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Geoheritage

GEOHERITAGE, A NATIONAL INVENTORY IN FRANCE

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ABSTRACT

Good protection measures for geological heritage should begin with an inventory of geosites. In France, for example, a law enacted in 2002, grants formal recognition to the notion of geological heritage. An inventory and evaluation was then established on a region-by-region basis. By April 2007, the French Ministry of Environment launched the inventory program for the nation's geological heritage and the data are now being collected at a regional scale. The data are being gathered and homogenised, then transferred to the French National Museum of Natural History for examination. The ratified site data are stored and available for public use on a website (http://inpn.mnhn.fr) in a similar structure to natural data that are also processed and stored (flora, fauna, ecosystems, habitats). Today, protecting global heritage is understood as a dynamic process. Instead of placing objects beneath a display case, the conservation approach is now a more modern, active effort, which facilitates access for knowledge and research.

KEYWORDS: GEOHERITAGE, FRANCE, EUROPE, INVENTORY, GEOTOURISM, GEOSITES.

Introduction

For many years, the protection of “nature” was conducted for cultural reasons. A good example is the case of the Fontainebleau Forest. In 1836, artists, naturalists and hikers succeeded in preventing the cutting of old-growth trees, and the replacement of oak with pine, with the help of the Barbizon’s School of Painters (Jean-Baptiste Corot, Jean-François Millet, Théodore Rousseau, Jules Coignet, and others). And no later than 1861, the first nature reserve was created in the Forest, also for artistic reasons. This 1,097 hectares reserve represents one of the first nature reserves to be established in the world, predating Yellowstone National Park which was created in 1872. The former area also became a biological reserve in 1953.

Fig. 1 Barbizon’s school of painting: Ernest Cherot (1814-1883), “*Peintres sur le motif*”, oil/canvas (Millet museum, Barbizon, May 2012). Photo: P. De Wever

Over the past 30 years, conservation priority has clearly been directed towards biological heritage. The idea of natural heritage emerged in France with the 1976 law regarding the protection of nature, which officially established the concept of nature reserves.

In this paper we focus on the geological inventory process with a primary focus on France. A general review of geoheritage regulation in France will be described elsewhere.

I- Geological heritage

Unlike biological conservation, geological conservation has so far lacked a continuously-supported mechanism to recognize and justify the most important elements internationally, i.e. those of the greatest value to the science (Wimbledon, 1996).

What is geoheritage ?

"Si vous voulez converser avec moi, définissez vos termes" [*"If you wish to converse with me, first define your terms"*] ; Voltaire

The concept of heritage conservation arises from the perception of an external threat. It incorporates the recognition of an eventual threat to an object or a site due to community action, through an economic project or through the use of the resource, and notwithstanding natural threats. Consequently, geoheritage status should, ideally, not be decreed by an extra-local authority, but instead claimed by a local community or the state which has the legal responsibility.

The United Nations Educational, Scientific and Cultural Organization (UNESCO, 1972) considers 'natural heritage' as:

"(1) 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;

(2) 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;

(3) natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty."

The 1972 general conference of UNESCO further noted that natural heritage was increasingly threatened with destruction not only by the traditional causes of decay, but also by changing social and economic conditions which aggravate the situation with even more formidable phenomena of damage or destruction. It considered that:

"- deterioration or disappearance of any item of the natural heritage constitutes a harmful impoverishment of the heritage of all the nations of the world,

- the existing international conventions, recommendations and resolutions concerning natural property demonstrate the importance, for all the peoples of the world, of safeguarding this unique and irreplaceable property, to whatever people it may belong,

- parts of the natural heritage are of outstanding interest and therefore need to be preserved as part of the world heritage of mankind as a whole,

- in view of the magnitude and gravity of the new dangers threatening them, it is incumbent on the international community as a whole to participate in the protection of the natural heritage of outstanding universal value, by the granting of collective assistance which, although not taking the place of action by the State concerned, will serve as an efficient complement thereto, have decided that this question should be made the subject of an international convention."

An important site of natural heritage can be listed as a World Heritage Site by the World Heritage Committee of UNESCO. The UNESCO programme catalogues, names, and conserves sites of outstanding cultural or natural importance as part of a common heritage of humanity. As of 2014, there were 1,007 World Heritage Sites: 779 cultural, 197 natural and 31 mixed properties, in 161 countries.

The concept of Geoheritage considers all significant objects (i.e. *ex situ* geoheritage) and sites (*in situ* geoheritage) related to the Earth sciences, thus emphasising an interest in a 'memory' of planet Earth. Such objects have to be placed in their natural framework and often represent one or several geological phenomena, or be, to all intents and purposes 'unique', the 'first' described example, or simply the 'best'. The term 'geology; has a wide connotation and includes: palaeontology, mineralogy, tectonics, sedimentology, geomorphology, to name a few included disciplines. Quantifying Geoheritage aims to establish the legacy of geological objects and sites, as well as intangible attributes encompassing the natural environment, landscapes, and landforms which belong to the concept of geodiversity. Heritage is that which is *inherited* from past generations, maintained in the present and bestowed for the benefit of future generations. The term 'geoheritage' is, therefore, derived from 'geo-inheritance'. It is a less scientific term and may be more easily comprehended by a wider audience interested in geoconservation.

The conservation of geoheritage focuses on preserving those most valued and significant elements and sites, as there are numerous threats that need to be considered such as unsustainable specimen collecting, coastal erosion, quarrying or infill of disused quarries, vegetation overgrowth, urban extension and so on. The concept of *geoconservation* (the conservation of geoheritage) is a recent phenomenon in most countries, in contrast to France which has had protected natural sites since 1836 (see above) and specifically 'natural monuments' since 1930. In 1913 E.-A. Martel, advocate of the concept of National Park, published a list of important geological sites by county (Martel, 1913). In 1928, he completed his work by publishing *La France ignorée*, an inventory of remarkable sites containing descriptions and illustrations (Martel, 1928, 1932). Ultimately, National Parks were created in France in 1960 and specific geological reserves were first created in 1982 (Saucats-la-Brède) (Fig. 2).

During the past quarter century, efforts by many geologists can be credited with progressively gaining protection and recognition of several of the geological reserves that were proposed (Fig. 2). As a result of these activities, the '*International declaration of the rights of the memory of the Earth*' was written during a seminal international meeting held in Digne-les-Bains, Provence, in 1991 (Fig. 3).

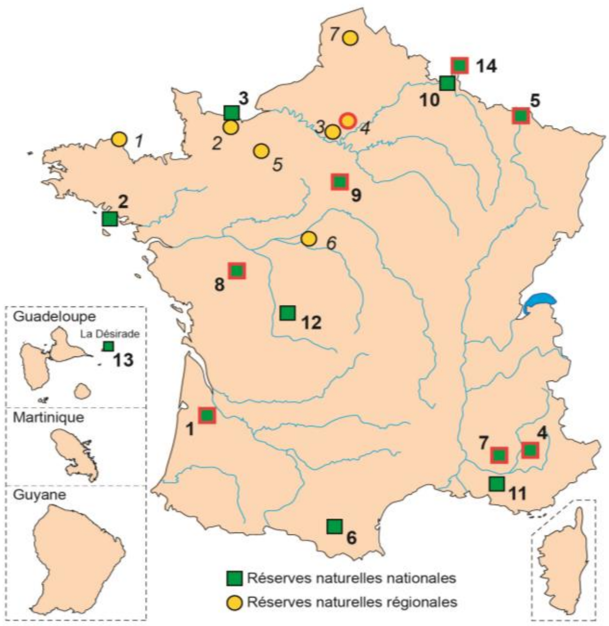

Fig. 2 Map of the reserves created for geological reasons in France. Those with a stratotype have a red border.

- Réserves naturelles nationales. 1) Saucats-La Brède (Aquitanian - Burdigalian). 2) François le Bail (Ile de Groix). 3) Falaise du Cap Romain. 4) Haute Provence (Barremian). 5) Hettange-Grande (Hettangian). 6) Grotte du TM 71. 7) Luberon (Aptian). 8) Thouars (Toarcian). 9) Sites géologiques de l'Essonne (Stampian). 10) Vireux-Molhain. 11) Sainte-Victoire. 12) Astroblème de Rochechouart-Chassenon. 13) La Désirade. 14) La Pointe de Givet: this reserve was not initially created for geological reasons, but it encloses the historical Givetian stratotype.

- Réserves naturelles régionales. 1) Sillon de Talbert. 2) Anciennes carrières d'Orival. 3) Site géologique de Limay. 4) Site géologique de Vigny-Longuesse. 5) Normandie Maine. 6) Pontlevoy. 7) Anciennes carrières de Cléty.

International declaration of the rights of the memory of the Earth

1 - Just as human life is recognized as being unique, the time has come to recognize the uniqueness of the Earth.

2 - Mother Earth supports us. We are each and all linked to her, she is the link between us.

3 - The Earth is 4,5 billion years old and the cradle of life, of renewal and of the metamorphosis of life. Its long evolution, its slow rise to maturity, has shaped the environment in wich we live.

4 - Our history and the history of the Earth are closely linked. Its origins are our origins, its history is our history and its future will be our future.

5 - The aspect of the Earth, its very being, is our environment. This environment is different, not only from that of the past, but also from that of the future. We are but the Earth's companion with no finality, we only pass by.

6 - Just as an old tree keeps all the records of its growth and life, the Earth retains memories of its past... A record inscribed both in its depths and on the surface, in the rocks and in the landscapes, a record which can be read and translated.

7 - We have always been aware of the need to preserve our memories - i.e. our cultural heritage. Now the time has come to protect our natural heritage, the environment. The past of the Earth is no less important than that of human beings. Now it is time for us to learn to protect, and by doing so, to learn about the past of the Earth, to read this book written before our advent: that is our geological heritage.

8 - We and the Earth share our common heritage. We and governments are but the custodians of this heritage. Each and every human being should understand that the slightest depredation mutilates, destroys dans leads to irreversible losses. Any form of development should respect the singularity of this heritage.

9 - The participants of the 1st internationl symposium on the protection of our geological heritage, including over a hundred specialists from over thirty nations, urgently request all national and international authorities to take into consideration and to protect this heritage by means of all the necessary legal, financial and organizational measures.

Written on the 13th June 1991 in Digne, France.

Fig. 3 The International declaration of the rights of the memory of the Earth (Digne-les-Bains, 1991)

The concept of biodiversity conservation and our need to protect biological heritage at local, national and global scales is well developed. The concept of geodiversity and geoheritage conservation, however, is less appreciated, although it is now beginning to develop some momentum. At a global level, a number of initiatives are now beginning to establish that geoheritage is an important element in our natural heritage and must be managed effectively.

The World Heritage Convention

The World Heritage Convention (1972) is unique in two respects. Firstly, it recognises both natural and cultural heritage, and secondly it provides a global mechanism for identifying and protecting important geological sites. The Convention promotes, at the global level, a wide range of geological heritage features– from small sites a few hectares in size to large areas within protected landscapes. There is considerable scope for developing new ideas and new ways of recognising outstanding geological and geomorphological heritage, and linking it with cultural and natural heritage values. To better understand how the World Heritage Convention might recognise geoheritage in the future, both in its own right and as a complement to other natural and cultural values, the International Union for Conservation of Nature (IUCN), the advisory body to the UNESCO World Heritage Committee on natural heritage, undertook a thematic study of the role of geology and geomorphology in the World Heritage Convention (http://whc.unesco.org/en/convention/).

The United Nations General Assembly proclaimed 2008 to be the International Year of Planet Earth and the effort was jointly initiated by the International Union of Geological Sciences (IUGS) and UNESCO. In its two latest sessions, the General Assembly of IUCN accepted that geodiversity, including geological and geomorphological diversity, is an important natural factor underpinning biological, cultural and landscape diversity (Resolutions WCC-2008-Res-040 and WCC-2012-Res-048: 2008 Barcelona: https://portals.iucn.org/library/efiles/documents/WCC-4th-005.pdf; 2012 Jeju: https://portals.iucn.org/library/efiles/documents/WCC-5th-005.pdf).

II- Socio-economic, socio-cultural dimensions of geoheritage

What we call geoheritage

Geology should be considered in a relationship with nature, culture and history - all of which permanently interact. Humans wish to understand the geographical, natural and socio-economic context in which they develop, and this cannot be successfully addressed in the absence of geosciences. Indeed the history of human-kind, animals, and plants is tightly connected with the Earth’s history. Landscapes, agricultural and commercial practices, including ancient industries, are all firmly dependent on the nature of the Earth (soil and bedrocks), and its resources. In today’s practices, local becomes global, and the effect of geology on the environment is also becoming global (natural resources, energy, water, etc) with natural hazards, pollution and climate change examples of such widespread impact.

What we term geoheritage here, are the geological features and sites with global, national, or local importance and that represent processes (magmatic segregation, metamorphism, dissolution, weathering, etc) or a testimony of the Earth's history (palaeontology, global tectonics, evidence of sea level change, etc). Geoheritage-related objects at any scale (country size to mineral size) are intrinsically or culturally important. They offer information or insights into the formation or evolution of the Earth, into the history of science, or can be used for research, reference, educational purposes or other societal purposes, such as artistic or spiritual inspiration.

Fig. 4. The famous ammonite slab in the Digne-lel-Bains geological reserve presents more than 1,500 ammonites, up to 70 cm in diameter, of Lower Sinemurian (Lower Jurassic) age, most belonging to *Coroniceras* ex grp. *multicostatum* (J. Sowerby). (Photo M.Guiomar, 2009)

What belongs to heritage?

We refer to heritage when we discuss items that belong to human-kind in a more global sense in contrast to 'patrimonial [i.e. heritage] value', when we refer to what is *selected*. Some objects, because their exemplarity or scarcity automatically belong to a 'geoheritage', such as the famous 'Ammonites slab' in the *Réserve géologique de Haute Provence* (Fig. 4) or some outcrops from South Morocco rich in Devonian orthocone nautiloids (Fig. 5).

Fig. 5. Limestone slabs rich in Palaeozoic orthocone nautiloids (Siluro-Devonian); South Morocco, Erfoud area. Photo: P. De Wever

Specimens from the latter region, however, are often assembled as composite slabs which include areas simply carved matrix. Geological objects such as this are sold in shops as artwork or ornamental material (and not as a geoheritage objects) and are intended to display beautiful fossils. Most geologists will recognise these pieces as being artificial and some artwork fossil 'designers' do clearly indicate in their shops that they design and make 'artificial' fossils (Fig. 6). When sold, such examples do provide an income for a local community, but the sustainability of the activity and potential danger to the geoheritage of the area is rarely considered.

Fig. 6. The wall of a shop clearly announcing what happens inside: "*fabrication des fossiles*" [= "fossil manufacturing"] (Erfoud, South Morocco). Photo: P. De Wever

Some objects, by themselves would not belong to heritage, but occasionally gain the status of heritage. By the end of the 20th century, microscopes had become popular and were therefore accessible as personal belongings. Some took this opportunity to create microscopic photographs of tiny objects or micro-organisms such as radiolarians, diatoms and scales of butterfly's wing (Fig. 7). Such images are original and are worthy of being part of our scientific heritage since they testify to a conjunction between the development of technology and private/personal interests and use. The way these microscope slides are mounted is called "*lutage à la tourette*" which indicates a method of protecting a small object using a thin coil of 'Judean pitch'. The tar is piped onto the slide as it rotates on a small stand, forming a perfect ring. This technique is no longer in practice so this technical testimony adds more value to the image itself.

Fig. 7. Two examples of micro-pictures: Lerft: Fountain with birds - a micro-picture made with the scales of butterfly wings (overall size: circa 1 to 2 mm). Right: A pink rosette constructed from hundreds of aesthetically arranged diatom shells. Photos: P. Loubry

Fig. 8A. Mounted slide with perfectly arranged radiolarians in the middle (grey, almost not visible) with a black coiled bituminous joint protecting them. Photo P. De Wever

Some objects are aesthetic on their own, carry a complementary testimony and hence gain heritage value: for instance, the models of a radiolaria made by German craftsmen as glassworker *chef d'oeuvres* (Fig. 9). This technique was developed by the German Leopold Blaschka (1822-1895) and later with his son Rudolf (1857-1939). Their work making spectacular glass models of natural history objects began in 1857. Each glass model is a unique blend of art.

