better understand how the World Heritage Convention can recognise geodiversity in the future, both as such and as a complement to other natural or cultural interests, the International Union for Conservation of Nature (IUCN), UNESCO's advisory body for natural heritage, has undertaken a thematic study on the role of geology within the framework of the Natural Heritage Convention. Indeed, the World Conservation Congress (WCC), held in Barcelona, Spain, 5–14 October 2008, in its Session 4th, *“calls on IUCN's members to support the Secretariat in the design, organization, hosting and funding of future IUCN World Conservation Forum sessions on geodiversity and geological heritage to ensure that this mechanism will achieve the widest possible involvement of government, independent-sector groups and international organizations around the world”* (IUCN, 2008 [39]). In 2012, a new resolution was passed [40]. This text insists on the consideration of geodiversity that we find here very French concerns. The new text ([40], WCCC-2012-Res 048-EN) insists on the fact *“not to exclude the geological diversity and heritage” of nature and “asks the Director General to launch a debate in the regions on the theme of the conservation of geodiversity and geological heritage, in the next intersessional programme. [ . . . ], requests the IUCN Commissions, and in particular the World Commission on Protected Areas [ . . . ] to encourage and support, together with UNESCO and IUGS, the realization and expansion of the inventory of sites of geological interest”*.

This observation was repeated in successive congress, and, more recently, during the IUCN congress, in Marseille in 2020, the WCC resolution 74 insisted on the need to take into account the geological heritage, [41]).

##### 4.1. Some European and International Initiatives

At the European level, meetings have been held for the last twenty years, following the meeting in Digne in 1991. In 1997, under the impetus of the National Nature Reserve of Haute-Provence (France) and the Reserve of the Petrified Forest of Lesvos (Greece), a new tool for the promotion and conservation of heritage was set up and quickly attracted two other partners, the sites of Vulkaneifel (Germany) and Maestrazgo (Spain), and the European *Geoparks* Network was created in 2000. This one differs from the field of heritage *sensu stricto*, since it considers the economic, cultural, and social aspects of the territories. The principle is to promote the Earth sciences to the public to protect this heritage, while taking care of the economic and social development of the territory, as highlighted in [38,40]. It is in line with sustainable development. This network is supported by the European INTERREG programme. From the four founding partners, the network has grown to 73 in 2018.

In 2004, the different partners (Division of Earth Sciences of UNESCO, *International Union of Geological Sciences*, *European Geopark Network* . . . ) met in Paris, in order to constitute the Global *Geoparks* Network of UNESCO. The model adopted by UNESCO is the *European Geoparks* [42–44]. In November 2015, the member states of UNESCO approved the statutes of a new International Geosciences and Geoparks Programme (IGGP). The Global Geoparks became UNESCO Global Geoparks (<https://fr.unesco.org/geoparcs-mondiaux-unesco> accessed on 15 June 2022). At present (2022), there are 177 UNESCO Global Geoparks in 46 countries. France has seven territories, labelled “UNESCO Global Geopark”: the Geopark of Haute-Provence (partly based on the Geological RNN of Haute-Provence) and the geoparks managed by the regional nature parks of Luberon, Bauges, Monts d’Ardèche, and Causses du Quercy. The Chablais Geopark, supported by the Syndicat intercommunal



d'aménagement du Chablais and since March 2018 the Beaujolais Geopark, supported by the Syndicat Mixte du Beaujolais (a grouping of intercommunities).

Contrary to popular belief, it is not the Geopark status that protects a site or sites. The site(s) must be protected before applying for *Geopark status*. The Geopark status is a quality label, which can only be obtained after various tests. This label is not acquired forever. It is reviewed at least every four years, but a report must be submitted every two years, and a commitment to participate in network meetings must be respected.

Additionally, at the European level, a working group met several times, since 1988. This is the association ProGEO, *The European Association for the Conservation of the Geological Heritage*. The first goal of this group is to promote the conservation of the European geological heritage. This association regularly organises meetings for exchanges and field visits in different parts of Europe and at international level. In 2020, ProGEO became *International Association for the Conservation of the Geological Heritage*.

#### 4.2. Brief Overview of Legal Frameworks in France for In Situ Heritage

Since its inception, heritage legislation has continued to expand its scope. For example, in France, as in many industrialised countries, the turnover of architectural firms from the development of old buildings has exceeded that of new construction, and this proportion grows with the wealth of the country, making heritage value an economic fact. Seaside resorts, or countries that want to develop “green” tourism, rely more on the respect of old spaces and architecture than on novelty. Ecological programs are constantly proclaiming the virtue of a kind of heritage resistance, both natural and cultural, which, while it was an exception to the right of ownership, seeks to become the rule. The measures of protection of a patrimony extended to sites, and entire regions, such as the fishing reserves, extend not only to spaces, but also to species in the safeguard of the genetic patrimony, a guarantor of the future of our planet.

A first “inventory of geological sites to be protected” was published in 1913 by the speleologist-geologist Édouard-Alfred Martel [13]. It distinguishes a priority list of about twenty sites (the Vénéon, the Loue, the Guil, the Vallouise and the Ailefroide, the Grande Chartreuse, the gorges of the Ardèche, the Cirque de Gavarnie, etc.) and draws up an inventory of several hundred other potential sites spread over seventy departments. However, not backed by legislation, its effect was relatively small, especially since violent reactions against the protection of such sites were published. There were opposing reactions, sometimes very acerbic, especially from the industry [38]. Nowadays, industrialists are generally less ostensibly aggressive because many have understood the benefits of working together to understand and enhance geodiversity. One example is the commitment made in 2003 by the International Council on Mining and Metals (ICMM)—which brings together 15 of the world’s largest mining and metallurgical companies—not to explore or exploit deposits located on World Heritage sites. The agreement signed by the ICMM includes a commitment to take all necessary measures to ensure that operations by member companies are not incompatible with the protection of the outstanding universal value of world heritage sites. It also includes the development of best practice guidelines, with relevant partners, to encourage the industry to contribute to the preservation of biodiversity, both on and around the sites. This commitment came after several months of discussions with the World Conservation Union (IUCN) and the UNESCO World Heritage Committee.

In France, the notion of natural heritage was made visible in 1976 with the law on the Protection of Nature (Table 1), which officially established the concept of a nature reserve. With the law of 10 July 1976 on the protection of nature, the legislator opened up the notion of natural heritage to geology, following on what the law on sites of 2 May 1930 had outlined. The first geological reserves were created in 1980 (voluntary natural reserve of Montredon) and 1982 (national natural reserve of Saucats-La Brède and François Le Bail—Ile de Groix).

**Table 1.** Main references of the French legislation concerning the protection of natural heritage.

Date	Title
30 March 1887	Law on the conservation of monuments and objects of art of historical and artistic interest
21 April 1906	Law on the protection of natural sites and monuments of artistic character
31 December 1913	Law on historical monuments
2 May 1930	Law on the reorganisation of the protection of natural monuments and sites of artistic, historical, scientific, legendary, or picturesque character
27 September 1941	Law on the regulation of archaeological excavations
1 July 1957	Law supplementing the 2 May 1930 of sites of artistic, historical, scientific, legendary, or picturesque character (and introducing the “natural reserve” regime)
22 July 1960	Law on the creation of national parks
10 July 1976	Law on the protection of nature
31 December 1976	Law reforming urban planning (and establishing sensitive natural areas)
9 January 1985	Law on the development and protection of the mountains
3 January 1986	Law on the development, protection, and enhancement of the coastline
8 January 1993	Law on the protection and enhancement of landscapes
2 February 1995	Law on the reinforcement of the protection of the environment
17 January 2001	Law on preventive archaeology
4 January 2002	Law relating to the museums of France
27 February 2002	Law on local democracy
20 February 2004	Ordinance on the legislative part of the heritage code
12 July 2010	“Grenelle 2” law
28 December 2015	Prefectoral decree of the protection of the geotope
8 August 2016	Law for the reconquest of biodiversity, nature, and landscapes

#### 4.3. *Reminder of Some Protection Laws for the In Situ Geological Heritage*

In France, there are two approaches to protecting natural areas: a land approach and a regulatory approach. The land approach consists of the protection by land acquisition of a surface. In this case, it is the owner’s right that provides the protection. The regulatory approach consists of identifying a zone that will be governed by a certain number of legal standards (see [14] for a review of regulatory tools and an exhaustive vision of the legal approach to geological heritage in France).