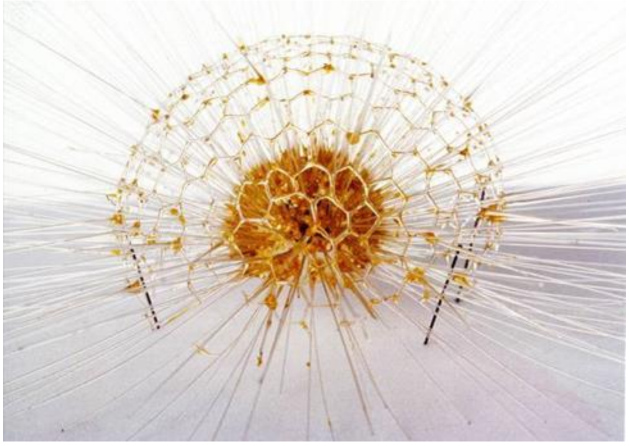

Fig. 9. Model radiolarian approximately 25 cm in diameter (the original organism is circa 0.2 mm). This art object testifies that the craftsman had to observe the original organism under a microscope and then manufacture the thin glassy spines to replicate the fossil structure. Blaschka glass artists.

Some objects have an aesthetic quality even if they do not justify being considered as a particular geoheritage of scientific value, such as the ‘*Pierre de rêve*’ (Fig. 10). But, when such a specimen is not isolated but rather belongs to a collection of tens of objects deposited in a museum and moreover when such specimens were gathered by famous individuals such as Roger Caillois (1913-1978), then the collection may in fact belong to a scientifically valued geoheritage. Caillois was well known for his passion for stone and wrote many poems about them (e.g. *Pierres* in 1966 and *L'Écriture des pierres* in 1970).

Fig. 10. An example of the Caillois collection of agates known as ‘*Pierres de rêve*’ (Dali Shi)

Some landscapes are interesting on their own, although they may not be worth registering on a specific geoheritage list, unless they are are also associated with complementary elements that provide a higher interest level. This is the case for instance for the Sainte-Victoire massif (Provence, France, Fig. 11). This massif corresponds to the front of an overthrust. It has been painted by several artists, especially Cezanne, who represented it in more than ten works and who further wrote: “*As I told you this morning, I need to know the geology, how Sainte-Victoire is rooting, the geologic colours of its earths, all this touches me, makes me better*”. In addition, however, Cretaceous red marls on its’ western flank are important for dinosaur eggs. The combination of these three elements contributes to an increase in geoheritage value.

Fig. 11. The Sainte-Victoire massif is the front of a southward overthrust (to the South, on the right). The stratification, almost horizontal on the upper part, is dipping on its front part and becomes almost vertical. This place is also famous because it was frequently painted by Paul Cézanne (Photo: P. De Wever)

A *geosite* is generally understood to be an exceptional geological place, geographically limited, with one or several geological elements with specific values for scientific, pedagogic, cultural or touristic interest (Brilha et al., 2005). Geosites are usually chosen on the basis of the opinions of experts with a relevant geological knowledge. Geological heritage is an important part of the world’s heritage, as it represents the unique record of the evolution of our planet, recorded in a large number of segments. Like a puzzle, these pieces only form a coherent picture when viewed collectively. Unfortunately, only a very limited number of pieces are accessible for human observation.

The term ‘geological heritage’ is often defined with the notion of ‘remarkable geological object’ that stands out due to its scientific, educational and historical value, its rareness, its exemplarity, its representativeness, its exceptional state of conservation and its aesthetic quality. Such remarkable geological objects of any size must benefit from *in situ* or *ex situ* protection and conservation. Today, protecting heritage is understood as a dynamic process: rather than placing the object beneath a display dome, the conservation approach is a modern, active one, facilitating access to knowledge or research.

How can we identify the most remarkable sites?

Geology encompasses a wide variety of topics and its scope in space and time is not always easy to comprehend. If one tries to label sites as ‘of international importance’, the consideration of priorities has to be fixed. There is no instant method for establishing these priorities, so a systematic approach is, therefore, a necessity. Several sets of data, well-directed and focused judgments are required before any decisions can be taken. It is easy to say that a site is special or unique, but it must also be established in an objectively identified process.

The French Ministry of Environment did not select a specific process framework in the initial phase of the French inventory programme despite the fact that such frameworks were recommended by ProGEO (this general process was, however, used for the Strategy to Create Protected Areas (*Stratégie de création d'aires Protégées* = SCAP) see section IV).

III- Which geodiversity is there in France?

The French territory encompasses over 550,000 km². The total national area, including overseas territory, represents 675,417 km². The latter territories are located in South America (Guyana), the Atlantic Ocean (Antilles: Guadeloupe, Martinique, Saint-Martin and Saint-Barthélemy; Saint-Pierre-et-Miquelon), the Pacific Ocean (French Polynesia, New-Caledonia, Wallis-et-Futuna and Clipperton); the Indian Ocean (La Réunion, Mayotte, Éparses Islands, Crozet islands, Kerguelen Islands and Saint-Paul-et-Amsterdam) and finally in Antarctica (la Terre Adélie).

The geodiversity (from which a geoheritage can be identified and extracted) of a country can be viewed, at a first glance, through a geological map. Detailed topographic maps, therefore, also bear witness of the geological richness by their content and by the patterns of their contours and other mapped features. Herein, we review the relevance and impact of maps in France given their influence on the subsequent geoheritage characterisation of the country.

The first geological maps

The first map with a global presentation of geology resulted from the desire to establish an inventory of mineral resources of France. The result was a topographical map covered with symbols. This map, signed by Guettard, Lavoisier and Monnet was finished in 1767 and published in 1780. The 1780 map, however, was preceded by a true geological map with contours drawn by Jean-Etienne Guettard, a naturalist who was supported by the Duc d’Orléans. He presented this first sketch of a map under the name “*Carte minéralogique sur la nature du terrein d’une portion de l’Europe*” in 1746 (Fig. 12). This map has no true chronological precision, but nevertheless displays the correlation and the continuity of rock bodies on each side of the Channel as it shows an essentially hypothetical continuation of deposits of sandy, marly and shaley beds from the Parisian to the English basins.

Fig. 12. "*Carte minéralogique sur la nature du terrein d'une portion de l'Europe'* (Jean-Etienne Guettard, 1746). The great novelty of this publication is the hypothetical continuation of strata on each side of the Channel. The author differentiates three main stripes (sandy, marly and shaley) which generally correspond to Cenozoic, Mesozoic and Palaeozoic rocks.

Although William Smith's well known geological map of 1815 of England and Wales was the first *national* geological map to be published in colour, it "…*was neither the first geological map of the 19th Century nor the first to show an ordering of the strata and to make use of the accompanying ordering of their fossil contents. Smith's Paris rivals, Georges Cuvier and Alexandre Brongniart published such a "Geognostique" map of the Paris Basin in 1808, seven years before Smith's map and republished it in 1811 and again in 1822"* (Schneer, 1954 - although the 1808 publication did not include a map) (Fig. 13). Later important geological maps of French territories include those published by Jean-Baptiste Julien d'Omalius d'Halloy (Fig. 14) which first coversed fpart of France (1816) and then all France with a part of Belgium, of Germany, of Switzerland and of Italy (1822). Although at the beginning of the nineteenth century, progress in mapping was already represented by contour details andthe use of colour, the concept of a geological map had actually been discussed by Martin Lister in 1684.

Fig. 13. 'Geognostic' map of the Paris basin, from Cuvier and Brongniart, dated as 1810 and printed in 1811. It covers circa 120 km (NS) x 150 km (EW).

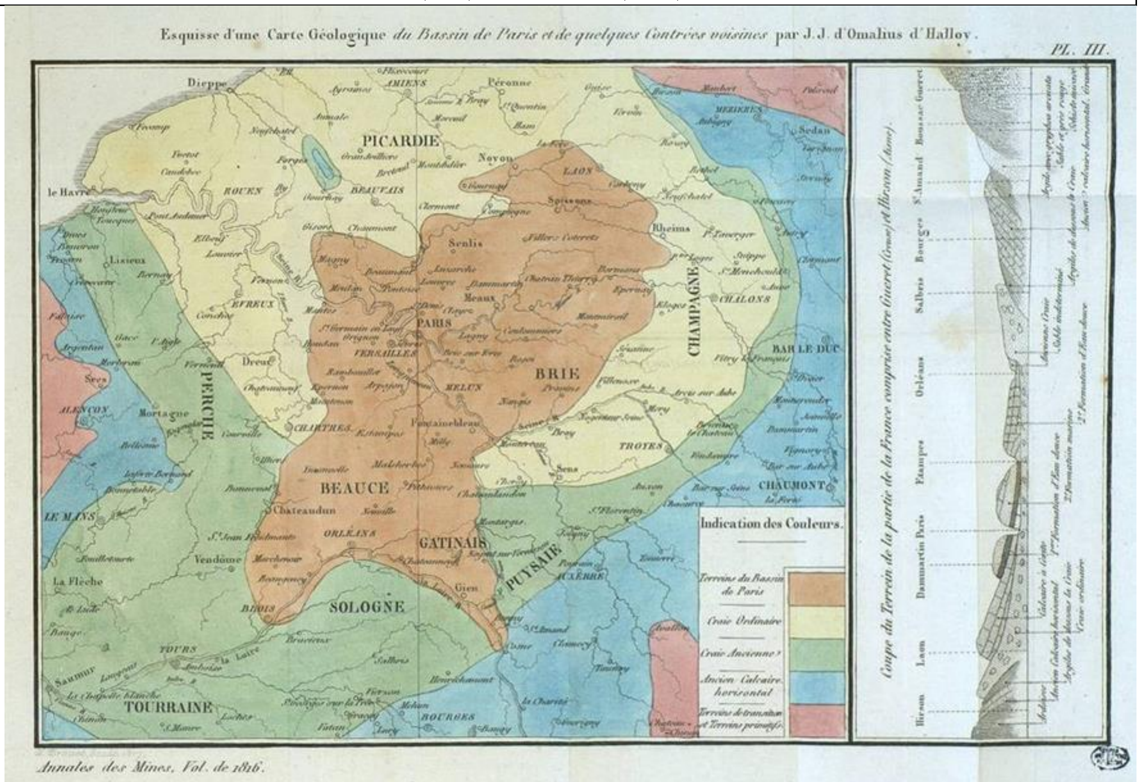

Fig. 14. Geological map of the Paris basin '*Carte géologique du bassin de Paris et de quelques contrées voisines*' by d'Omalius d'Halloy (1816). This map demonstrates clearly, for the first time, the famous rings (Jurassic = blue, Cretaceous = green and 'Tertiary' = orange) around the basin. It also displays the first synthetic cross section of this basin with stacked strata (Doc. MNHN Central Library)

Following Guettard's map, it seems that colour appeared on maps in Germany in circa 1770 (with Gläser 1775 and Charpentier 1778). The Belgian Omalius d'Halloy used a set of colours for his map of the Paris basin (1816). On this map he used a pink-red colour for basement, blue for the ‘old limestone’, green for ‘old chalk’; pale yellow for the ‘ordinary chalk’ and orange for ‘Parisian terranes’ (which corresponds to the Cenozoic’). If we question the reason for these colours, it appears that the decision was likely to have been led by the colours of the rock themselves. Indeed, when limestone cliffs are seen in the countryside they seem to be bluish. At that time the most representative limestone strata were those of the Jura Mountains. These deposits were therefore represented in blue and now represent the Jurassic. In the Paris basin, overlying the Jurassic limestone is a green sand (due to a richness in glauconite) which is quite well known since it supports one of the most important aquifers. These deposits were therefore represented as green and later more generally representing the Cretaceous. More recent sediments in the Paris basin are mainly represented by light sand (white to yellow): hence these colours were used for the Cenozoic. Initially, the colours represented lithology since the first uses of geologic maps were for exploration for natural resources. A homogenization of colours began setting in between 1830 and 1860 with the publication of new maps (Fig. 15 and Fig. 16). Scientific organisations subsequently worked out a consistent scheme of colours to use for maps, including internationally.

Fig. 15. J.J. d’Omalius d’Halloy’s map dated as 1822. It does not appear familiar as a geological map since the colours are not the same as those used today- here for instance the green colour corresponds to the Triassic and Jurassic.

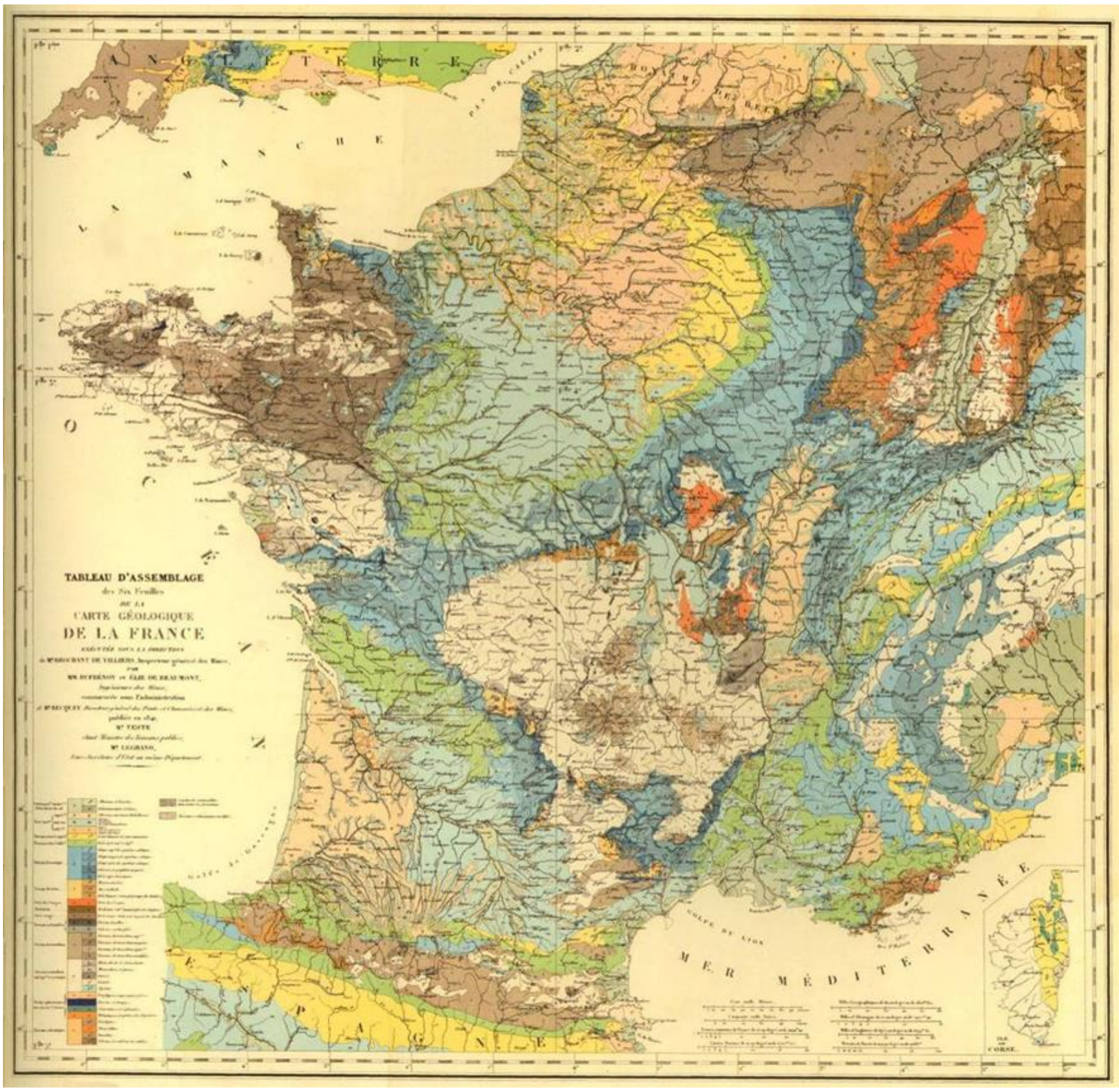

Fig. 16. The Dufrénoy and Elie de Beaumont, dated 1841. This map appears familiar as a geological map since the colours are close to those used today (although the basement is not generally represented by light to dark browns). On this map the subdivisions are henceforth clearly made on age rather than lithology.