It may be useful to examine the different laws that have succeeded one another and that have effectively led to the preservation of sites of geological interest. Thus, a number of laws have contributed to the consideration and preservation of heritage, but not all of them have concerned geological heritage. It is, for example, the case of the law of 31 December 1913, relating to the historic monuments, which aims at preserving: (1) buildings, the conservation of which presents, from the point of view of history or art, a public interest (including megalithic monuments or the grounds which contain prehistoric deposits), (2) movable objects, the conservation of which presents, from the point of view of history or art, a public interest. This law contributes, in a fundamental way, to the conservation of the national cultural heritage; nevertheless, it does not concern the geological heritage itself and will, therefore, not be developed here.

##### 4.3.1. Law of 21 April 1906 Organising the Protection of Sites and Natural Monuments of an Artistic Nature

The end of the 19th century was marked by an awareness of the heritage value of certain remarkable landscapes in artistic, intellectual, and associative circles. We have already mentioned the protection of the forest of Fontainebleau for the impressionist painters (Figure 1). Other events generate the mobilization of numerous personalities and the emergence of the first French law for the protection of the environment.

In the Doubs, first of all, a hydraulic development project for the Lison springs moved the inhabitants of Nans-sous-Sainte-Anne. Their mobilization led, in 1901, to the creation of the French society for the protection of landscapes and the aesthetics of France, and then to the law of 21 April 1906 organising the protection of sites and natural monuments of an artistic nature.

This law is inspired by the provisions set up since 1900 by the prefect of Côtes-du-Nord, who creates a commission in charge of making an inventory of the picturesque sites, more particularly of the rocks of “pink granite” (we mention this name in quotation marks because it is an established name. It has the meaning given to it by the quarrymen (granite workers), and the geological name would be with an e for granite) threatened with destruction by the exploiters of materials. As soon as the law was voted, the municipal council of Bréhat asked for the protection of its island, considering, according to its deliberation of 19 May 1907, that “*the numerous foreigners who come to Bréhat during the bathing season and whose number increases every year find the island so picturesque and so beautiful that they testify the desire to classify it*”. This innovative law proposes two major provisions. Firstly, articles 1 and 2 provide that “*in each department, a commission of sites and natural monuments of an artistic nature shall be constituted [ . . . ]*”, which “[ . . . ] *shall draw up a list of landed properties whose conservation may be of general interest from an artistic or picturesque point of view*”. Secondly, article 3 allows for the classification, by ministerial order, of the buildings designated by the commission. Any modification of the state or aspect will then be forbidden, except for special authorization from the commission and approval from the Minister of Public Instruction and Fine Arts. Violations were then punished by a fine of 100 to 3000 Francs (at the time), which was quite considerable (100 and 3000 Francs of 1906 corresponded to about 400 EUR and 12,000 EUR of 2018). However, the means of implementing this law were limited, since classification required the agreement of the owner or his expropriation.

Between 1906 and 1930, 589 classifications were pronounced, including 92 rocks or groups of rocks in 25 departments. These are essentially punctual elements of the landscape, but some large sites are still classified like the Pelvoux in the Hautes-Alpes (Decree of 22 June 1911). However, these rocks, groups of rocks, or massifs are classified as natural monuments and not for their geological interest.

#### 4.3.2. Law of 1930 Reorganising the Protection of Natural Monuments and Sites of Artistic, Historical, Scientific, Legendary or Picturesque Value

The limits of the 1906 law led the legislator to modernise the text with the law of 2 May 1930, whose purpose was to reorganise the protection of natural monuments and sites of an artistic, historical, scientific, legendary, or picturesque nature.

This new law has many advantages: (1) it provides for new reasons for classification, including the “scientific” reason, which will make it possible to protect sites of ecological interest, geological objects, or remarkable works of art; (2) it allows for classification without the owner’s consent by decree in the Council of State; (3) it introduces several protection regimes:

- The *classified site*, it is the resumption of the provision of the law of 1906, which provides for the issuance of a special authorization for the modification of the state or the aspect of the site;
- The *registered site*, which is a perimeter whose purpose is to put remarkable sectors under surveillance by requiring owners to declare to the administration the work they are planning four months in advance. In case of threat to the site, the administration can initiate a classification procedure to protect the site;
- The *classification procedure* is a procedure implemented by decision of the minister in the case where a project would be able to definitively compromise the interest of a site that deserves to be classified. From the day the owner receives the notification of the classification procedure, he cannot make any changes to the state of the site or to its appearance for a period of 12 months, which gives the administration time to pursue the classification of the site;

- The *protection zone* around a classified site allows for the enactment of rules for the control of urbanization and advertising (provision repealed by law 83-8 of 7 January 1983).
- It provides for a regime of strong criminal sanctions:
- Work without authorization in a classified site: two years of imprisonment and a fine of EUR 300,000;
- Work without authorization in a listed site: six months imprisonment and a fine of EUR 30,000;
- Unauthorised work in a site awaiting classification: one year's imprisonment and a fine of EUR 150,000.

Among the 2859 classified sites (589 between 1906 and 1930 and 2270 between 1930 and 2017), only 103 sites were classified for a “scientific” purpose (another reason for classification was generally also retained, often the “picturesque” or “historical” value). Among these 103 sites classified for a scientific reason, the geological interest concerns about fifty of them.

For example, the underground chalk quarries of Meudon were classified by decree on 7 March 1987 for both historical and scientific reasons. The scientific reason concerns: (1) the stratigraphic interest: contact between the Campanian chalk and the Meudon limestone (visible nowhere else), (2) the tectonic interest: system of faults and karst having trapped Tertiary sediments (Sparnacian clay and Meudon conglomerate), and (3) the paleontological interest (remains of a *Coryphodon*, *Mosasaurus* . . . ). However, a classification is not necessarily a strong protection, since this site is today (2022) threatened with filling. Indeed, the public authorities (city hall, DRAC, prefecture) have given their agreement this year for the quarries to be filled with the waste from the construction of Grand Paris. This project is controversial, with the opposition of scientists, cataphiles, speleologists, local residents, and defenders of heritage and the environment.

Only five sites are classified on the basis of the only scientific reason and concern geology: (1) “the remains of the fossiliferous deposit known as Bracheux at a place called Butte de la Justice in Marissel” (Beauvais—Marissel) (Oise); (2) “the ensemble formed by parcels 308 and 907 section B, located in Saint-Laurent-de-Trèves and bearing dinosaur footprints” (Lozère); (3) “the cliffs of the commune of Luc-sur-Mer and the corresponding public maritime domain”; (4) “the paleontological site of Champclauson” (Gard); (5) “the whole formed by the network of the Aven-d’Orgnac, the Aven de la Forestière, Orgnac 3, the Baume de Ronze as well as their surroundings” (Ardèche).

The law of 2 May 1930 is the starting point for the protection of geological heritage for its scientific interest. The number of classified sites of geological interest remains minimal, compared to the number of classified sites (less than 2%). This law, if it proves to be very efficient to ensure the conservation and preservation of the geological heritage, thanks to its special authorization regime, presents numerous limits, on the other hand. The law does not provide for: (1) a management structure for the sites, (2) a scientific council, (3) financial means, and finally (4) management documents. Moreover, the law does not allow for specific prescriptions to be laid down in the decree or order of classification. The act of classification only defines a perimeter within which any modification of the state or aspect of the site is subject to special authorization by the minister in charge of sites after the opinion of the departmental commission of sites, perspectives, and landscapes (called departmental commission of nature, sites, and landscapes, since the decree No. 2006–672 of 8 June 2006, relating to the creation, composition, and functioning of administrative commissions of a consultative nature). However, it turns out that the administration in charge of sites, as well as the departmental commissions of sites, perspectives, and landscapes, count in their ranks very few geologists able to provide technical opinions in this field.

#### 4.3.3. Law of 1957: Reorganisation of the Protection of Sites of Artistic, Historical, Scientific, Legendary or Picturesque Character

The 1957 law (law No. 57–740 of 1 July 1957, completing the law of 2 May 1930 on sites of an artistic, historical, scientific, legendary, or picturesque nature) remedies certain shortcomings. This text adds to the law of 1930 an article introducing the status of nature reserve and allows for imposing special requirements for the conservation and evolution of species. These prescriptions are imposed on the owner. This new text, which is brief, also shows its limits: (1) it is aimed specifically at the conservation of species and cannot concern the geological heritage, (2) it does not introduce specific sanctions, (3) it does not provide for a management body, a management plan, or financial means.

Its implementation has, therefore, been limited, and only 36 nature reserves have been created in 20 years. Nine of these reserves contribute to the preservation of a geological heritage, although the primary reason for the classification is not geology. They are: (1) the nature reserve of Lake Luitel (15 March 1961, 17 ha) Isère; (2) the nature reserve of Néouvielle (8 May 1968—2313 ha)—Hautes-Pyrénées; (3) the nature reserve of Banc d’Arguin (4 August 1972—4360 ha)—Gironde; (4) the nature reserve of Aiguilles rouges (23 August 1974—3676 ha)—Haute-Savoie; (5) the nature reserve of Dune Marchand (December 11, 1974—83 ha)—Nord; (6) the nature reserve of Sagnes de la Godivelle (27 June 1975—24 ha)—Puy-de-Dôme; (7) the nature reserve of Scandola (9 December 1975—1919 ha, Corsica) (Figure 9)—South Corsica; (8) the nature reserve of Roque-Haute (9 December 1975—154 ha)—Hérault; and (9) the nature reserve of the Caravelle peninsula (2 March 1976—388 ha)—Martinique.



**Figure 9.** Rhyolitic organs, Scandola nature reserve, Corsica. ©Patrick De Wever. In the hole of the cliff (centre right), the Corsicans see an image (reversed) of the outline of their island.

#### 4.3.4. National Parks Act of 1960

The dynamics of taking into account the natural heritage is clearly launched, and the law of 1960 (Law No. 60-708 of 22 July 1960, relative to the creation of national parks) continues this evolution. It introduces specific tools for the protection of natural heritage. Its article 1 states that *“The territory of all or part of one or more municipalities may be classified by decree in the Council of State as a “national park” when the conservation of the fauna, flora, soil, subsoil, atmosphere, water, and, in general, of a natural environment is of special interest and it is important to preserve this environment against any effect of natural degradation and to remove it from any artificial intervention likely to alter its appearance, composition and evolution. The territory delimited by the decree may extend to the public maritime domain.*

#### 4.3.5. Law of 1976 on the Protection of Nature

The idea of natural heritage did not really emerge in France until the law of 1976 (law n°76-629 of 10 July 1976 relating to the protection of nature), which: (1) created the environmental impact study regime; (2) created the status of protected species; (3) extended the “protection forest” regime of the forestry code to the conservation of ecosystems; and (4) created a nature reserve regime independent of the sites classified under the law of 2 May 1930. This last point constitutes a sort of emancipation of the laws relating to the protection of nature from the administration in charge of sites and historical monuments.

Article 16 of this law introduces, for the first time in French law, the notion of geological heritage in an explicit way: “parts of the territory of one or more communes may be classified as nature reserves when the conservation ( . . . ) of mineral and fossil deposits ( . . . ) is of particular importance or when it is appropriate to remove them from any artificial intervention likely to degrade them ( . . . ) Are taken into consideration for this reason: ( . . . ) The preservation of biotopes and remarkable geological, geomorphological or speleological formations”. This law creates a status of a national nature reserve and a status of voluntary nature reserve (status since abrogated). It takes up the main principles of the laws of 1930 and 1957 (special authorization for the modification of the state or the aspect of the places, procedure of classification, possibility of issuing conditions, or prohibitions necessary to the protection of the reserve in the act of classification) and completes them with new and very expected provisions: (1) designation of a management body endowed with financial means; (2) creation of an advisory committee allowing local actors to participate in the management of the nature reserve; (3) creation of a scientific committee; (4) drafting of a management plan validated by the scientific bodies and approved by the classification authority; (5) creation of a system of fines: contravention from 2nd to 5th class (35 EUR to 1500 EUR). It nevertheless presents some limits and constraints: (1) weakness of the penal sanctions compared to the law of 2 May 1930: (2) cumbersome procedures, such as (a) creation by decree in the Council of State; (b) authorization for work issued by the prefect or the minister in charge of the environment after the opinion of the municipal council, the departmental commission for nature, landscapes and sites, and the regional scientific council for natural heritage; (c) drafting of a management plan and renewal of the first management plan after 5 years and then every 5 or 10 years. The cumbersome nature of the procedures is, however, a guarantee of the legal soundness of the act of classification and of the rigorous management of the reserve.

The law of 27 February 2002 (Law No. 2002-276 relating to local democracy) replaces the status of voluntary nature reserve by a status of regional nature reserve and Corsican nature reserve. It also opens the possibility for Regional Councils to classify nature reserves by simple deliberation with the agreement of the owners.

In 2022, the network of nature reserves has 357 classified nature reserves, including: 169 national nature reserves for 171,070,244 hectares; 181 regional nature reserves for 41,404 hectares; 7 Corsican nature reserves for 86,624 hectares. Among these 357 nature reserves, 81 contribute to the protection of geological heritage, and 23 were specifically created on this scientific basis such as the National Nature Reserve of the geological sites of Essonne.

#### 4.3.6. Law of 1976 Reforming Urban Planning and Creating Sensitive Natural Areas (ENS)

The year 1976 was marked by a second important law for the protection of natural heritage: the law of 1976 (Law No. 76-1285 of 31 December 1976 on urban planning reform). This law instituted sensitive natural areas (ENS) to replace the “sensitive perimeters” created by decree in 1959 in an attempt to limit the uncontrolled urbanization of the coastline. This ENS policy was entrusted 9 years later to the General Councils (which have since become Departmental Councils) by the law of July 18, 1985 (Law No. 85-729, relative to the definition and implementation of development principles).

Thanks to this law, the departments can finance this policy by instituting a departmental share of the development tax intended to finance the ENS. They can also create pre-emption zones; tools that are cruelly lacking in other legislation in favour of environ-

mental protection. Thus, the departmental policy of sensitive natural areas can be carried out independently of the creation of nature reserves or classified sites or in synergy.

#### 4.3.7. Law 2002 on Local Democracy

If the principle of the preservation of the geological heritage was introduced, since the law of 10 July 1976, the recognition of the geological heritage as such goes back only to the law of 2002 (Law No. 2002-276 of 27 February 2002, relating to the democracy of proximity).