On geological maps, colours, therefore can have an international meaning: blue for Jurassic, green for Cretaceous, yellow for Cenozoic, and so on. The history of selection for these colours is not simple, however, butthey remain quite simple in their intent. The first coloured map of the Paris basin (Fig.14) and the one of France (Fig.16) are familiar to our eyes since the colours are close to those used today. On these maps, Jurassic is blue because the limestone displays such a grey-blue tint. Cretaceous is green because of the importance of the Albian glauconite-sands and the Cenozoic is yellow because the sands are often yellow-orange coloured. Later, Triassic was represented as pink-violet, because it is characterised by the red bundsandstein, and the Palaeozoic darker as brown. The Carboniferous with its abundant coal, is shown as dark grey. As one can imagine, the acceptance of these colours has been strongly and widely discussed. This was more specifically the case during the second international geological congress in Bologna, in 1881 (Capellini G. 1882). Some countries would have preferred a variation from the three main colours: red, blue and yellow. Others favoured variation on the theme of the colours of the rainbow. Debate was sustained by imagination, as well as practical or national reasons but the fact remains that the strength of usage seemed to play an important role.

Some testimonies of the geoheritage in France

The geodiversity and geoheritage of France is quite remarkable. The main geological objects and sites are well represented: old massifs (Armorican Massif, Ardennes, Massif Central, Saint-Pierre et Miquelon) and more recent folded belts (Alps, Pyrenees, Caledonian Alps), insular arcs (Antilla), hot spots (La Réunion), large igneous Provinces (Kerguelen); large sedimentary basins (Paris Basin, Aquitanian and SE basins), graben basins (Alsace, Limagne). The territory also provides testimony of a history spread over 2 billion years. Geological phenomena such as volcanism (present and past, mid oceanic or intraplate, extensional or compressional), metamorphism, erosion, transport, and sedimentary deposits are well represented. All types of rocks are present (deeply formed, sediments, volcanic, metamorphic, etc.).

There are currently numerous international references on the national territory. Some rocks or minerals keep the name of their origin (Table 1 and 2), or the name of a French geologist/mineralogist (Table 3). This is also true for selected names of the geological time scale (Table 4).

Table 1. Selected rocks (lithotypes) with a name based on a French locality or French geologist.

Rock	**Toponym**	**Remark**
Ariegite	Ariège department	A variety of pyroxenolite
Avezacite	Avezac-Prat, Pyrenees	A variety of hornblendite
Cantalite	Verrières, Cantal, Massif Central, Plomb du Cantal	A variety of trachyandesite
Corsite	Santa Lucia di Tallano, near Sartène, Corsica	Orbicular gabbro = Napoleonite
Domite	Puy-de-Dôme, Massif Central	A variety of trachyte
Doreite	Mont-Dore, Massif Central	A variety of trachy-andesite
Esterellite	Boulouris, Esterel Massif	A variety of microdiorite
Evisite	Evisa, Corsica	A varieties of granite
Florinite	Sainte-Florine, Massif Central	A variety of theralite
Fraidonite	Fraidon, in Normandy or Cévennes	A variety of kerssantite
Kersantite	Kersanton (near Brest), Brittany	A variety of lamprophyre. Used to build the famous Breton Calvary.
Lherzite	Lherz pond, Pyrenees	Hornblendic dykes
Lherzolite	Lherz pond, Pyrenees	A variety of peridotite
Lindinosite	Lindinosa, Evisa, Corsica	A variety of granite
Luscladite	Lusclade, Mont-Dore, Massif Central	A variety of theralite
Mareugite	Mareuge, Mont-Dore, Massif Central	A variety of theralite
Miagite	Miage glacier, Mont-Blanc, Alps	A variety of orbicular gabbro
Napoleonite	Santa Lucia di Tallano, near Sartène, Corsica	Orbicular gabbro = Corsite
Oceanite	Piton de la fournaise, La Réunion island	A variety of basalt
Ordanchite	La banne d’Ordanche, Massif Central	A variety of theralite
Ouenite	Ouen island, New Caledonia	A variety of gabbro
Peleite, peléeite	Pelée mountain ; Martinique	A variety of basalt
Pyromeride	Mont Vinaigre, Esterel Massif	A variety of rhyolite
Sancyite	Puy de Sancy, Massif Central	A variety of trachyandesite
Tahitite	Papenoo, Tahiti, Polynesia	A variety of syenite
Vaugnerite	Vaugneray (near Lyon)	A variety of syenite
Vogesite	Grendelbruch, Vosges mountains	A variety of andesite
Vosgesite	Vosges mountains	A variety of lamprophyre
Rock	**Patronymic**	**Remark**

Hauynite, hauynitite	René-Just Haüy (1743-1822), pioneer in crystallography	A variety of basanite rich in haüyne
Blavierite	Edouard Blavier	A variety of rhyolite

Table 2. Selected minerals with a name based on a French locality.

Mineral	**Toponym**	**Remark**
Ardennite	Ardennes Mountains	Occurs in pegmatites and quartz veins in schist and in magnesium sediment rich in aluminium
Autunite	L'Ouche de Jau, St. Symphorien, and other places near Autun, Saône-et-Loire, France	Secondary mineral associated with uraninite
Bauxite	Baux (or Beaux), near St. Rémy, Bouches-du-Rhône	Outcomes of granite alteration in tropical climates
Bourboulite	La Bourboule, Mont-Dore Massif, Puy-de-Dôme, Auvergne	
Capgaronnite	Cap Garonne Mine	Occurs in copper-lead mines within cavities, in Triassic conglomerates and sandstone
Carboirite	Carboire, Ariège, Midi-Pyrénées	Germanium mineral which occurs in metamorphic zinc deposits of the French Pyrenees
Chabournéite	Chabournéou Glacier, near Jas Roux, Pelvoux Mt., Valgaudemar, Hautes-Alpes, Provence-Alpes-Côte d'Azur	Jas Roux deposit in dolomitic limestone, Hautes-Alpes
Chaméanite	Chaméane Uranium deposit, Chaméane, Sauxillanges, Puy-de-Dôme, Auvergne	Late stage deposit in veins cutting granite
Chessylite	Chessy-les-Mines (near Lyon)	‘the blue mine ‘
Compreignacite	Margnac-en-Compreignac mine, Haute-Vienne, Limousin	A very rare oxidation product of pitchblende in uranium deposits
Fougèrite	Fougères Forest, Ille-et-Vilaine, Brittany	(a ‘green rust’ see also Trebeurdenite
Guyanaite	Merum river, Kamakusa, Mazarumi district, French Guiana	
Hureaulite	Village of les Hureaux, Haute Vienne, Limousin	Occurs in pegmatite and granite
Ménilite	Ménilmontant, Paris	A variety of opal, used as a very specific white pigment by Vincent Van Gogh
Montdorite	Mont-Dore, Charlannes, La Bourboule, Rochefort-Montagne, Puy-de-Dôme, Auvergne	A variety of mica
Montebrasite	Montebras Mine, Montebras-en-Soumans, Boussac, Creuse, Limousin	Occurs in pegmatites rich in lithium
Montmorillonite	Montmorillon, Vienne, Poitou-Charentes	A variety of smectite
Nontronite	Nontron, Dordogne, Aquitaine	A variety of smectite
Plombièrite	Plombières-les-Bains, Vosges, Lorraine	A gelatinous substance which hardens in air, formed from thermal water
Ranciéite	Le Rancié Mine, Vicdessos, Ariège, Midi-Pyrénées	Formed in cavities in limonite
Romanéchite	Romanèche, Saône-et-Loire	Manganese deposits
Rosiéresite	Rosières, Carmaux, Tarn	Comes from an abandoned copper mine
Trébeurderite	Trébeurden, Côte d’Armor	Nitrate destructive (could be used to solve the bloom of green algae in Brittany)
Trimounsite	Trimouns, municipality of Luzenac, Ariège	Rare earth titanosilicates
Vosgite	Cernay, Haut-Rhin, Vosges	An altered plagioclase

Table 3. Selected minerals with a name based on a French patronymic.

Mineral	Patronymic	Remarks
Adamite	G.-J. Adam (1795-1881), mineralogist, who supplied the first specimen	A secondary mineral found in zinc deposits containing arsenic-bearing minerals
Agardite	Jules Agard (1916-2003), geologist, BRGM, Orleans	A rich rare-earth mineral
Agriniérite	Henri Agrinier (1928-1971), engineer in the Mineralogy Laboratory of the French Atomic Energy Commission	Magnac mine, Compreignac, Haute-Vienne, Limousin, topotype in Ariège
Alluaudite	François Alluaud (1778-1866), mining engineer of Limoges, who discovered the mineral	The discovery of the mineral is disputed: maybe this mineral was named by Alexis Damour in honour of François Alluaud
Asselbornite	Eric Asselborn (b.1954), mineral collector and surgeon, Montrevel-en-Bresse, Dijon, in whose collection the mineral was first found	Radioactive mineral
Aubertite	J. Aubert (b.1929), French geophysicist who collected the first specimens	Comes from an oxidized zone of a copper deposit in Chile
Bariandite	Pierre Bariand (b.1933), mineralogist	Comes from an oxidized zone of uranium or vanadium deposit
Barrandite	Joachim Barrande (1799-1883), geologist	Synonym of strengite and variscite
Barroisite	Charles Barrois (1851-1939). Geologist, Lille University	A variety of amphibole
Beaumontite	Leonce Elie de Beaumont (1798-1874), Geologist	Synonym of heulandite
Becquerelite	Antoine Henri Becquerel (1852-1908), chemist and physicist who discovered radioactivity in 1896	Radioactive mineral
Behierite	Jean Behier (1903-1965), mineralogist, who found the mineral in 1959	Occurs in pegmatite
Berthierine	Pierre Berthier (1782-1861), chemist/mineralogist, who discovered the bauxite mineral	A variety of serpentine, topotype in Hayange, Meurthe-et-Moselle
Berthierite	Pierre Berthier (1782-1861), chemist and mineralogist, who discovered the bauxite mineral	Topotype in Chazelles-Haut, Mercoeur, Haute-Loire, Auvergne
Bertrandite	Emile Bertrand (1844-1909), mineralogist	Topotype near the town of Nantes, France
Beudantite	François Sulpice Beudant (1787-1850), mineralogist, University of Paris	A secondary mineral occurring in oxidized zones of polymetallic deposit
Biotite	Jean-Baptiste Biot (1774-1862), physicist who studied the optical properties of the mica	A variety of mica, occurs in granitic rocks
Boulangérite	Charles Louis Boulanger (1810-1849), a mining engineer.	Topotype in Molières, Gard, Languedoc-Roussillon, easily confused with Jamesonite
Bournonite	Count Jacques Louis de Bournon (1751-1825), crystallographer and mineralogist.	Contains Pb, Cu, Sb, and S
Boussingaultite	Jean-Baptiste Boussingault (1802-1887), chemist, Lyon University	A variety of picromerite
Brochantite	André Jean Marie Brochant de Villiers (1772-1840), geologist and mineralogist	Secondary mineral, formed in arid climates or in rapidly oxidizing copper sulphide deposits
Carnotite	Marie-Adolphe Carnot (1839-1920), chemist	A radioactive mineral
Cassedanneite	Jacques.P Cassedanne (b.1928), mineralogist, University of Rio de Janeiro	Occurred on a museum sample from the oxidized zones of gold-bearing quartz vein, Russia
Cesbronite	Fabien Cesbron (1938-), mineralogist, Orléans	Located in Bambollita mines, Sonora, Mexico in which two thin veins are exposed and cesbronite occurs in only one, in small quantities (some grams)
Chenevixite	Richard Chenevix (1774-1830), chemist, analyst of an arsenate of copper and iron from Cornwall in 1801 (later shown to be Chenevixite).	An uncommon secondary mineral in the oxidized zone of hydrothermal polymetallic mineral deposit

Chervetite	Jean Chervet (1904-1962), mineralogist.	Comes from an uranium mine in Gabon
Claudetite	F. Claudet, French chemist, who first described the natural material.	Produced as a sublimate during mine fires
Coquandite	Henri-Jean-Baptiste Coquand (1813-1881), Professor of Geology and Mineralogy	This mineral is the third naturally occurring antimony oxy-sulphate known
Cordierite	Pierre Louis A. Cordier (1777-1861), mining engineer and geologist, who first studied this species, National Museum of Natural History, Paris	Occurred in magmatic, metamorphic and pegmatitic rocks
Cumengéite	Edouard Cumenge (1828-1902), a mining engineer who worked in the Boleo mines, Mexico	It is an extremely rare mineral which occurs in oxidized zones of sedimentary copper ores associated with boleite
Curienite	Hubert Curien (1924-2005), mineralogist and crystallographer	Comes from an uranium and vanadium mine in Gabon
Curite	Pierre Curie (1859-1906), physicist who discovered radioactivity, radium and polonium with his wife Marie Curie	Radioactive mineral
Damourite	A. Damour (1808-1902), mineralogical chemist	A variety of muscovite
Daubréite	Gabriel Auguste Daubrée (1814-1896), mineralogist and geologist, who worked extensively with meteorites, National Museum of Natural History, Paris	Occurs in the oxidization zone of a bismuth deposit, Constancia mine, Bolivia
Daubréelite	Gabriel Auguste Daubrée (1814-1896), mineralogist and geologist, who worked extensively with meteorites, National Museum of Natural History, Paris	Found in small amounts in many meteorites
Delafossite	Gabriel Delafosse (1796-1878), mineralogist and crystallographer	Principally a secondary mineral which occurred near the base of the oxidized zone ofcopper deposits
Deloryite	Jean-Claude Delory (b.1953), mineral collector and land surveyor, who collected the first specimen	Cap Garonne Mine, Le Pradet, Var, Provence-Alpes-Côte d'Azur
Dervillite	Henri Derville, palaeontologist, Strasbourg University, who noted the original specimen	Found on a museum specimen from Gabe Gottes Mine, Ste Marie-aux-Mines, Haut-Rhin, Alsace
Descloizite	Alfred des Cloizeaux (1817-1897), mineralogist who first described the mineral	A secondary mineral often found in the oxidation zones of base metal deposits
Despujolsite	Pierre Despujols (b. 1888), founder of the Moroccan Geologic Survey	Hydrothermal manganese deposit
Devilline	Henri-Etienne Sainte-Claire Deville (1818-1881), chemist	Rare and unusual secondary mineral found in the oxidized portions of copper sulphide ore deposit
Dolomite	Déodat Gratet de Dolomieu (1750-1801), mineralogist and geologist, National Museum of Natural History, Paris. A character, who inspired several authors in literature (de Laclos …)	Dolomsite is a rock, andDolomites are mountain ranges in N. Italy
Dufrénite	Ours-Pierre- Armand Dufrénoy (1792-1857), mineralogist	Anglar, Haute-Vienne, Limousin
Dumortierite	M. Eugène Dumortier (1802-1873), palaeontologist	Ducare’s Quarry, Chaponost, Beaunant, Rhône-Alpes, used for the manufacture porcelain
Dussertite	Désiré Dussert (1872-1928), mining engineer who worked in Algeria	Product of arsenopyrite alteration
Ellenbergerite	François Ellenberger (1915-2000), geologist, founder of the French Comity for thehistory of geology (COFRHIGEO)	Occurs as inclusions in pyrope porphyroblasts
Faujasite	Barthélemy Faujas de Saint-Fond (1741-1819), 1st professor of geology at the National Museum of Natural History, Paris	It occurs as a rare mineral in several locations worldwide and is synthesized industrially
Fischesserite	Raymond Fischesser (1911-1991), mineralogist and crystallographer, former director of the National School of Mines, Paris	No particular remarks
Fontanite	François Fontan, mineralogist, University of Toulouse	A rare secondary mineral from the Rabejac uranium deposit, near Lodève, Hérault, France