This law, which extends the definition of natural heritage to “*geological, mineralogical and paleontological riches*”, provides for the creation of an inventory of this heritage (the national inventory of geological heritage—INPG). The law placed this inventory under the scientific responsibility of the National Museum of Natural History, which must, therefore, validate the geological inventory sheets, an integral part of the national natural heritage inventory. This inventory, effectively launched in 2007 by the ministry in charge of the environment, aims to describe and prioritise geological sites, in order to allow public authorities to take them into account in development projects and to define adequate protection measures, if necessary [10,45].

#### 4.3.8. 2008: A New Dynamic for Strengthening the Protection of Sites: The Strategy for the Creation of Protected Areas (SCAP)

In 2008, the French government set up a major program on the environment called “Grenelle de l’Environnement”. This major reflection led to the definition of a set of political or scientific environmental actions to be carried out on the territory. One of the results of this work was the observation that the network of so-called “highly protected areas” was not sufficiently developed in France. The so-called “highly protected” areas are governed by the following regulatory tools: nature reserves (national, regional, and Corsican), the hearts of National Parks, prefectural orders for the protection of biotopes (and geotopes, since 2015), and classified sites. These areas currently represent 1.2% of the surface area of metropolitan territory. The areas protected by less restrictive protection tools represent 10% of the surface of the metropolitan territory. In order to improve this situation, a strategy has been put in place. This Strategy for the Creation of Protected Areas (SCAP), officially launched by the Ministry in charge of the environment in 2009, aims to place at least 2% of the terrestrial territory of Metropolitan France under strong protection by 2020 and to improve the representativeness and coherence of the network of the protected areas.

Concerning geology, a special “geodiversity” working group was mandated by the Ministry to conduct an analysis to insert this theme into the strategy. This work mainly extended from 2009 to 2011 [46]. As the results of the national inventory of French geological heritage were not yet available at that time, it was necessary for this working group to define “geological categories” that would serve as a guide for the people contacted to inform sites.

Four categories of geological sites were, thus, distinguished: (1) international standards (such as stratotypes or Global Boundary Stratotype Section and Point or GSSP (= boundary stratotype), (2) “point” conservation sites (such as dinosaur footprint sites or sites of mineralogical interest), (3) large geological and tectonic assemblages (e.g., the ophiolites of Mount Chenaillet in the Alps), and (4) geological landscapes, at the interface between geology and geography (e.g., karst landscapes or the Gavarnie cirque in the Pyrenees). A first list of 140 major sites remaining to be preserved in metropolitan France have been compiled from this work.

#### 4.3.9. Decree 2015 on the Protection of Sites of Geological Interest

The tools of protection in favour of the geological heritage being relatively heavy to implement, whether it is about nature reserves or classified sites, it seems necessary to the State to have a more flexible tool to intervene on the model of what already exists in the field of nature protection with the prefectural decrees of protection of biotope.

The decree of 28 December 2015 (Decree No. 2015–1787 on the protection of sites of geological interest taken in application of Article 124 of Law No. 2010-788 of 12 July 2010 on the national commitment to the environment), therefore, completes the environmental code with two new tools.

First of all, in each department, the prefect decides on the list of sites of geological interest that benefit, following their inscription, from general protection measures. The inscription of a site on this departmental list entails a ban on the destruction, alteration, or degradation of the site, as well as the prohibition to collect, destroy, or degrade fossils, minerals, and concretions. The prefect can nevertheless deliver exceptional authorizations to take fossils, minerals, and concretions for scientific or teaching purposes. To be registered on this list, these sites must meet at least one of the following criteria: (1) to constitute an international reference, (2) to present a scientific, educational, or historical interest, (3) to contain rare geological objects.

The advantage of this tool is that it is relatively flexible, since a single decree can protect a group of sites on a departmental scale. On the other hand, inclusion on this list does not allow for the enactment of protection measures specific to the local context.

On the basis of this list of sites of geological interest, the prefect can, in addition, issue a prefectural decree for the protection of geotopes and prescribe specific measures to prohibit or limit certain existing activities, while being proportionate to the protection issues and the local context.

However, these two tools suffer from an important limitation that we are reminded of in a note dated 1st December 2016 from the Ministry of the Environment, Energy, and the Sea: “[ . . . ] it is advisable to bring the prescriptions of the decrees setting the departmental lists and the decrees of site protection measures to the attention of the mayors when drawing up the urban planning documents. In fact, there is no obligation to annex to local urban plans (PLU) or land use plans (POS) the prescriptions resulting from an order establishing the departmental list or an order for protection measures, as they are not included in the list of public utility easements. A nuance must be made for the remarkable and characteristic spaces of the coastline. In fact, for the protection of the coastline, the urban planning code has been modified so that documents and decisions relating to the vocation of zones or the occupation and use of land preserve certain spaces and environments (articles L121-23 and R121-24 of the Urban planning Code).

The first sites to benefit from this type of protection are located in Yvelines. Indeed, by order of 25 May 2018, the prefect of Yvelines has adopted the first departmental list of sites of geological interest in France. On the basis of this list, on 26 May 2018, he issued two prefectural orders for the protection of geotopes of the Lutetian sites in the municipalities of Thiverval-Grignon (33.6 ha), on the one hand, and Beynes (9.6 ha), on the other. These two geosites present fossiliferous deposits of an extraordinary richness recognised worldwide, within the same geological formation (a more detailed explanation is provided by [38,47]).

Summary of the tools currently available for the protection of sites of geological interest Knowledge:

- The national inventory of geological heritage—INPG (article L411-1-A of the Environment Code).

Regulatory protections under the environmental code:

- Sites classified under the law of 2 May 1930 (article L341-1 of the Environment Code);
- National, regional, and Corsican nature reserves (article L332-1 of the Environment Code);
- The departmental lists and prefectural decree of the protection of the geotope (I of art R411-17-1 of the Environment Code);
- The geotope protection orders (III of article R411-17-1 of the Environment Code).
- Protection under the urban planning code:
- Article R121-4 of the urban planning code (development and protection of the coastline);
- Land protection and enhancement tools:
- The sensitive natural areas of the departments (article L113-8 of the town planning code);



- The Conservatoire de l'espace littoral et des rivages lacustres (article L322-1 of the environment code);
- The regional conservatories of natural areas (article L414-11 of the environment code).

#### 4.3.10. Presentation of Nature "Protection" and "Management" Tools in France

Until the law of 27 February 2002, relating to the democracy of proximity, geology, and its affiliated disciplines, were generally not directly taken into account in the texts of laws. The terms used in the texts were generic: "nature", "natural diversity", and often interpreted as biological nature, not geological. As a result, many nature protection tools, and a large number of protected area creation projects in France, have been based on biological, not geological, reasons. This explains why many of the protection tools do not "directly" protect geology. Nevertheless, some of them are applicable to the protection of geological sites or objects, and remarkable geological objects can be found in each of these areas.

Several types of protection are used on the metropolitan territory. On a national scale, there are three legal methods of protecting natural areas [48]:

- The regulatory approach consists of limiting, or even prohibiting, generally by decree or by order (depending on the body responsible for protection), human activities according to their impact on the natural environment;
- The conventional approach aims at delegating to a third party for a determined period of time the management and the preservation of a natural space within the framework of an agreement of use control;
- The land approach is based on the acquisition of freehold land, in order to ensure the definitive protection of a natural area.