Friedelite	Charles Friedel (1832-1899), chemist and mineralogist	Montagne d'Azet, Adervielle, Hautes-Pyrénées, France
Fluckite	Pierre Fluck, mineralogist at Strasbourg University, who discovered the first specimen of the species	Gabe-Gottes mine, Saintes-Marie-aux-Mines, Haut-Rhin, Alsace
Garniérite	Jules Garnier (1839-1904), geologist who discovered this ore	It is a generic name for a green nickel ore
Gatelite	Pierre Gatel, founder president of the « Association Française de Microminéralogie » (AFM)	Trimouns talc deposit, Luzenac, Ariege, French Pyrenees
Gaudefroyite	Abbe Christophe Gaudefroy (1888-1971), mineralogist	An uncommon hydrothermal mineral in manganese deposits
Gaylussite	Louis Joseph Gay-Lussac (1778-1850), chemist and physicist	It is an unstable carbonate mineral which dehydrates in dry air and decomposes in water
Geffroyite	Jacques Geffroy (1918-1993), metallurgist at the French Atomic Energy Commission	Chaméane Uranium Deposit, Chaméane, Sauxillanges, Puy-de-Dôme, Auvergne
Giraudite	Roger Giraud, electron microscopy engineer, CNRS, Orleans	Chaméane Uranium Deposit, Sauxillanges, Puy-de-Dôme, Auvergne
Gonnardite	Ferdinand Gonnard (1833-1923), mineralogist	La Chaux de Bergonne, Saint-Germain-Lembron, Puy-de-Dôme, Auvergne
Gorceixite	Claude-Henri Gorceix (1842-1919), mineralogist and founder of the Mining School in Ouro Preto, Brazil	Secondary mineral, variety of phosphate
Grandidierite	Alfred Grandidier (1836-1921), naturalist and explorer, an authority in Madagascar	A rare accessory mineral which occurs in pegmatite, gneisses, aplites, xenoliths
Grunerite	Louis Emmanuel Gruner (1809-1883), Swiss-French chemist, who first analysed it.	Sarvengude ravine, Collobrières, Var, Provence-Alpes-Côte d'Azur
Guarinoite	Cap Garonne Mine, Le Pradet, Var, France. From a French collector : André Guarino	Belongs to the green rust family
Guerinite	Henri Guerin [1906-], French chemist who synthesized the compound.	A recent weathering product in oxidized arsenic-rich mineral deposit
Guettardite	Jean-Etienne Guettard (1715-1786), naturalist	Low temperature hydrothermal origin, in marble
Guilleminite	Claude Guillemin [1923- 1994], chemist and mineralogist, co-founder of the International Mineralogical Association.	It is an hydrated selenite of uranium and barium: it is the first mineral of natural selenite found
Haüyne	René Just Haüy (1743-1822), pioneer in crystallography	A variety of feldspathoid
Hibonite	Paul Hibon, prospector who discovered this mineral	Radioactive mineral, present in meteorites
Hocartite	Raymond Hocart (1896-1983), professor of mineralogy at the University of Paris	A variety of stannite
Krautite	François Kraut (1907-1983), mineralogist, National Museum of Natural History, Paris. He proved the meteoric origin of the Rochechouart crater.	Found on a mineral specimen from the Museum which comes from the famous gold ore of Sacarimb (Nagyag) in Romania.
Lacroixite	After Alfred Lacroix (1863-1948), mineralogist. National Museum of Natural History, Paris	Occurred in druses in granite
Laffittite	Pierre Laffitte (b.1925), director of the National School of Mines, Paris	Jas Roux, Pelvoux Mt., Valgaudemar, Hautes-Alpes, Provence-Alpes-Côte d'Azur
Laforêtite	Claude P. Laforêt (b. 1936), metallographer who first observed the mineral at the Montgros Mine.	Pinols, Haute-Loire, Auvergne
Laumontite	Gillet de Laumont (1747-1834), mineralogist who discovered it	Secondary mineral in basalt and andesite
Moissanite	Henri Moissan (1852-1907), chemist	Encountered in samples of lunar meteorites
Morinite	E.A Morineau, Director of the tin mine at Montebras who supplied the first specimen	Montebras Mines, Montebras, Soumans, Creuse, Limousin
Natrodufrénite	Ours-Pierre- Armand Dufrenoy (1792-1857), mineralogist and geologist. Co-author of one of the first geological maps of France	Rochefort-en-Terre, Morbihan
Offretite	Albert Offret (1857-1933), mineralogist and professor of the faculty of Sciences, Lyon	Mont Simiouse, near Montbrison, Loire
Orcelite	Jean Orcel, (1896-1978), mineralogist and professor of	

	the National Museum of Natural History, Paris	
Parapierrotite	Roland Pierrot (1930-1998), mineralogist	Jas Roux, Hautes-Alpes,
Permingeatite	François Permingeat (1917-1988), mineralogist, university of Toulouse	A product of hydrothermal mineralization
Picotite	Baron Philippe Picot de Lapeyrouse, mineralogist, founder of Toulouse Natural History Museum	A dark brown variety of spinel containing chromium and iron
pierrotite	mineralogist, Roland Pierrot (1930-1998), mineralogist	Jas Roux, Pelvoux Mt., Valgaudemar, Hautes-Alpes
Pisanite	Félix Pisani (1831-1920), chemist and minerals dealer	A variety of melanterite
Proustite	Joseph Louis Proust (1754-1826), chemist	One of the ruby silver ores
Rameauite	Jacques Rameau (1926-1960), French prospector who discovered the deposit where the mineral was found.	Margnac uranium deposit, Compreignac, Haute-Vienne, Limousin
Roméite	Jean Baptiste Romé de l'Isle (1736-1790), eminentcrystallographer	An accessory mineral in metamorphosed manganese ores
Roquesite	Maurice Roques, geologist, university of Clermont-Ferrand	Charrier, Allier, France
Roubaultite	Marcel Roubault (1905-1974), geologist, university of Nancy. Pioneer and organizer of uranium exploration in France	Comes from the oxidation zone of the uranium deposit, Shinkolobwe, Congo
Routhierite	Pierre Routhier (1916-2008), professor of economic geology	Jas roux, Pelvoux Mt., Valgaudemar, Hautes-Alpes
Sabatierite	Germain Sabatier (b.1923), mineralogist, formerhead of Orleans's CNRS	Formed in calcite veins
Sainfeldite	Paul Sainfeld (b.1916), mineralogist of the Musée de Minéralogie, Mines School, Paris, who discovered the mineral	Gabe Gottes mines, Sainte-Marie-aux-Mines, Haut-Rhin, Alsace
Schubnelite	Henri J. Schubnel (b.1935), mineralogist and gemmologist, National Museum of Natural History, Paris	Discovered at the base of the oxidized zone of a uranium deposit, Mounana mine, Gabon
Sénarmontite	Henri Hureau de Sénarmont (1808-1862), Mineralogist, School of Mines, who first described the species.	Comes from oxidation of antimony minerals
Thenardite	Louis JacquesThénard (1777-1857), professor in chemistry, University of Paris	Non-marine evaporite from arid climate deposit
Thérèsemagnanite	Thérèse Magnan for her contributions to knowledge about the Cap Garonne mine, Var (France).	From Cap Garonne Mine, Le Pradet, Var, Provence-Alpes-Côte d'Azur
Vauquelinite	Louis Nicolas Vauquelin (1763-1829), Chemist, discoverer of chromium.	A rare mineral of the oxidized zones of hydrothermal base-metal deposits
Vesignéite	Louis Vésigné (1870-1954), mineral collector, former president of the Mineralogical Society of France	A rare secondary mineral found as geodes in Mg ore in Germany
Villiaumite	Maxime Villiaume, traveller who investigated the islands of Los, former French Guinea, where this mineral was discovered	A variety of halite
Weilite	René Weil (b.1901), professor of mineralogy, University of Strasbourg, known for his study of Alsatian minerals	Rare arsenate mineral, occurs in the oxidized zone of the arsenic-bearing hydrothermal veins
Wurtzite	Charles A. Wurtz (1817-1884), French chemist	
Wyartite	Jean Wyart (1902-1992), Professor of Mineralogy, Sorbonne University, Paris	A radioactive mineral

France possesses more than 40 historical stratotype sites and has a great variety of paleontological and mineralogical sites.

Table 4. Selected French stratotypes. Some of the names are still in use, whereas others are obsolete or have a more local value. Others are currently no longer in use, including Suessonian (d'Orbigny 1852), Parisian (d'Orbigny 1852), Rauracian (Greppin 1867), and Argovian.

* Although the Danian was established primarily in Denmark, sites at Vigny (Val d'Oise) and Laversines (Oise) were defined as co-stratotypes (Desor 1847).

The colours used are approximately those of the standard French geological time scale.

Stages	***Origin***	***Author***
RUSCINIAN	*Ruscino***,** Latin name of Perpignan – Pyrénées orientales	Fahlbusch, 1976
REDONIAN	*Condate Redonum* – Latin name ofRennes-, Ille-et-Vilaine	Dollfus, 1906
BURDIGALIAN	*Burdigala* [Roman name of Bordeaux], Aquitaine	Depéret, 1892
AQUITANIAN	Aquitaine	Mayer-Eymar, 1858
ASTARACIAN	Astarac, part of the Gers department	Fahlbusch, 1976
ORLEANIAN	Orléans, Loiret	Ginsburg, 1975
AGENIAN	Agen, Lot-et-Garonne	Fahlbusch, 1976
STAMPIAN	*Stampae* [Latin name ofEtampes], Essonne	d'Orbigny, 1852
SANNOISIAN	Sannois, Val d'Oise	Munier-Chalmas et de Lapparent, 1893
LUDIAN	Ludes, Marne	Munier-Chalmas et de Lapparent, 1893
MARINESIAN	Marines, Val d'Oise	Dollfus, 1907
AUVERSIAN	Auvers-sur-Oise, Val d'Oise	Dollfus, 1880
BIARRITZIAN	Biarritz, Pyrénées-Atlantiques	Hottinger et Schaub, 1960
LUTETIAN	*Lutetia* [Latin name ofParis]	de Lapparent, 1883
CUISIAN	Cuise-la-Motte, Oise	Dollfus, 1880
SPARNACIAN	*Sparnacum* [Latin name of. Epernay], Marne	Dollfus, 1880
DANIAN	From Denmark*	Desor, 1846
GARUMNIAN	*Garumna* [Latin name of. Garonne], Haute-Garonne	Leymerie, 1862
VITROLLIAN	from Vitrolles, Bouches-du-Rhône	Matheron, 1878
ROGNACIAN	Rognac, Bouches-du-Rhône	Villot, 1883
BEGUDIAN	La Bégude [locality], Bouches-du-Rhône	Villot, 1883
FUVELIAN	Fuveau, Bouches-du-Rhône	Matheron, 1878
VALDONNIAN	Valdonne [locality], Bouches-du-Rhône	Matheron, 1878
CAMPANIAN	Champagne, Charente	Coquand, 1857
SANTONIAN	Saintes, Charente-Maritime	Coquand, 1857
CONIACIAN	Cognac, Charente	Coquand, 1857
SENONIAN	Sens, Yonne ; from the Gallic tribes of Sénones	d'Orbigny, 1842
TURONIAN	Tours, Indre-et-Loire	d'Orbigny, 1842
CENOMANIAN	*Cenomanum*,[Latin name ofLe Mans], Sarthe	d'Orbigny, 1847
ALBIAN	from *Alba*, Aube river, Aube	d'Orbigny, 1842
CLANSAYESIAN	Clansayes, Drôme	Breitstroffer, 1947
GARGASIAN	Gargas, Vaucluse	Kilian W., 1887
BÉDOULIAN	Bédoule, Bouches-du-Rhône	Toucas, 1888
APTIAN	Apt, Vaucluse	d'Orbigny, 1840
BARREMIAN	Barrême, Alpes-de-Haute-Provence	Coquand, 1862,
BERRIASIAN	Berrias, Ardèche	Coquand, 1871
ARDESCIAN	Ardèche [*Ardesca*]	Toucas, 1890
CRUSSOLIAN	Crussol, Ardèche	Rollier, 1909
SÉQUANIAN	from Séquannes, a Gallic tribe from the source of the Seine	Marcou, 1848
VESULIAN	Vesoul, Haute-Saône	Marcou, 1848
BAJOCIAN	Bayeux, Calvados	d'Orbigny, 1849
TOARCIAN	Thouars, Deux-Sèvres	d'Orbigny, 1849
LOTHARINGIAN	Lorraine ; from Lotharingie, Carolingian province	Haug, 1910
SINEMURIAN	Semur-en-Auxois, Côte-d'Or	d'Orbigny, 1849-1850
HETTANGIAN	Hettange-Grande, Moselle	Renevier, 1864
AUTUNIAN	Autun, Saône-et-Loire	Bergeron, 1889
STEPHANIAN	Saint-Etienne, Loire	Munier-Chalmas et de Lapparent, 1893
STRUNIAN	Etroeungt, Nord	Barrois, 1913
GIVETIAN	Givet, Ardennes	Gosselet, 1879
BRIOVERIAN	*Brioveria*, ancient Celtic name of Saint-Lô, Manche	Barrois, 1899
PENTEVRIAN	Penthièvre, Saint-Brieuc bay	Cogné, 1959

Other stratotypes reflect a combination between science and culture (based on a lithic industry) because they were established for prehistoric archaeology. They are listed here because of this link (Table 5).

Table 5. Selected Prehistoric stages with a name based on a French patronym.

Stages	***Origin***	***Author***
Abbevillian	Abbeville (Somme)	Boucher de Perthes, 1836.
Acheulean	Saint-Acheul near Amiens (Somme)	Gabriel de Mortillet, 1872
Artenacian	Artenac (Charente)	?
Aurignacian	Aurignac cave, Haute-Garonne	Henri Breuil & Émile Cartailhac, 1906
Azilian (= Tourassian)	Mas d'Azil cave, Ariège (La Tourasse cave, Saint-Martory; Haute-Garonne)	Edouard Piette, 1889 (Gabriel de Mortillet in1872)
Badegoulian	Badegoule, Dordogne	André Cheynier, 1938, Vignard, 1965?
Castelnovian	Châteauneuf-les-Martigues (Bouches-du-Rhône)	Max Escalon de Fonton, 1956
Chassean	Chassey-le-Camp (Saône-et-Loire)	J. Déchelette, 1912
Chatelperronian (= Castelperonnien)	Châtelperron	Henri Breuil, 1906
Chellean	Chelles (Seine-et-Marne)	Gabriel de Mortillet, 1878
Gravettian	La Gravette shelter, near Bayrac, Dordogne	Fernad Lacorre, 1960
Levalloisian	Levallois-Perret quarries (Hauts-de-Seine)	Victore Commont?
Magdalenian	La Madeleine near Tursac, Dordogne (Upper Palaeolithic)	Gabriel de Mortillet, 1883
Montadian	La Montade cave, Plan-de-Cuques (Bouches-du-Rhône)	Max Escalon de Fonton, 1954
Mousterian	Moustier shelter, Peyzac-le-Moustier (Dordogne),	Édouard Lartet, 1860
Peu Richardian	Peu Richard hill, Thénac (Charente-Maritime)	M. Colle, 1956
Sauveterrian	Sauveterre-le-Lémance, Lot-et-Garonne	Laurent Coulonges, 1928
Solutrean	La Roche de Solutré (Saône-et-Loire)	Henry Testot-Ferry, 1866
Thenacian	Thénac (Charente-Maritime)	?

Apart from a richness of *in situ* elements present at geoheritage sites, museums and universities host millions of objects (*i.e.* an *ex situ* geoheritage) represented by rocks, fossils, minerals, piston and drilling cores and a suite of other items often with the associated documentation.

The protection of geoheritage must necessarily rely on a legal status specifically for remarkable geological objects. The so-called French ‘Barnier’ law passed in 1995, which was intended to establish a national listing of protected geological sites, but this never saw fruition. Such a list, however, is not easy to compile and it requires an inventory and an evaluation. Such an inventory is required by law, which in France was enacted in 2002. In April 2007, the French ministry in charge of the environment launched the inventory of the nation’s geological heritage. A national methodology was developed and a dedicated software program was produced and widely distributed (Fig. 18).

IV – Inventory

Why and how?

The law enacted in 2002 grants formal recognition to the notion of geological heritage for the first time (French Law 2002-276, February 27th, art.411-5, see annexe 1).

"*The inventory of natural heritage is set up for the entire national territory of France. A natural inventory encompasses the inventory of the richness of ecologic, faunistic, floristic, geologic, mineralogical and paleontological richness*[1]*. It is also defines that the inventory is conducted under the scientific responsibility of the National Museum of Natural History of France*".

To properly conduct the inventory, the methodology must be fixed at a national scale by the ministry in charge of the environment in order to maintain homogeneity at the national level. The process of documentation for the inventory is 'bottom–up', however. This methodology has now been fixed for the national territory (both in continental and overseas areas) but the data are documented at a regional scale and discussed by a specific commission composed of geologists (professional or amateur) from academic, industrial or education disciplines. This commission represents a regional committee for geoheritage (*Commission régionale pour le patrimoine géologique* or CRPG) and each committee has about a dozen members.

The collection of data is then discussed at a regional level by Départments or for the entire Région. The list of sites that the CRPG agrees upon is submitted to the regional committee (*Conseil scientifique régional du patrimoine naturel*, CSRPN of figure 17). The data are combined into a database with online access (iGeotope), homogenised, checked by a regional commission, then transferred to the National Museum of Natural History where it is examined by a national commission composed of geologists from different disciplines, different regions, and belonging to different institutions, and appointed by the National Museum of Natural History.

The ratified site data are stored at the national level and transferred onto a public website: http://inpn.mnhn.fr[2] for widespread public use. These data are on the same website as other scientific inventories dealing with nature. The advantage for this geoheritage data collection process is that it is perfectly compatible with other data sets for nature (flora, fauna, ecosystems, habitats –ZNIEFF[3], etc.).

[1] The terms «mineralogical and paleontological» are superfluous since these disciplines are subdivisions of geology but since they are specifically mentioned in the law, we let them here

[2] INPN = *Inventaire national du patrimoine naturel (Natural heritage of France website)*

[3] ZNIEFF : *Zone Naturelle d'Intérêt Écologique, Floristique et Faunistique* = Natural zone of ecologic, faunistic or floristic interest.

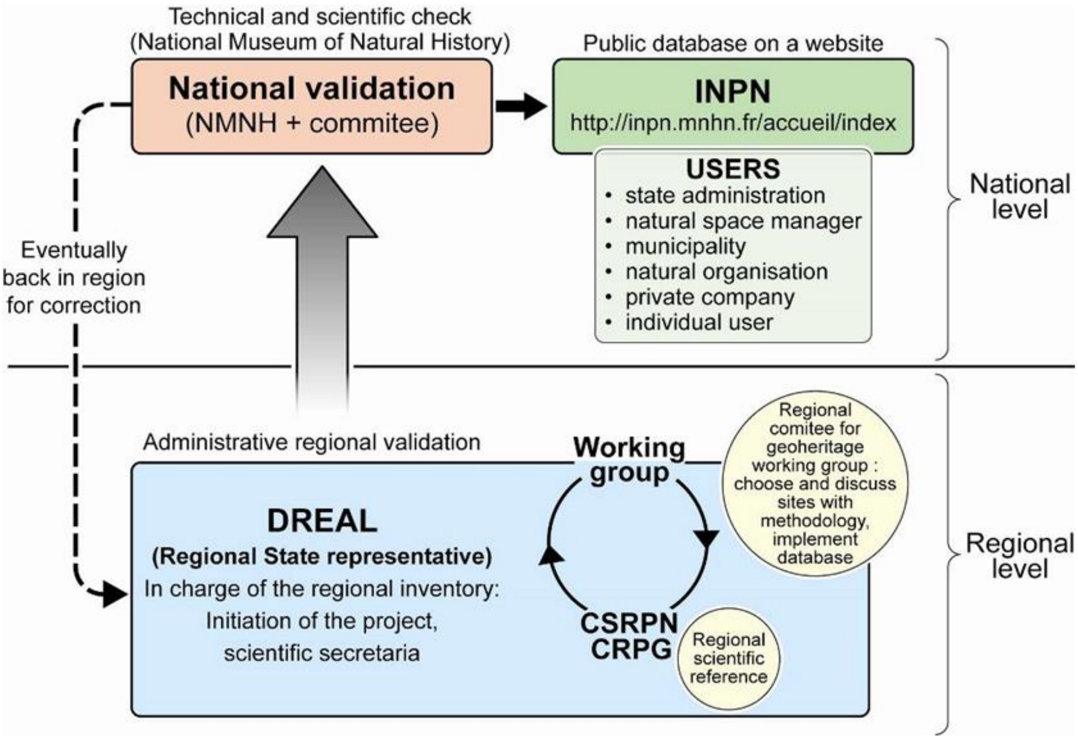

Fig. 17. Flow chart of the protocol for geoheritage inventory.

The inventory of geological sites is a result of two main activities: evaluating the most important sites, then establishing their organisation into a hierarchy. It is only at this second stage of the process that the most remarkable sites are identified and recorded on a national list. The geoheritage site can be selected according to the number of calculated ‘stars’ (Table 6). This inventory also includes collections in museums or in universities.

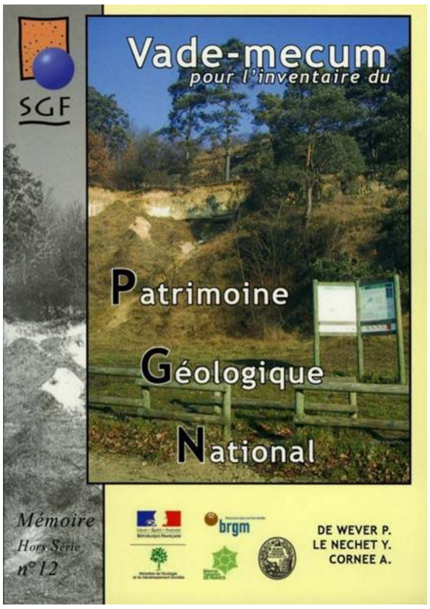

Fig. 18. The methodology for the inventory of national geoheritage is presented in a dedicated volume of the *Société géologique de France* (De Wever *et al*., 2006).

The CRPG experts also provide a bibliographic set of references which are required, such as geological maps, journal articles, handbooks, geological maps, and so on. The inventory characterisation and the assessment of geological heritage are carried out in a systematic manner. Several local or regional inventories which already existed at an administrative department level or carried out by a geoconservation organisation (*Réserves Naturelles de France, Parcs Naturels, etc*) have been incorporated in the national procedure.

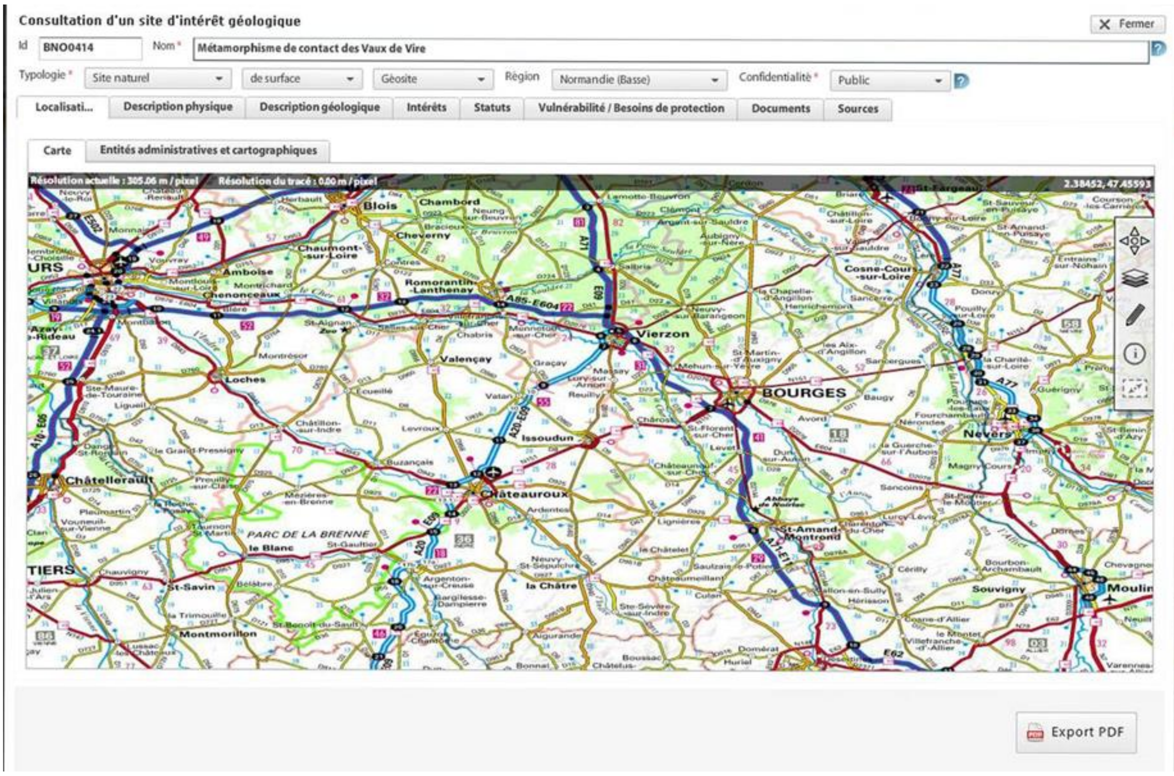

Fig. 19. Screen-shot from the website '*iGéotope*'. Users can gain access through this interface through a passcode and can directly access the database.

The content of each file of the inventory:

For each site, it is mandatory that a certain number of items are included (Fig. 19 and Appendix 2):

- A site identifier (automatically provided by the computer) to avoid duplication of site numbers. The identification code is composed of an acronym of the region's name + a number. For example (based on figure 19): **BNO**0414 for the "**B**asse-**NO**rmandie" region.
- A name (usually a locality name), with the type of rock and age; e.g., '*Metamorphisme de contact des Vaux de Vire* = Vaux de Vire (locality name) contact metamorphism.
- A typology: such as '*geosite de surface*' (surface geosite) or '*natural/anthropic'*.
- An indication of confidentiality: this field defines if the data may be publicised or should remain confidential (accessible only on request). For example, in this case it is 'Public".
    - A location with:

  - at least one geographic coordinate (several polygons can be included per site), in a GIS (geographic information system) format so that they can be mapped and integrated with other natural data (fauna, flora, etc.) (Fig. 20).
  - at least one reference to a topographic map (from the national geographic Institute). For example, VIRE (1414E) and SAINT-SEVER-CALVADOS (1414O). Several topographic maps may be referenced.
  - at least one reference to a geological map (name and number of sheet). For example ‘VIRE 0174’, which is the name and number of the geological map where the site is located. Several geological maps may be referenced.
  - a specific region. This inventory program is constructed by the regional state representative, so sites can only be in one region. A “trans-regional” site cannot be processed as is. Instead, the part on each side needs to be processed separately by the respective administration.
  - at least one department (101 departments for the whole territory). For example, in this case it is ‘Calvados’. Several departments may be referenced.
  - at least one municipality. For example, in this case, it is ‘Vire’. Several municipalities may be referenced.
  - a surface (even if only approximate) in hectares or square kilometres, 3.6 hectares in this example.

- A physical description of the site.
- A geological description of the site:
  - full description of the different elements and phenomena.
  - at least one geological age, both stratigraphic and numerical (for example, in this example: Brioverian, 540 Ma).
  - a GILGES code (The Global Indicative List of GEological Sites) is an international standard of classification. For example here ‘D category’: sedimentary petrology, metamorphic, igneous, texture and structure.
- A main geological interest, ‘Metamorphism’ in this case.
- A secondary geological interest, ‘Plutonism, in this case. A site could have no secondary interest.
- An indication of rarity (scale or level of significance), which is “regional”in this case.
- An evaluation of patrimonial interest: e.g. 28 (on a scale of 48).
- A rating about the need of protection: e.g. 5 (on a scale of 12).
- Bibliographic references.
- Graphic documents (photo, map, cross-section, etc.).
- Names of one or several authors.

(See annex 2 for the whole example of a geological site.)

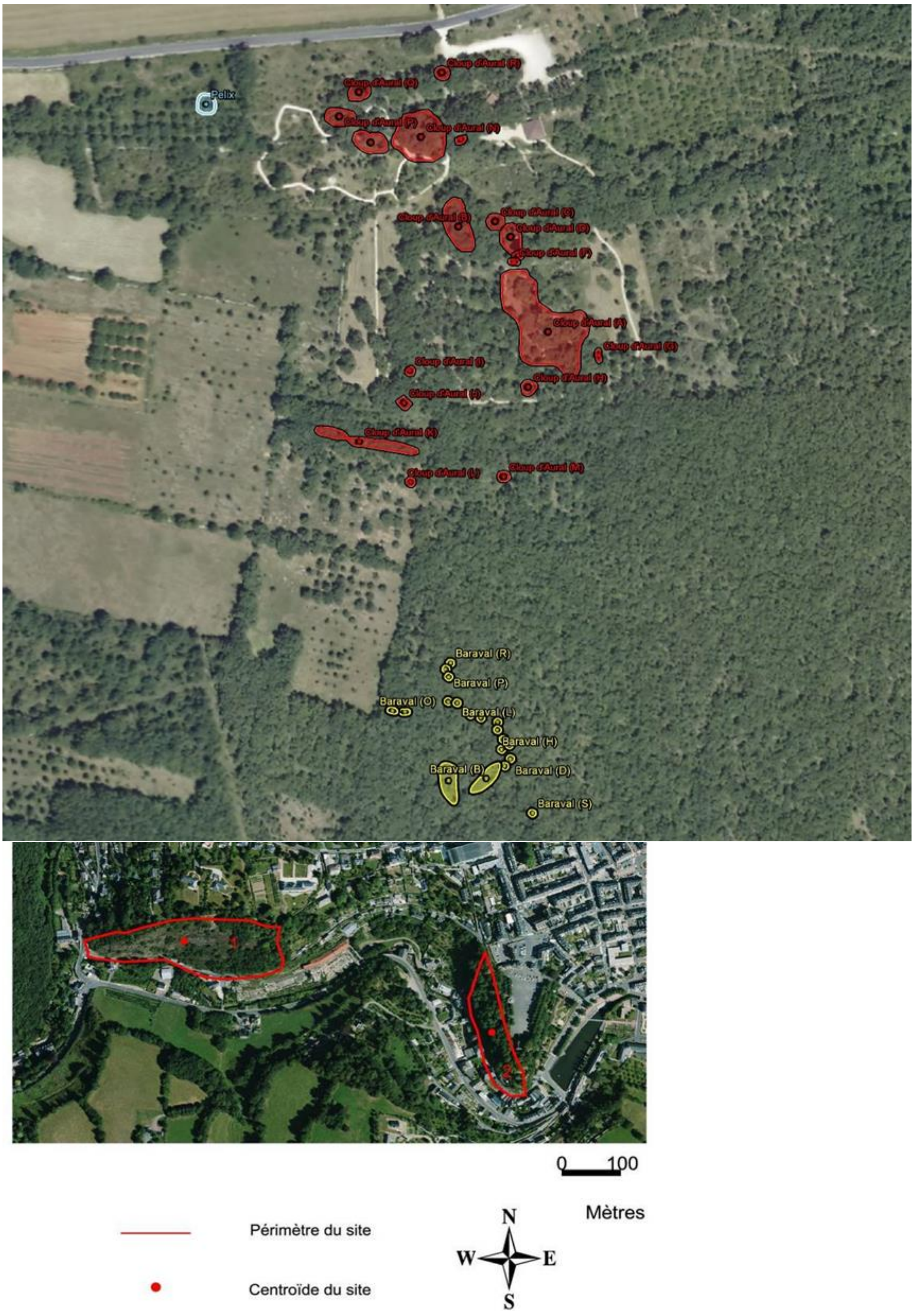

Fig. 20. Two examples of polygons for a site. A - In Normandy (NW France)
B-Example of polygons and points used for the location of three geological sites. Phosphorites du Quercy Area. Bach, Lot (S France).