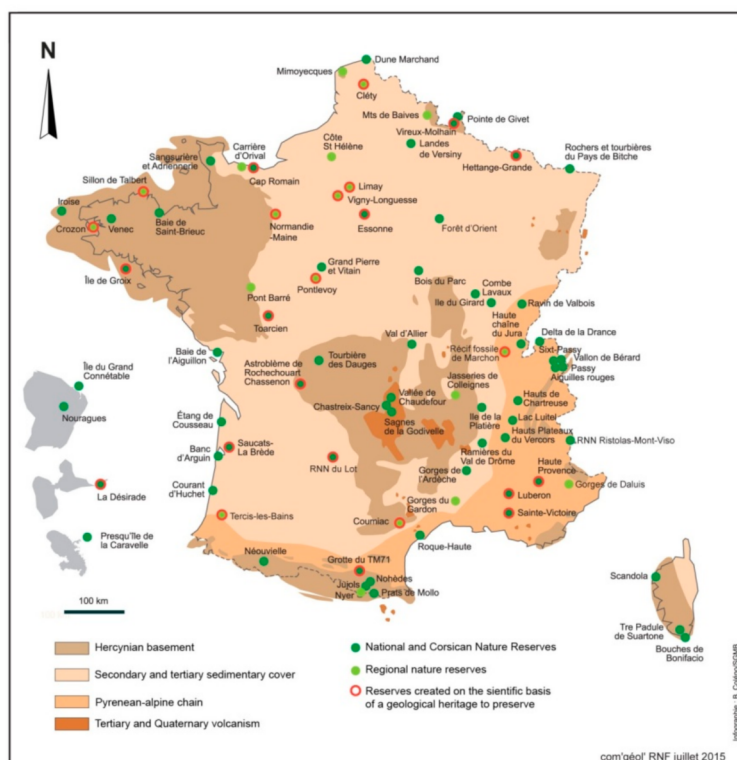
A protection tool can sometimes fall under two different approaches. We present here only those that concern the geosciences, directly or indirectly. There are also protected areas in the French overseas collectivities corresponding to as many legal statuses and categories of protected areas, some of which are under special jurisdiction. They are not treated here.

##### Regulatory tools

- **National parks (NP).** Protection and management tools, they are the responsibility of the State. Their creation, after public consultation, is the result of a decree by the minister in charge of nature protection. In 2022, there will be 11 national parks in France. The NPs are public establishments in which the legislation is strong, especially on the "heart" of the park. The original idea was to define territories of total nature reserve. Traditional activities (e.g., pastoralism) may be authorised. We can mention, for example, the Cévennes NP, the Pyrenees NP, etc.
- **National nature reserves (RNN).** Protection and management tools. Their creation, after public consultation, is the result of a decree from the ministry in charge of the protection of nature. The reserves are grouped together in a national network, the association "Réserves naturelles de France" (RNF). This association includes a Geological Heritage commission. There were 169 RNN in 2022. Geology, if it is well-explained in the decree of creation, is taken into account (some RNN have been created on geological grounds (Figure 10)). One can cite for example that of Saucats and La Brède, Hettange-Grande, the Island of Groix, etc.
- **Regional nature reserves (RNR) and Corsican nature reserves.** Protection and management tools are supported by the Regions (Regional Councils and Assembly of Corsica), and these reserves are also part of the RNF network. The processes and effects of classification are slightly different from those of RNN. Some former "voluntary nature reserves" are now classified as RNR. There were 181 RNR in France (in 2022), including 7 in Corsica (2020). Examples include the Sillon de Talbert, the geological reserve of Pontlevoy, etc.
- **The biological reserves of the National Forestry Office (RB/ONF).** Biological reserves are a protection tool specific to State forests (domanial) and to forests of com-

munities subject to the forestry regime (municipalities, departments, and regions). As such, they are managed by the Office National des Forêts. The lands managed by the ONF are areas under the forestry code. The spaces can be classified as integral biological reserves (RBI) or directed (RBD). In these cases, geology is taken into account in the same way as biology in the protection and management of the territory. One example is Mont Ventoux, a remarkable geological site that is partly a biological reserve of the ONF. The available numbers at moment indicated that there are: (1) in mainland France: 157 directed biological reserves (RBD), 56 integral biological reserves (RBI), and 21 “mixed” RBs (RBI + RBD), for a surface area of 24,145 ha of RBDs and 21,868 ha of RBIs; (2) in the overseas departments: 9 RBDs, 7 RBIs, and 1 mixed RB, for a total of 10,007 ha of RBDs and 94,582 ha of RBIs.

- **Classified sites.** A protection tool, but not management tool, at the initiative of the Departmental Commission for Nature, Landscapes, and Sites. The order or decree of the minister in charge of sites. Works that tend to modify the site are subject to special authorization, from the moment the classification is pronounced. France has more than 2800 classified sites and 4000 registered sites, i.e., 4% of the national territory. We can quote for example the two capes Gris-Nez and Blanc-Nez;
- **Prefectural protection decree.** A protection tool, but not a management tool. Order of the prefect of the department. There is no public inquiry, but there is public consultation. The law of 12 July 2010, concerning the national commitment for the environment, has extended the scope of application of the biotope protection orders to geotopes. This tool, flexible and effective, can, therefore, be used since the decree of December 28, 2015. In 2018, there were more than 900 biotope protection orders in metropolitan and overseas France and two geotope protection orders.



**Figure 10.** Map of the reserves with a remarkable geological heritage, situation in 2015. Coléno/SGMB, RNF.

### Conventional protections

- **Regional nature parks.** A development tool, they are initiated by the regions and are officially established by decree in the Council of State. The municipalities that

join a nature park sign a charter of commitment concerning nature, its development, its preservation, etc. The parks are managed by a mixed syndicate and can manage nature reserves, Natura 2000 sites, etc., which would be in their territory. We can cite the regional nature park of Luberon, that of Chablais. There were 58 regional nature parks in 2022.

- **Natura 2000 sites.** Fundamental tools of the European policy of biodiversity preservation, the Natura 2000 sites aim at a better consideration of biodiversity issues in human activities. These sites are designated to protect a certain number of habitats and species representative of European biodiversity. In 2018, France has 1773 sites, covering nearly 13% of the terrestrial territory of Metropolitan France and 11% of the exclusive economic zone of Metropolitan France. The Natura 2000 network approach favours the collective search for the balanced and sustainable management of spaces that consider economic and social concerns:
  - a. Human activities and infrastructure projects are possible in Natura 2000 sites. In order to avoid activities detrimental to biodiversity, projects likely to have an impact on protected species, and habitats must be subject to prior assessment.
  - b. On a day-to-day basis, the management of Natura 2000 sites is a participatory process involving the stakeholders of the territory. A steering committee defines, for each site, conservation objectives and management measures that are then implemented in the form of charters and contracts co-financed by the European Union. We can mention the Gorges de la Dourbie and the surrounding causses, the Hauts Plateaux du Vercors. The elements relating to geology are not concerned by this measure.
- **UNESCO World Heritage Sites.** The sites, proposed by the States, are subject to a decision of the International Committee for Natural Heritage. The status of protection is regulatory and conventional, and it is provided by the State. There were five in France in 2018: four for nature alone (Scandola in Corsica; lagoons of New Caledonia; cirques and peaks of Reunion Island; Chaîne des Puys-Faille de Limagne); another is mixed, culture and nature (Mont Perdu-Cirque de Gavarnie in Midi-Pyrénées).

#### Protection by land control

- **Sensitive natural areas (ENS).** A tool for the protection and management of the departments, they are implemented by the departmental councils and the sites are open to the public (law of 18 July 1985). The departmental councils can institute pre-emption zones on sensitive natural areas, on which they can substitute themselves for any buyer. The departmental share of the development tax can be used to finance sensitive natural areas. Today, 99 departments carry out this policy, constituting a national network of more than 4000 sites representing 200,000 hectares of nature [49].
- **The conservatories of natural areas (CEN).** CEN have existed for over 30 years in France. They are based on the associative system and work for the preservation of natural heritage and landscapes. According to a survey conducted in 2011 for the CEN and RNF, the interventions of the conservatories of natural spaces concerning geology mainly concern the management of geological sites or sites with a recognised heritage character and their development (in terms of animation for example) [50]. They intervene for the knowledge and the management of spaces that already benefit from land control or use (convention, lease, etc.) or a regulatory status (natural reserves, Arrêtés de protection de biotope). The CEN network works on 3108 sites, among which, 19 are identified as “geological”.