For each site, several scores are assigned and a coefficient is also attributed which is related to the relative importance of the topic (Table 6). The scores from 0 to 3 are related to the importance of the site, i.e. its value.

Table 6. Criteria used to calculate the patrimonial interest

Criterion	**Value: from 0 to 3**	**coefficient**
Main geological interest	From weak (0) interest to remarkable (3)	4
Secondary geological interest	From no interest (0) to remarkable (3)	3
Educational interest	From no interest (0) to remarkable (3)	3
Historical interest	From no interest (0) to remarkable (3)	2
Rarity of site	From common(0)to rare (3)	2
Preservation state	From poorly (0) to well preserved (3)	2

In this example, the global note varies from 4 to 48.
According to the note obtained on the patrimonial interest, a number of stars are attributed:

Note ≤ 10:	no star
Note from 11 to 20:	*
Note from 21 to 30:	**
Note from 31 to 48:	***

These stars categorise the importance of the sites *within* France – national importance is established through comparisons with all similar sites nationally and international significance though a similar international comparison (although these latter assessments are not the primary aim of the initial national process).

In addition to this information, it is also useful to define the need for protection to avoid destruction if a site is under natural or anthropic threat (Table 7). Therefore, a level of protection is calculated for each site on the following basis:

Table 7 Criteria used to define the need for site protection

Criterion	**Level, from 0 to 3**
Geoheritage interest	According to the number of stars
Natural vulnerability	From none to extreme threat
Anthropic threat	From none to extreme threat
Effective protection	From maximum to no protection.

The level establishes the need for protection and varies between 0 (no threat) to 12 (absolutely necessary to protect).The double level of examination (regional committee and national committee) allows a homogenization at a regional and national level.

This inventory is a open in order that geosites can be added, modified or deleted from the list at any time. For this reason, some regions were able to establish a list with only a few sites whereas other regions chose to have as many geosites as possible from the beginning of the process. For example, the Nord-Pas-de-Calais Region fixed only circa 60 sites whereas the Midi-Pyrénées Region is working on more than 1,200 sites.

Status in autumn 2014

In mid-2011, the Ministry in charge of the inventory launched a general inquiry on the progress of the inventory project within the different regions. The survey has been conducted continuously since that date. The Ministry sent a questionnaire to its contacts in the regions (Directions Régionales de l'Environnement, de l'Aménagement et du Logement, DREAL) for both continental and overseas territories. All but 3 answered the questionnaire (23 positive responses) (Fig. 21).

Most regions have devoted a specific commission (CRPG) to this activity, mainly composed of geologists. Almost 300 geologists are involved in these commissions at the moment (26 regions have started their inventory to date). These members of the commissions belong to more than 40 institutions.

The inventory has been completed in 8 regions (all metropolitan) and 3 departments. To date, some 4,700 geosites are included; 3,400 are documented in full or partially, and more than 2,000 geosites are complete. At the moment (April 2015), 21% of the informed geosites have stratigraphy as the first interest, 16% sedimentology, 16% palaeontology, 12% geomorphology, 9%volcanism, 6%natural resources, 6% metamorphism, and so on. The percentage of main interest varies according to the geology of the region. For instance, volcanism is dominant in the Massif Central, whereas palaeontology is dominant in sedimentary basins.

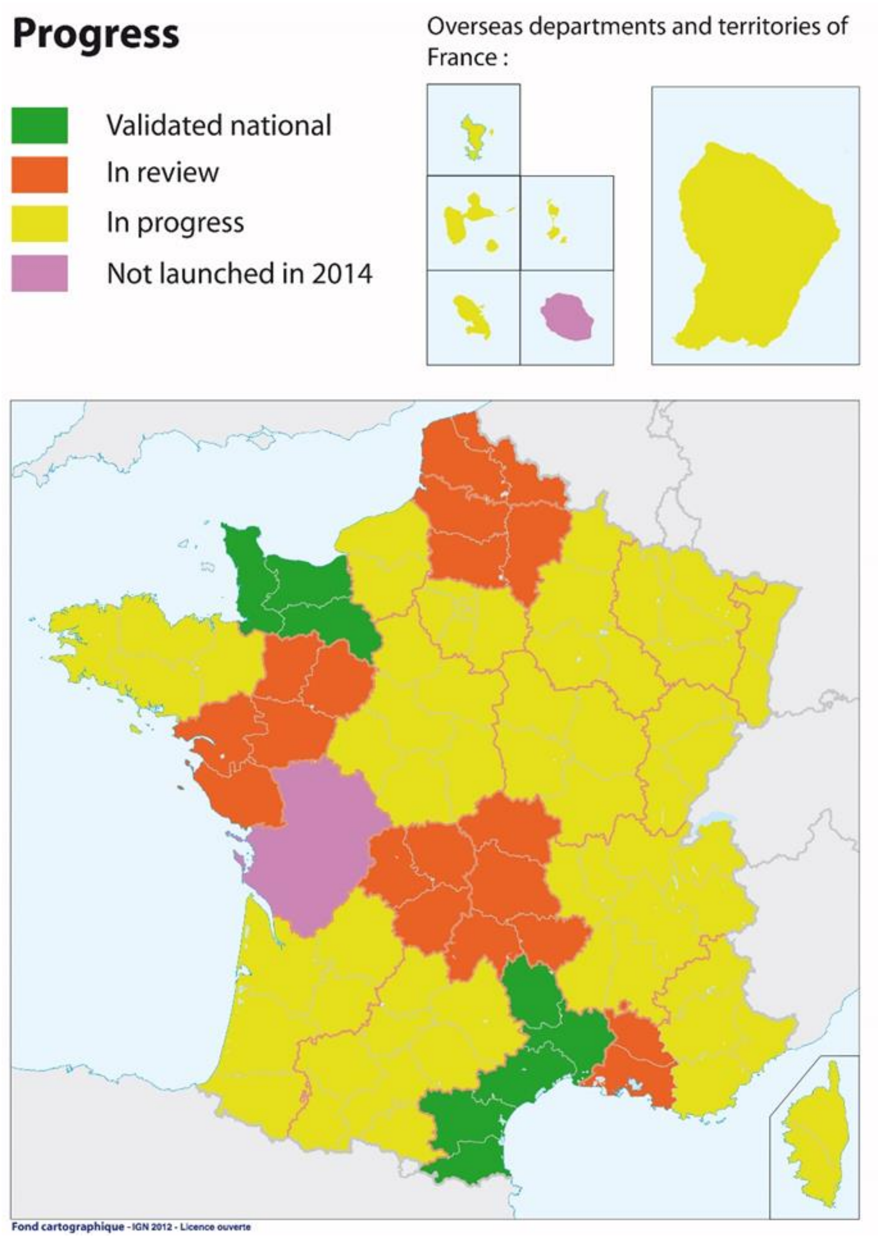

Fig. 21. Progress on the national inventory of geosites by region (as of February 2015). Three regions are already completed.

Regions that documented a restricted number of sites selected the most important ones and so they have a high proportion of 3 stars. In the Nord-Pas-de-Calais region, for instance, with about 60 geosites, there are no sites with 0 star, 18% with 1 star, 43% with 2 stars and 39% with 3 stars. In contrast, a region such as Midi-Pyrénées, with more than 1200 geosites, has 62% of its sites with zero star, 24% with 1 star, 10% with 2 stars, and 4% with 3 stars. Among the 2,000 geosites completed, 1% has no stars, 22% have 1 star, 43% have 2 stars and 34% have the 3 stars. As this national inventory is a continuous one, these regions will establish sites of lesser importance at a later date. Quite a variety of main interests exist between regions according to the geological context. Table 8 and Figure 22 show the main interest for the 2,000 geosites completed.

Table 8. Main interest reported for the French geosites as of spring 2015

Stratigraphy	21%
Sedimentology	16%
Palaeontology	16 %
Geomorphology	12 %
Volcanism	9%
Natural resources	6%
Metamorphism	6%
Geochronology, hydrogeology, hydrothermalism, mineralogy, plutonism and tectonics share the remaining.	14%

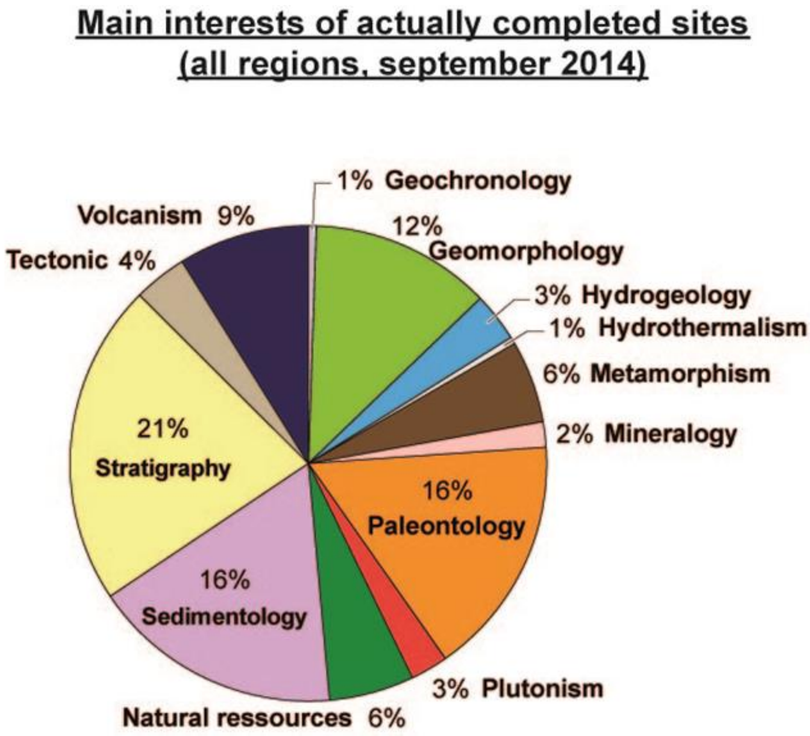

Fig. 22. Distribution of the main interest reported for the French geosites as of spring 2015

Table 8 and Figure 22 show that stratigraphy, sedimentology, and palaeontology are the main interest for most sites since they cover more than half of the sites (53%).

Who is involved?

Besides the geologists and members of the commissions (CRPG and others), many other geoscientists are involved in the inventory process. The inventory has mobilized approximately 350 geologists belonging to 62 institutions (universities, regional administrations, companies, museums, education and so on), from all around France.

The need for an inventory; the SCAP

In 2008, the French government set up a programme focused on the environment, called '*Grenelle de l'environnement*'. This new focus encompasses a set of public or scientific actions dealing with the environment to be carried out in the entire country. One of the results indicated an insufficient presence of 'highly protected' areas. They currently represent 1% of the inland territory, and another 10% as slightly protected. In order to improve this situation, a strategy has been developed. This *Stratégie de Création d'Aires protégées*" (SCAP, strategy to create protected areas) was officially launched by the ministry in charge of the environment in 2009 to get a better idea of the protected areas network and establish a better representation of biodiversity and geodiversity. The ministry aims to place 2% of the French inland territory under stronger protection in the next ten years.

For geology, a specific group was organised by the government to analyse and propose geosites within this strategy, due to national inventory not yet being finished. For this purpose, several categories were distinguished.

- International standards (such as stratotypes or GSSP),
- Restricted sites (such as places with dinosaurs tracks or specific mineralogical content),
- Main geological complexes (such as the ophiolitic complex of Mount Chenaillet in Alps),
- Landscapes important for their geomorphology (such as karstic countryside or the Gavarnie cirque in the Pyrenees).

An initial list with more than 140 major sites has been proposed on this basis and may benefit from stronger regulation. The implementation of this strategy is still ongoing.

V- Overview of some inventories in Europe

Some European countries have a long history concerning the protection of geological heritage with well-developed strategies. Others have very limited legislation in this regard. One of the oldest known geological conservation case is in Germany, in the Baumannshöle cave where, from 1668, access for visitors was limited in order to preserve the site's stalactites and stalagmites (Erikstad, 2008).

In the early twentieth century, laws on nature protection sprang up in many European countries with more or less effect on the protection of geology. But it was not until the second half of the twentieth century that modern legislation, inventories and conservation strategies mainly developed. The creation of the European Association for the Conservation of Geological Heritage (ProGEO) in 1988 marked the beginning of the gathering and dissemination of information relating to geoconservation. In 2004, the protection of geological heritage was even included as a recommendation by the Council of Europe and is beginning to be visible in the policy of the European Union (Council of Europe, 2004).

To position the French inventory relative to what is done in other European countries, a comparative study was conducted in 2014. Four culturally different European countries were selected besides France: Spain, Finland, Great Britain and the Czech Republic (Fig**.** 23). The study focused on the motivations, context, actors, methodology, scale of the inventory, content of geological inventories, etc.. Particular attention was paid to criteria for selecting geological sites and to the various means of dissemination employed.

Fig. 23. Countries included in the study of inventories (IGN, 2012).

Comparative study

All five studied countries possess geological inventories with different names as shown in Table 9 below. Note that Great Britain has two separate inventories: the Geological Conservation Review (GCR) and Regionally Important Geological and Geomorphological Sites (RIGS). Also, the Finnish inventory was conducted in several stages, successively addressing different topics, which explains the various titles (Husa & Teeriaho, 2004). The number of sites recorded in inventories varies depending on the country: from 1,500 sites expected in Spain to 4,717 sites listed in Finland. There are currently just over 611 confirmed sites in France and 305 in Spain, as these inventories are still underway.

Table 9. Names and number of sites in the studied inventories. Data for Spain from García-Cortés & Carcavilla (2009), for Finland from the Finnish Environment Institute (2014), for

France from De Wever et al.(2006), for Czech Republic from Wimbledon & Smith-Meyer (2012) and for Great Britain from Ellis (2011) and GeoConservation UK (2014). In Northern Ireland, however, nationally important sites are recorded in the Earth Science Conservation Review (ESCR) and locally important sites are recognised as Sites of Local Nature Conservation Importance (SLNCI) (Wimbledon & Smith-Meyer, 2012). The ESCR and SLNCI are the equivalent to the GCR and RIGS, respectively. For simplification matters, in this study, we will only use data from British inventories (GCR and RIGS).

Country	Inventory	Number of sites
Spain	Spanish Inventory of Sites of Geological Interest (IELIG)	1,500 (expected)
Finland	National bedrock inventory	4 717
	National inventory of moraine structures	
	National inventory of coastal and wind formations	
	National boulder field inventory	
France	National inventory of geological heritage	4,700 (estimate)
Czech Republic	Significant Geological Localities of The Czech Republic	2 799
Great Britain[4]	Geological Conservation Review (GCR)	3,000
	Regionally Important Geomorphological and Geological Sites (RIGS)	Over 3,400 (estimate)

Fig. 24 compares the number of geological sites depending on the size of each country, showing that the country where geological sites have the highest density is the Czech Republic.

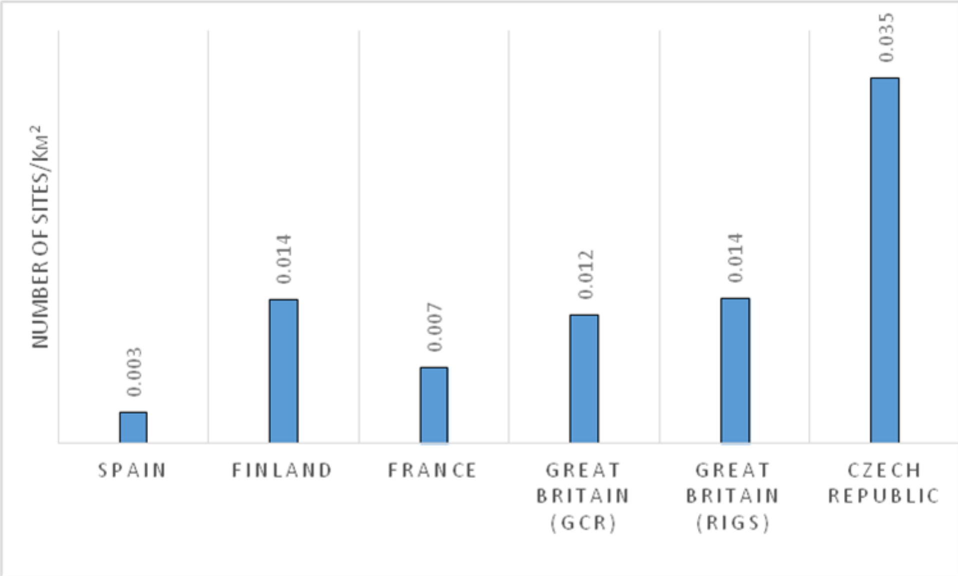

Fig. 24. Diagram showing the number of geological sites per km^2. Inventories in progress are indicated by a dashed line.

Origins and legal context

Among modern inventories, the Geological Conservation Review, started in 1979 in Great Britain, is the first initiative of a systematic and comprehensive assessment of the geological heritage of a country (Ellis, 2011 – although earlier national site listings go back to the 1940s and the process of selecting RIGS sites effectively started in the 1970s). Finland, Spain and the Czech Republic launched their inventories in the late 20th century, followed by France in the beginning of the 21st century. In 2008, Spain published the results of its inventory of geosites of international significance (Global Geosites), and in 2009 revised its previous national methodology from 1978, later testing it at regional and local (municipal) scales (García-Cortés, 2012).

In most European countries, geological inventories result from nature and landscape protection laws. In Finland, however, the geological inventory was created in 1982 as the result of the Land Extraction Act MAL 551/1981. This law controls the excavation and exploitation of the ground and the use of bedrock as dimension stone and aggregate. The Land Extraction Act forbids the destruction of unique natural occurrences, whose uniqueness can be assessed on both geological and biological grounds. Thus, extraction is regulated in the sites assessed in the Finnish geological inventory. However, as long as extraction is not incompatible with the provisions of the act, an extraction permit can be granted (Finland's Ministry of Justice, 2014).

Purpose and scale

Setting goals is a crucial part of the methodological approach. The methodologies of geological inventories in Europe share three main objectives:

- scientific knowledge,
- protection of geological heritage and,
- economic development of the local community.

A second observation shows that there are three types of inventories (Table 10):
- organized around the preliminary identification of ‘frameworks’ characteristic of the geological history of a country. In Spain for geosites of international relevance, and in the GCR (Great Britain), sites of geological interest are not selected regardless of their context but in a geological ‘framework’ previously selected for its interest. These ‘geological themes’ or ‘Selection Blocks’ (e.g.: Marine Devonian stratigraphy’ in the British GCR) are obtained by dividing up the geology and geomorphology of a country in several topics. These topics can be a regional geological phenomenon, stratigraphic series, a tectonic event, etc.. ‘Frameworks’ provide a structure for the selection of geological sites and ensure a balanced distribution of sites among the various Earth science aspects existing in the country (Ellis, 2011). Without using that name, it is also the rationale that was used to set up a list of sites for the National Strategy for the Creation of Protected Areas (SCAP) in France (Egoroff *et al.*, 2011), e.g. carried out according to the processes which formed the geological formations (e.g. moraines, eolian deposits, etc, as in Finland; carried out regardless of representative geological frameworks or processes, as it is the case in France, Spain (local, regional and national inventories) and the Czech Republic, identifying sites of geological interest (*sensu lato*) for a general knowledge base.

We also note that inventories are carried out at different levels: international, national, regional or local (Table 10).

Table 10.Methodology types and scale of the studied inventories. Data for Spain from García-Cortés & Carcavilla (2009), Agueda Villar et al., 2009, for Finland from Husa & Teeriaho (2004), for France from De Wever et al. (2006), for Czech Republic from Kubalikova & Kirchner (2013), for Great Britain from Ellis (2011) and Mason & Stanley (2000).

Country	Methodology type	Scale
Spain	*Frameworks* (for international) and systematic inventory (for local, regional and national)	Local, regional, national and international
Finland	Nature of geological formation	National and regional
France	Systematic inventory	National and regional
Czech Republic	Systematic inventory	National and regional
Great Britain	GCR : *Selection Blocks* (i.e ‘frameworks’)	National and international
	RIGS : Systematic regional inventory	Local, regional

Selection criteria

Once geological sites have been identified, selection criteria are applied to assess their interest as geoheritage. In general, three topics are addressed: scientific and educational interest, secondary interests (cultural, aesthetic, tourism...), and vulnerability of the site. Some criteria are common to all methodologies, such as criteria related to the main geological interest and the protection of the site. However, other criteria, such as the average temperature (weather criterion) in Spain or the number of colours in the landscape in the Czech Republic are scarcer (Kubalikova & Kirchner, 2013). As part of a compatibility with a biotic natural heritage inventory, Spain, Finland, France and the Czech Republic, the inventories record the existence of biological interest or protected species within geological sites. In addition, it was found that the Spanish and French methodologies are those that have the most comprehensive selection process, with more than 40 fields to be filled in on their evaluation sheets, whereas other countries have between 20 and 30.

Finally, in the five methodologies (Spain, France, Finland, Czech Republic and RIGS in Britain), the selected sites are scored and classified by degree of scientific importance and / or vulnerability. These assessments are intended to highlight the sites with the highest heritage interest, or requiring greater protection. However, the assessment of the vulnerability of a site, does not mean its legal protection. Only three of these methodologies (Finland, the Czech Republic and the GCR in Great Britain) include the listing of sites for their legal protection (Table 11) (although RIGS sites do have some status in development planning systems).

Table11. Types of protection applied to sites in the different inventories. Note. Data for Spain from García-Cortés & Carcavilla (2009), Finland from Finland’s Ministry of Justice (2014), France from De Wever et al. (2006), Czech Republic from Wimbledon & Smith-Meyer (2012), and for the UK from Ellis (2011 - for the GCR) and from Mason & Stanley (2000 - for RIGS).

Inventory	Type of protection
Spain	No direct protection. The inventory is used by regional governments to define protected areas.
Finland	Legal protection. Destruction and damaging are forbidden. Excavation and construction are restricted.
France	No direct protection. The inventory will be used as the basis for the definition of future protected areas (SCAP…)
Czech Republic	Legal protection. Fines for damage or destruction (40-80,000€).
GCR (Great Britain)	Legal protection against destruction, damage and neglect.
RIGS (Great Britain)	Protection typical indirect, e.g. through local planning processes.

Means of dissemination

Information gathered in geological inventories is frequently used to disseminate knowledge about geoheritage to the general public, scientists, nature conservation institutions and others. Multiple media are used: publication of descriptive sheets in books or on the internet or creation of online databases and interactive maps.

The first observation is that access to information is very uneven across countries. Much information is freely available on the internet. However, some descriptive sheets are published in expensive books with only incomplete information being available online (mainly legal documents only, e.g. the GCR in Britain) or even sold out (first reports in Finland); sometimes the databases only partially accessible to the general public (e.g. RIGS in Britain). In addition, the size of the disseminated sheets varies from one line (Spain) to approximately 8 pages (France) (Fig. 25). Some are very descriptive (GCR in Britain, Finland), others are restricted to keywords (Czech Republic, Spain). There is also a significant difference between the information provided on the assessment sheets of geosites and the information disseminated to the general public. The most obvious case is that of Spain, which has the largest number of selection criteria but only one line of description available for each site

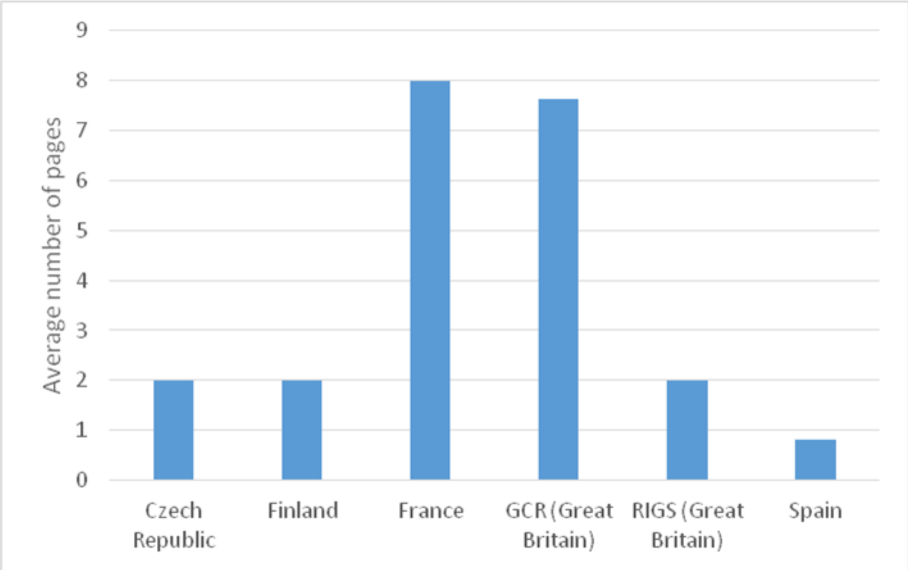

Fig. 25. Average number of pages for the disseminated descriptive sheets by country. Data for Czech Republic from the Czech Geological Survey (2014), Finland from the Finnish Environment Institute (2014), France from De Wever *et al*. (2006), for the GCR (UK) from the Joint Nature Conservation Committee (2008) and RIGS from GeoConservation UK (2014) and for Spain from García-Cortés *et al*. (2013).

Concerning the content, regardless of the inventory, the information included on each descriptive sheet is related to the location of the site and to its main geological interest. 'Secondary' interests do not appear on the disseminated descriptive sheets for Spanish and Czech inventories. Similarly, only Finland, France and the Czech Republic, and to a lesser extent RIGS in Great Britain, evoke vulnerability and protection on their final descriptive sheets (although for all nationally protected GCR sites, full management plans and conservation objectives have been compiled, but may not be publically readily accessible).

Illustrations are often attached to descriptive sheets, the most common being topographic maps and site plans, geological cross-sections, photographs and drawings. The boundaries of protected areas that include nationally protected GCR sites and most RIGS sites are, however, availability as GIS layers.

The results of the comparative study of geological inventory methodologies are summarized in the following Table 12

Table 12. Synthetic table. Data for Spain from García-Cortés & Carcavilla (2009), for Finland from the Finnish Environment Institute (2014), for France from De Wever et al. (2006), for the Czech Republic from Wimbledon & Smith-Meyer (2012) and Kubalikova & Kirchner (2013), for GCR from Ellis (2011) and for RIGS from Mason & Stanley (2000).

	SPAIN	FINLAND	FRANCE	CZECH REPUBLIC	GREAT BRITAIN (excluding Northern Ireland)	GREAT BRITAIN
					GCR (SSSI)	RIGS
NAME	Spanish national inventory of sites of geological interest (1978-1988 and 2007 onwards).	National bedrock inventory, 1989-2004.	National inventory of geological heritage, 2007.	Significant Geological Localities of The Czech Republic, 1992	Geological Conservation Review (GCR), 1979.	Regionally Important Geological and Geomorphological Sites (RIGS), 1990 (although some regional selections go back to the 1970s).
	Several local and regional inventories.	National inventory of moraine structures, 2007.				
	Spanish geosites of international relevance (1998-2008)	Nation inventory of coastal and wind formations, 2005-2009.				
		National boulder field inventory, 2012.				
CONTEXT	Law 42/2007 about natural heritage and biodiversity	MAL 551/1981 Land Extraction Act (articles 3 and 7)	Law 27/02 2002 on local democracy	Law 114/1992 Coll. on nature and landscape protection	Wildlife and Countryside Act 1981 ; Countryside and Rights of Way Act 2000 in England and Wales (see Page and Wimbledon 2009 for regional differences)	Various elements of national and local spatial planning legislation.

	SPAIN	FINLAND	FRANCE	CZECH REPUBLIC	GREAT BRITAIN (excluding Northern Ireland)	GREAT BRITAIN
					GCR (SSSI)	**RIGS**
GOAL	Selection, description and assessment of sites of geological interest towards their management and protection.	Identify remarkable sites for biological, geological and landscape interest from a national point of view or for the protection of the environment	Identify all the sites and objects of geological interest, *in situ* and *ex situ*. Collect and enter their characteristics on appropriate forms. Rank and validate heritage oriented sites. Assess their vulnerability and protection needs.	Compile field data on major geological sites to inform the general public and provide information to nature protection institutions.	Identify sites of national and international importance which constitute scientific key elements of British geoheritage (excluding Northern Ireland).	Locally identify sites of local, regional or national interest, for geodiversity (e.g. at a county level).
SCALE	Local, regional, national and international	National and regional	National and regional	National and regional	National and international	Local, regional and national
MAIN STAKEHOLDERS	Geological Survey of Spain (IGME), regional and local administrations	Finnish Environment Institute (SYKE) and Geological Survey of Finland (GTK)	French Ministry of Environment-DREAL (regional State representative)-French National Museum of Natural History	Czech Geological Survey (CGS)	'Country' conservation agencies, Joint Nature Conservation Committee (JNCC)	The Royal Society of Wildlife Trusts (RSWT)/ local RIGS groups and Geology Trusts, local area government organisations, (most are affiliated to GeoConservationUK)
METHODOLOGY TYPE	Systematic (local, regional and national) and frameworks (international)	Nature of geological formation	Systematic	Systematic	Framework/ Systematic	Systematic

	SPAIN	FINLAND	FRANCE	CZECH REPUBLIC	GREAT BRITAIN (GCR) (excluding Northern Ireland)	GREAT BRITAIN (RIGS)
SELECTION CRITERIA	Scientific, educational, touristic and protection interests	Geological-geomorphological (representativeness, rarity, diversity), biological, ecological, landscape, and environmental interests	Representativeness educational and scientific interests, rarity, protection status, additional interests	Scientific value, relationship with the biosphere, cultural and historical links, attractiveness	International importance, presence of exceptional objects, representativeness	Geodiversity, educational and geological, cultural, economic, heritage interests, access notes and security
NUMBER OF SITES	1,500 (expected)	4,717	4,700 (expected)	2,799	3,000	More than 3,000 (estimate)
DISSEMINATION MEDIUM	Database, reports and publications	Reports	Database	Database	Database and books	Database (although in some areas site details - may not be readily available) and publications
PROTECTION	No protection from the inventory (competence of regional and local administration)	Legal protection. Restricted extraction and construction	No protection	Legal protection of geosites. Fines in case of damage or destruction (40€-80,000€).	Legal protection against construction, damage and dereliction	Protection mainly through local planning systems
INTEGRATION OF BIOLOGY	No	Part of the inventory	Complementarity	In the evaluation	Integration within designated protected sites	No
NUMERICAL EVALUATION OF SITES	Yes	Yes	Yes	Yes	No	Some networks only.
EVALUATION OF PROTECTION NEEDS	Yes	No	Yes	Yes	Yes	Yes

Main similarities and differences

At first, when looking at each inventory, we note that four of them have the word ‘inventory’ or a synonym (i.e. review) in their name (Finland, France, Sapine-IELIG- and GCR in Great Britain). Concerning geoheritage vocabulary, we find that different methodologies use similar words (inventory, geosite ...) but with different meanings. For example, in France, a geosite is the “bounded space that offers the opportunity to observe the geological elements and / or events which have an interest for the understanding of Earth Sciences" (De Wever et al. 2006). In contrast, in the GCR (Great Britain) and in Spain, geosites are restricted to "sites of national or international interest used to describe the key elements of the history of geology" (Ellis, 2011) of the involved country. Thus, this difference of meaning has a direct impact on the number of geological sites included each inventory.