#### “Labels”

- **The great sites.** The “Grands sites” label is awarded by the State, with the ministry in charge of the sites (generally the ministry in charge of the environment) for a period of six years. It requires a commitment to participate in the network. It is awarded in recognition of excellence in management to sites classified under the 1930 law that enjoy a high level of notoriety and are subject to significant tourist traffic. Out of

approximately 2500 sites classified under the Law of 1930, a good hundred potentially correspond to the concept of “Great Site”. In 2018, 43 members are part of the Grands Sites de France network, and 17 sites have obtained the Grand Site de France label. We can mention, for example, the Dune du Pilat, the Gorges du Tarn, the Two Caps Blanc Nez-Gris Nez, and the Sainte-Victoire Mountain.

- **Geoparks.** The Geopark label (European Geopark or UNESCO Global Geopark) is obtained after the protection and management tools have been put in place. This label testifies to a quality approach involving sustainable development, education, research, etc. Obtaining this label does not directly bring any material means. These are “regional nature park”-type structures, and the project leaders commit to a charter that is revised every four years. The structures are committed to participating in the work of the European Geopark Network (since 2000) or the Global Geopark Network (since 2005). France initiated these geoparks, since it has the first geopark in the world, initially (2000) based on the territory of the geological reserve of Haute-Provence (n°1). Since then it has obtained six other labels, the latest of which was the Beaujolais in April 2018.

#### 4.4. Ex Situ Heritage

*“In our life as geologists, every time we meet a rock, we ask its name, its age, why it is there, how it was formed, and in order not to forget its answers, we bring back a fragment of it in our collections”,* a sentence attributed to Jules Gosselet (1832–1916), founder of the Geological Museum of Lille [51].

The natural heritage must be preserved in nature (in situ heritage), but the objects which are extracted from it deserve to be preserved just as much (ex situ heritage) because the natural sciences are sciences of comparison and, thus, require having objects of reference (rocks, minerals, fossils, etc.). This aspect is all the more important, as the notion of type specimen prevails in the definition of objects, whether for minerals, fossils, and even, but to a lesser degree, rocks. These objects constitute many witnesses of past environments. Moreover, Karl Popper had underlined that *“science [ . . . ] is a phenomenon that must be understood as in perpetual growth, that is essentially dynamic, and that nothing is ever completed”*. He also emphasised that scientists must look for the reality hidden behind the appearances. An alchemical antiphon applies particularly well to the study of the samples: the VITRIOL: *Visita Interiora Terrae Rectificandoque Invenies Occultum Lapidem*, that is to say, “Visit the interior of the Earth and by rectifying you will find the hidden stone” (the concealed reality). Moreover, science progresses by trial and error, and some samples, even those already well-studied, must be re-examined with a new look and/or with new tools. Their conservation is, therefore, necessary. A few examples illustrate the point. The most obvious is that of samples from the Moon. We can also cite the thousands of meters of drilling cores, terrestrial or oceanic. Some samples come from countries that are now difficult to access or from abandoned mines. Sometimes, it is not the cost of renewal that is important, but only a new look: for example, the Neanderthal baby rediscovered by chance and the “conodont animal” that was waiting in a drawer [52,53].

Collections are at the heart of the *raison d’être* of museums. The way they acquire objects is, therefore, one of their important concerns. With nature protection laws, researchers are now responsible for the legal use of the specimens presented in their publications [28,54]. The regulations are as much about the commercial value of the objects as they are about political aspects. Some objects can, indeed, reach very high sums: half a gram of the Orgueil meteorite (fallen towards Montauban on 14 May 1864) was sold for USD 2500 (which makes the kilogram USD 5 million!), the *Tyrannosaurus rex*, named “Sue”, was auctioned in 6.5 min at USD 8.36 million at Sotheby’s in 1997.

More recently, on 21 October 2021 a Triceratops, only 60% complete, extracted from South Dakota in 2014, nicknamed “Big John”, was sold at the Hotel Drouot, Paris, to a private American collector for EUR 6.6 million, for “his personal enjoyment”, to the dismay of scientists.

In fact, today, as for other products, international legislation imposes a traceability of geological objects, even if it is not yet at an equivalent level to that which applies to protected species or genetic resources. For example, a dinosaur fossil that was extracted in Mongolia and smuggled to the United States was returned to Mongolia because the export of fossils is prohibited in that country. The Rio Declaration on Environment and Development, known as the Rio Convention (1992), regarding the ownership of genetic resources, was reinforced by the Nagoya Protocol in 2014, which requires permission before any sampling. We are still far from these restrictions for geological objects in France; nevertheless, we should not forget that any object comes from a property (private or public) and that such an authorization to collect is required (traceability), which puts any collection holder in a certain embarrassment (also see article 2.4 of ICOM [55]). Moreover, some natural objects can be protected as cultural objects! Thus, the “gogottes” of Fontainebleau (Figure 11), for example, which sell for a high price, are subject to surveillance by the State services. Some gogottes of less than a metre were put on sale at several tens of thousands of euros.



**Figure 11.** Gogotte of Fontainebleau. Natural history Musuem © Joyofmuseums, CC-BY-SA4.0.

The Bilboquet is a particular gogotte of a sandstone block emblematic of the Fontainebleau region. The numerous sandstone concretions with varied forms have often evoked various ideas to the observers and were, thus, allotted names of an imaginary nature. ©Michel Colombe.

The ICOM Code of Ethics [55], which applies to all museums worldwide, specifies the conditions for acquiring specimens from nature:

*Section 2.2 Valid Title: No object or specimen shall be acquired by purchase, gift, loan, bequest, or exchange unless the acquiring museum is certain of the existence of valid title. A deed in a given country does not necessarily constitute good title.*

*Article 2.3 Provenance and Due Diligence: Prior to the acquisition of an object or specimen offered for purchase, gift, loan, bequest, or exchange, every effort should be made to ensure that it has not been illegally acquired in (or exported from) its country of origin or a country of transit where it might have had legal title (including the country in which the museum is located). In this regard, a duty of care is imperative to establish the full history of the object since its discovery or creation.*

*Section 2.4 Unscientific or Unauthorized Objects and Specimens: A museum should not acquire objects if there is any reason to believe that their recovery has been at the expense of the prohibited, unscientific, or intentional destruction or deterioration of monuments, archaeological or geological sites, species, or natural habitats. Similarly, there should be no acquisition if the owner, occupier of the land, or the relevant legal or governmental authorities have not been notified of the discovery.*

*Section 2.6 Protected Biological or Geological Specimens: A museum shall not acquire biological or geological specimens collected, sold, or otherwise transferred in violation of local, national, or regional laws or international treaties relating to the protection of species and nature.*

The French cultural heritage is very well-regulated and protected. Additionally, a collection deposited in a “Musée de France” is subject to this type of protection. A collection is then protected in an inalienable and imprescriptible way. Its export becomes impossible. However, a temporary loan for a temporary exhibition, for example, requires the signature of the minister of culture. A decree defines what is considered as cultural property and gives a list of 14 categories and the criteria for each of them. One category concerns the collections and specimens of zoology, botany, mineralogy, and anatomy, as well as the collections of historical, paleontological, ethnographic, numismatic, and philatelic interest, which, above a sum of EUR 50,000, require an authorization from the Ministry of Culture for their export. This protection goes even further because it stipulates that, if a French institution wants to acquire an object, it has a right of pre-emption.

As for the collections deposited in establishments that do not have the status of “Musée de France”, such as the Écoles de Mines of Paris, Saint-Etienne, Alès, the museum of Decazeville, etc., the situation is quite different, and they are sometimes in great danger of being not only dispersed, but also simply destroyed. This situation was extensively discussed at a colloquium held in 2002 at the Muséum national d’Histoire naturelle, Paris [52].

We could have dealt in this section with other ex situ objects, such as maps, manuscripts, photographs, and data associated with collections, but these documents are sometimes just as much the responsibility of libraries, archives, and sometimes the Ministry of Culture. The complexity of the cases are even greater, and we have not dealt with them here.

## **5. To Make Known (to Valorise, to Disseminate)**

The protection of local, national, or global geoheritage requires funds that are generally public. Good acceptability for these projects is, therefore, if not a prerequisite, at least welcome.

Explaining what heritage is then is a very useful step. This starts with a better knowledge of the sites by the public. In order to popularise geoheritage, in the general sense of the term, several methods are possible: conferences for the general public, books intended for a non-specialised public, field trips, collections of booklets explaining the relations between geology-urban, and rural architecture-history, or targeted exhibitions.

Depending on the country, and therefore, on the culture, specific means it must be implemented. A study carried out in the Western Alps [56] revealed that Latin cultures (Italy, France, the Romance part of Switzerland) seem to prefer museums, whereas Germanic cultures (Germany, Austria, and German-speaking Switzerland) would prefer in situ devices: hiking trails with explanatory panels.

### *5.1. At the International Level*

The International Union of Geological Sciences (IUGS) has been interested in the concept of Geosites since 1994 without major effect. The ambition was then to involve the whole geological community to promote the protection of sites for research and teaching purposes. In 1995, the IUGS joined forces with UNESCO for the creation of a database by a Global Geosites Working Group, whose mandate was to safeguard sites of international value, but also to support national and regional efforts, in particular, through meetings with the association movement, and finally, to serve as a referent and advisor to the IUGS and UNESCO bodies. This work was to be performed in association with the ProGEO group, but after a few years, the collaboration ended around 2002-2003. Subsequently, the IUGS organised a Geoheritage Task Group dedicated to geoheritage, which was formally launched in November 2010 and became the International Commission on Geoheritage in 2016. The commission on Geoheritage (IUGS-ICG) comprises three key areas that

give recognition to IUGS Global Geosites, GeoCollections, and Heritage Stones, with the GeoCollections subcommission being more official than active.

The Geosites programme was an idea initially evoked by IUGS in 1994. This project has now been reformulated by IUGS-ICG, including the participation of UNESCO Global Geoparks, IGCP, ProGeo and many IUGS affiliated organization worldwide. This long demanded scientific programme is now working in the context of the new IGCP-731 IUGS Global Geosites project.

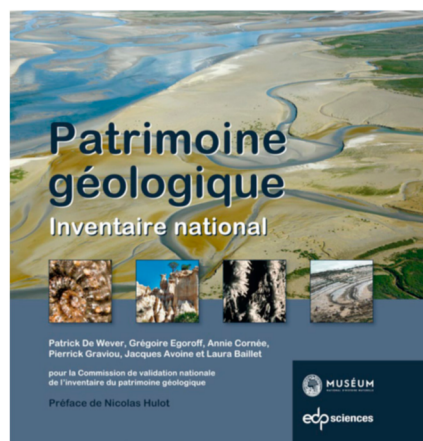
The IUGS Global Heritage Stone Resource (GHSR) exists to enhance the geological knowledge, use, and conservation of natural stones of historical importance worldwide.

We have seen that, at the European level, there is a ProGEO group, whose main goal is conservation. However, ProGEO is also interested in the dissemination of heritage data and in advising the national and European public on aspects of protection within a global framework of nature. They have a journal entitled “Geoheritage”, published by Springer, and a book presenting geoheritage and its conservation in Europe was published in 2012 [57].

In recent years, with the emergence of this interest in geoheritage, the number of journals and books has increased accordingly, for example, the International Journal of Geoheritage (published in China) or books published by [57–60]. More recently a 450-pages book, “Geoheritage: assessment, protection and management”, edited by Emmanuel Reynard and José Brilha, considers the different aspects of geoheritage [61].

### 5.2. At the National Level

Many sites have been destroyed by the simple ignorance of the decision-makers of what they represented. The law of 2002 imposes the realisation of an inventory, which makes it possible to list the sites that deserve our interest, at the regional or national level. In order to make this inventory known, a restitution symposium was held in Chambéry in 2018. On this occasion, a book was published [62], which presents about a hundred sites (one per department), one of the goals of which is also to make it known (Figure 12).



**Figure 12.** Cover of the book published in 2018 to mark 10 years of the National Geologic Heritage Inventory [62].

State of the art: after 15 years of program, and the active participation of more than 650 people belonging to more than 70 institutions or associations, nearly 3500 records have been validated at the national level, and 1500 are being revised. In total, more than 5000 records are expected for the first phase. It is also important to note that this is a continuous inventory, so the figures are constantly changing.

The data of the national inventory of the geological heritage, available on a web site (INPN = Inventaire National du Patrimoine Naturel [63]), also allow us to feed a base dedicated to education, in particular, to secondary education, in order to offer to the teachers an effective means to set up geological excursions with their pupils, thanks to sites

gathered in the “national lithothèque” and other sites, such as Planet-Terre (ENS-Lyon), are of free access.

During the International Year of Planet Earth in 2008, France had chosen outreach as one of the strong themes. The result was a revelation for many academic researchers: more than two thirds of the projects selected by the French committee were related to geoheritage.

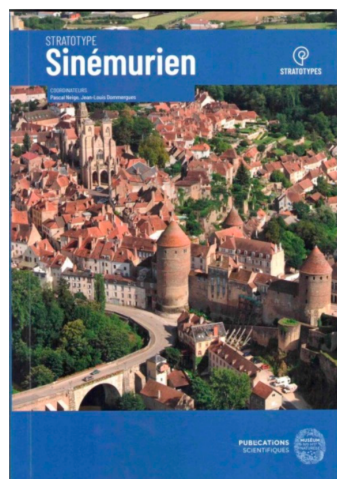
Before protecting, it is often necessary to make people aware of the situation, in order to promote the acceptability of interventions, which are constraints. Awareness-raising and mediation actions have then been undertaken by individuals and several associations, and some have been concretised by books [64–71].

Several books that intended to raise awareness of geology and geological heritage have already been published by different publishers, with different formats. Recently, several collections have been launched: *Stratotypes*, *Geological walks*, *Geotourism*, *Geological guides*, etc.

### 5.2.1. The “Geological Heritage” Collection

The geological scale is based on the notion of a stratotype. France has more than 40 stratotypes, and, even if some of them are only of historical interest, since they are replaced by others (such as Rupelian, which is preferred to Stampien), stratotypes are good supports to approach the notion of geological heritage to a large public. They allow us to explain palaeontology, sedimentology, and the importance of time in geology, most of the concepts used in geology.

The Muséum National d’Histoire Naturelle launched a collection entitled “Patrimoine géologique. Stratotypes” in 2008, which was initially co-published by the Muséum National d’Histoire Naturelle, the BRGM (French Geological Survey), and Biotope, then only the Muséum. The objective is to devote a volume to each stratotype. Intended for a wide audience, the collection aims to explain what a stratotype is, namely a scientific standard of international value, which, as such, deserves conservation and protection and, thus, to make the reader aware of the value of his heritage. Each book retraces the history of the works devoted to this time interval and gathers the geological data on this stage. It also presents the influence of this geological heritage on human activities (agricultural and industrial practices, architecture, construction, sculpture, etc.). As far as possible, the work lists the collections associated with this level (content, abundance, and places of conservation), emphasizing that the geological heritage covers both in situ and ex situ objects. Ten volumes have now been published (Figure 13): Albian, Aquitanian, Cenomanian, Givetian, Hettangian, Lutetian, Stampian, Turonian, Danian, and Sinemurian. Several others are in progress, in variable states of progress: Aptian, Barremian, Autunian, Berriasian, Brioverian, Sparnacian, and Toarcian.



**Figure 13.** Cover of the latest volume of the collection “Stratotypes” [71].



### 5.2.2. The “Geological Walks” Collection

Geology is often perceived as an austere and difficult discipline, sometimes even off-putting. In order to change this state of mind, a collection of booklets describing geological tours in the city was created, which show the relationships between rocks, architecture, city planning, and history, and which seek to associate art and science. The aim is to demonstrate that, similar to art, science belongs to culture. Generally, this approach is very successful. The project covers all of France and is initially associated with the Muséum national d’Histoire naturelle, the Société Géologique de France, the BRGM (French Geological Survey), and Biotope. The first volume was published in 2008. More than 40 booklets are now published by the museum alone. Their success proves that these geological walks in the city are good tools for raising public awareness of geology.

### 5.2.3. The “Geological Guides” Collection

This collection, co-published by Omniscience and BRGM (French Geological Survey), was launched in 2011 and includes 25 titles to date. In each volume, 10 discovery routes, especially for hiking, are presented, selected for their originality and accessibility.

### 5.2.4. “Geological Curiosities” Collection

This collection, published by BRGM (French Geological Survey), and sometimes co-edited with other editors or regional/national institutions, was launched in 2009. It includes more than 25 titles to date. The first part is devoted to the chronology of rocks and geological phenomena, and the second part of the book offers the passionate reader to discover or rediscover remarkable geological sites during itineraries marked out by “freeze frames”.

### 5.2.5. The “Geotourism” Collection

The Geotourism collection, co-published by the SGMB and Biotope, makes Breton geological heritage accessible to a wide audience. On a selection of sites, the memory of the rocks and the formation of some landscapes are deciphered. The access to the sites, as well as the itineraries, are specified by means of extracts of IGN map at 1:25,000-scale. The four issues published concern Brittany: Finistère, Ille-et-Vilaine, Côtes-d’Armor, Morbihan, and more recently, Hérault in southern France.

### 5.2.6. Vigie-Terre: Participative Science Programme

As a result of natural or anthropic actions (erosion, land development, etc.), new outcrops are constantly being uncovered. Some are of potential geological interest, but their accessibility is generally limited because they are often only temporarily exposed. To overcome the problem of the ephemeral nature of these outcrops, it is obvious that they need to be rapidly brought to the attention of specialists. In order to achieve this, the use of citizen science seemed to be a relevant solution, as it allows us to involve participants throughout the territory under consideration. Based on this observation, a citizen science programme called Vigie-Terre, conceived in 2007, was implemented by the National Museum of Natural History in 2015 and officially launched in 2020.

It allows participants (non-geologist observers, amateurs, or professionals) to report and describe new outcrops online [72,73]. A step-by-step protocol for locating and describing outcrops is used. The data provided is open access, but also transmitted to a network of experts, academic, or professional geologists, spread over the territory to assess the geological value (scientific, educational, or heritage) of the sites.

The programme does not yet make it possible to systematically save sites of geological value, but it can favour the collection of samples to keep a record of such sites. Over the long term, it will provide insight into the proportion of sites of geological interest to raise the consciousness of decision-makers to the consideration of geological heritage (Figure 14). The programme was designed for the French territory, but it can be used for other countries.



**Figure 14.** Page on the Vigie-Terre website for online entry [72].

### 5.2.7. Geo-Routes

In nature, entrails or “georoutes” allow for access to geology in situ at different scales: over distances covered on foot or by car. Several routes have been developed with this objective: the Via Geoalpina and the Trans-Pyrenean Geological Route.

- **Via geoalpina:** This large-scale project was initiated by the IUGS and UNESCO in the framework of the International Year of the Earth. It brings together organizations from six Alpine countries (Austria, France, Germany, Italy, Slovenia, and Switzerland) ([www.viageoalpina.org](http://www.viageoalpina.org)). This Via GeoAlpina is developed along the Via Alpina, a hiking route crossing all the countries of the Alpine arc from Trieste to Monaco. It aims to develop and extend the knowledge of geology, geomorphology, hydrology, natural hazards, and material uses. While walking along marked trails, tourists and hikers are informed about the history of the formation of the Alps and the secrets of the planet Earth.
- **Trans-Pyrenean Geological Route:** This geological route, realised by French (GéolVal) and Spanish (GeoAmbiente and GeoTransfert) associations, crosses the Pyrenees and proposes the discovery of the geology of the Aspe valley and the High Aragon. It is more than 200 km long and has 25 stops with explanatory panels [74]. In addition to these great routes, there are also other signs posted and commented nature tours, of which, geology is a part, for example, in the bay of the Somme.
- **The Tour de France cycling race:** Since its birth, more than a century ago, the Tour de France has become a part of our national heritage. Initially, it was really the Tour de France, even if the number of stages was reduced. The Tour goes far beyond the mere sporting competition. So much so that some members of parliament have asked for it to be included in UNESCO’s Intangible Cultural Heritage in 2019. Not only is it a sporting saga, it is also a great rite, renewed every year. It is watched on television by millions of people, and a significant proportion follow it mainly for the landscapes, in which geology plays a preponderant role. It was then logical to try to include geology in the comments. This was performed since 2016, and a booklet intended for the general public is available on websites (including that of the Geological Society of France), and it is now available in several languages.

## 6. Conclusions

In spite of a long-standing interest in heritage (paradoxically since the French Revolution and its ravages) and in geoheritage (first inventory in 1913 by Martel), this subject has often been little considered, or even poorly considered, by the geosciences community, at least in France. Only a few people or structures have been interested in the knowledge of geological heritage and geoconservation. This was, in particular, the case of the Nature Re-

serves of France. One of the highlights was the meeting they organised in Digne-les-Bains in the reserve in 1991 [1], under the high patronage of UNESCO, perfectly international, during which the International Declaration of the Rights of the Memory of the Earth was proclaimed. Since then, other initiatives have followed, including the first national days of geological heritage held in the premises of the Ministry of the Environment in Paris in 1997 [2]. Almost at the same time, the Ministry of Higher Education and Research showed its interest by accepting a Plan Pluriformation “Patrimoine géologique national”, which has now become an ASM (Action Structurelle du Muséum).

More recently, a revival of interest was triggered by the publication of the Local Democracy Law twenty years ago, imposing, in particular, the need for an inventory. Nevertheless, it must be recognised that geodiversity benefits from much less attention than biodiversity, even though the European community has emphasised that taking an interest in geodiversity improves biodiversity management, since geodiversity is the foundation of biodiversity (see, as example, [75]). It is also worth noting that, in April 2018, a workshop was held, entitled “Workshop on Global Geoheritage. International Significance and Biodiversity Values”, with a theme specifically on the role of GSG in IUCN WCPA, exploring the links between geodiversity and biodiversity in the management of protected areas. These geodiversity–biodiversity relationships (up to geogastronomy) have been recalled, or at least addressed, in an issue of *Géochronique* in 2020 (No. 155) and on the websites of Planet-terre and Planet-vie [76].

We can then hope that naturalists will become aware in the future that nature is a whole and that the human is one of its components, among many others.

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