To this difference of meaning must be added the link between the objectives and the types of methodologies. The ‘frameworks’ methodology is used to review nationally or internationally important geosites (Spain, GCR in Great Britain). In this type of organisation, ‘frameworks’, typical aspects of the geological history of the country, are defined first, and then geosites that best represent these frameworks are chosen (Agueda Villar et al., 2009), often limiting the number of geosites due to a perceived need to avoid duplication or less representative sites. In contrast, in inventories carried out more comprehensively in order to develop a ‘knowledge base’ and conducted at a national and / or regional scale (France, Finland, Czech Republic, RIGS in Britain, Spain), the number of sites is higher.

There is also a link between the selection and/or evaluation criteria and the purpose of the inventory. When the emphasis is on geological or educational interest and the vulnerability of a site, the aim of the inventory is to gather information about geological heritage and also to provide solutions for the protection of this heritage. This is the case for French, Finnish, Spain and the GCR (UK excluding Northern Ireland) inventories. However, some inventories (Spain, Czech Republic, most RIGS, UK), in addition to gathering knowledge about geoheritage, attach importance to conditions of access to the site, potential use of the site, already existing infrastructure, etc.. One of their aims is to contribute to the economic development of a region or a locality.

Britain constitutes a particular case because it has two separate inventories. The oldest, the Geological Conservation Review, as previously mentioned, is a list of geological sites of national or international importance representative of the history of British geology (Ellis, 2011). All the sites listed in the GCR in Britain are under legal protection. However, this inventory excludes many geological sites of lower importance. Scientists and volunteers, alerted by the deterioration of some sites not listed in the GCR, decided to establish the concept of ‘RIGS’ "to inventory local, regional or national sites of interest for geodiversity" (Mason & Stanley, 2000). It is a small-scale initiative, coordinated by NGO associations (such as GeoConservationUK), while the GCR is managed by the Joint Nature Conservation Committee, on behalf of ‘country’ conservation agencies, funded by the British government. Both inventories are completely independent in terms of their organization, their goals and their methodology. However, this does not prevent geological sites from overlapping: a nationally important site may also have a more local interest.

Development prospects

Behind the term ‘geological inventory’ there are several different entities. Each country sets up a specific inventory in order to meet its objectives and its needs in terms of geoheritage conservation; there are as many inventories as countries, or even more in the case of Great Britain and Spain. This multitude of approaches and strategies makes comparisons difficult. One thing is sure, the process of carrying out geological inventories in Europe is well underway since, at the present time, the majority of European countries have launched or are planning to launch a geological inventory (Wimbledon & Smith-Meyer, 2012) (Fig. 26). However, in the context of a possible geological inventory project on a European or global scale, given the methodological differences between the various national inventories, the issue of interoperability of the different inventories will arise. Harmonization work would be necessary in order to obtain a coherent and homogeneous data set at an international level (for instance in the context of the Global Geosites project).

Fig. 26. State of progress of national geological inventories in Europe with the number of geosites up to October 2014. Data from Wimbledon & Smith-Meyer(2012) and see Appendix 3 for additional sources. Mapping from IGN, 2012.

[insert]

VI- Outreach

Knowledge and geoconservation

The inventory is a preliminary work, essential for understanding geological heritage (and therefore natural heritage), but it is not its sole interest. The methodology allows the evaluation of the registered sites, the identification of the heritage value and protection needs of each site. It constitutes a reference for spatial planning policies and for the definition of conservation strategies and the enhancement of this heritage, in various ways, both regionally and nationally or even internationally, by providing a tool / program able to rank sites of geological interest across the territory, at multiple levels of needs (heritage, protection etc.).
The geoheritage inventory is a tool of knowledge that has no legal value. However, it is used to notify the various administrations and local authorities, particularly municipalities: it mentions the elements to take into account when preparing their planning documents. It indicates the presence of outstanding geological sites that need special attention as required by the 2002 Act in France. This acknowledgment can prevent the destruction of the sites due to ignorance, as has sometimes been the case (Fig. 27).

Fig. 27. A roundabout constructed on an outcrop of the '*Falun d'Etrechy'*, part of the historical Stampian stratotype, but nevertheless ignored by the local planning authorities (photo: P. De Wever)

This inventory provides a criterion to identify areas of higher density of geosites as important sites, and identify the priorities to determine protected areas as part of geoconservation plans as well as choosing the best protection tool (Fig. 28 and 29).

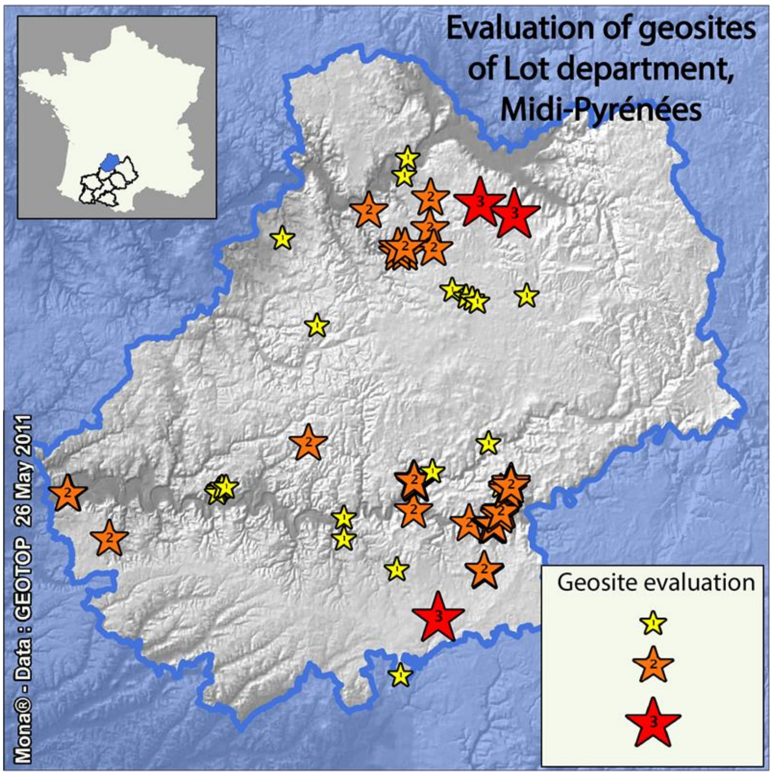

Fig. 28. Map of part of a region with: (a) local geosite evaluation and (b) the main geological interest of the geosites (tectonic / sedimentary / paleontological, etc.).

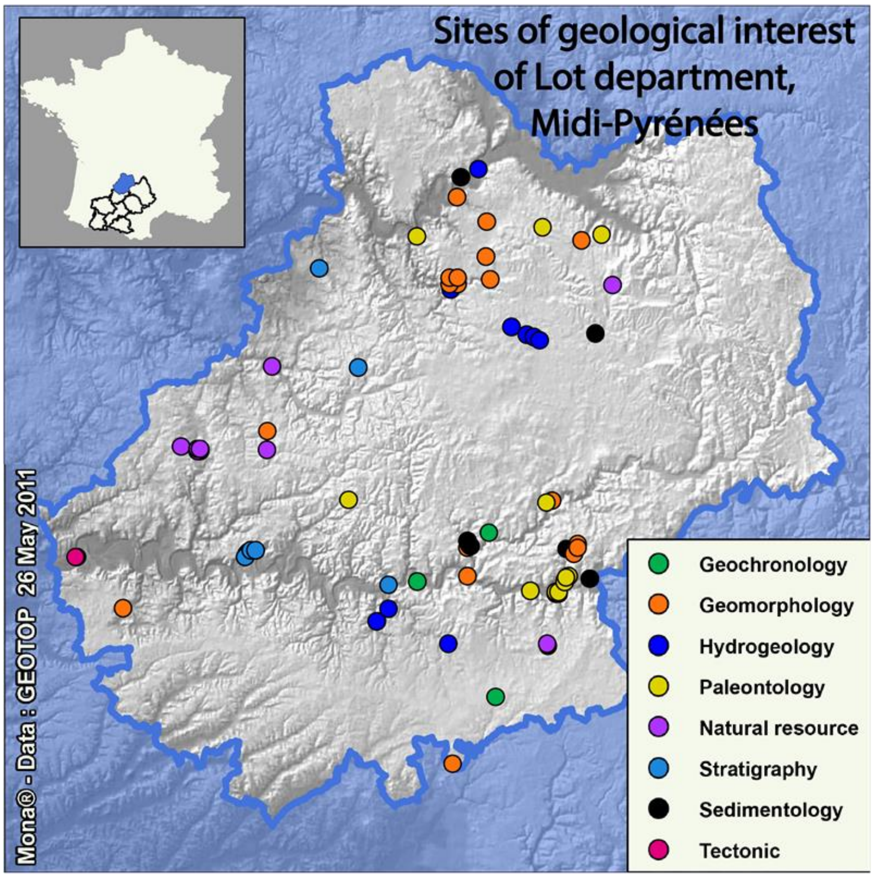

Fig. 29. Automatically generated regional report map displaying various densities of geosites.

Integration into a global information system on nature and landscape and data dissemination

Together with the other programs of knowledge of natural heritage, the INPG (National inventory of geological heritage) helps to promote knowledge of nature, whether they are inventories such as ZNIEFFs (natural areas of ecological interest, flora and fauna) or evaluation networks such as Natura 2000 sites or red species lists (for more details see the INPN (National inventory of natural heritage) at http://inpn.mnhn.fr). The INPN provides data on nature for policy makers, conservation stakeholders, researchers, etc, and the general public. These are the challenges of major national, European and international programs for the protection of nature. In France, data from these programmes feed the 'Information System on Nature and Landscapes' (SINP). This information system is a partnership between the ministry in charge of the environment, public institutions, associations and local authorities involved in the production, validation, management, processing, enhancement and dissemination of information on nature or landscape.

The official tool for disseminating data on nature collected in this context is the INPN website, managed by the French National Museum of Natural History (MNHN). The INPN (http://inpn.mnhn.fr) is the 'reference system' of the SINP.

The mapping of each site of the inventory allows the representation of the outstanding sites of geological interest, along with data from other nature inventories on the whole territory. One can display on a map of the territory, information concerning the geology, as well as the flora, or both, and compare them. This is a major advantage of this ‘national’ and multi-layer dimension of the inventory.

Use and development of the inventory

The promotion of geological sites can be done in different ways and is aimed at a variety of audiences:

- The data from the inventory provides resources to supply a database, called ‘*lithothèque nationale*’, dedicated to education, particularly for secondary school teachers, in order to provide them with an effective way to set up field trips for their students (Fig. 30 & 31).

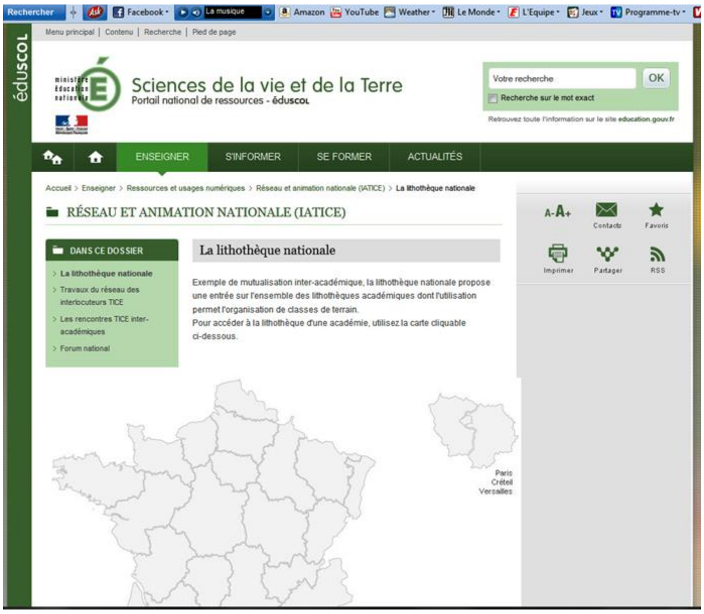

Fig. 30. Home page of the ‘*lithothèque*’ website for geosites, dedicated to education on the (from EducScol - http://eduscol.education.fr/svt/enseigner/ressources-et-usages-numeriques/reseau-et-animation-nationale-iatice/la-lithotheque-nationale.html).

Fig. 31. Example of the *lithothèque*' webpage for the Stampian.

- Recent years have seen the rise of publications intended to raise awareness of geology and geological heritage, aimed at a wider audience, some directly related to the creation of the inventory (e.g., Jonin, 2008; Robaszinsky and Guyétant, 2009). Recently, several new collections were launched: "*Stratotypes"* (stratotypes) (Fig. 32), "*Balades géologiques"* (geological strolls) (Fig. 33), "*Géotourisme"* (geotourism) (Fig. 34), "*Guides géologiques"* (geological guides).

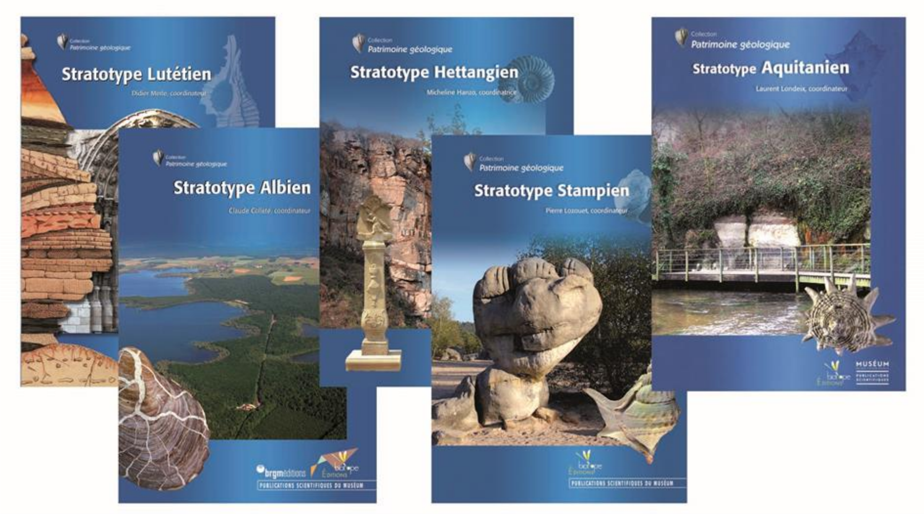

Fig. 32. Covers of the first 5 books dealing with stratotypes: Lutetian (Merle, 2008), Albian (Colleté, 2010), Hettangian (Hanzo, 2012), Stampian (Lozouet, 2012) and Aquitanian (Londeix, 2014). The last one has received the patronage of UNESCO. Launched by the French National Museum of Natural History, the collection "*Patrimoine géologique-Stratotypes"* (Geoheritage-Stratotypes) aims to explain what a stratotype is, namely a scientific standard of international value, and to increase awareness of the value of this heritage.

Fig. 33. Examples of geological itineraries: Etampes (Billet *et al*., 2008), Milly-la-Forêt (De Wever *et al*., 2009), Dourdan (Egoroff *et al*,. 2011) and Bordeaux (Caro *et al*., 2010). The booklets in the '*Balades Géologiques'* (geological itineraries) collection, created by the French National Museum of Natural History, describe geological city tours that show the

relationships between rocks, architecture, city planning and history, combining art and science.

Fig. 34. '*Géotourisme*' collection: small books that present geosites by department. Here is the book on "*Côtes-d'Armor*" (Graviou, 2012).

- An awareness and a better understanding of geology is also shown through the development of sites and geological tours or routes. Geological trails or roads provide access to *in situ* geology at different scales: on distances covered by foot or by car. Several road tours have been developed with this objective. e.g. *Géoroute du Chablais* (Chablais geological road), *Via GeoAlpina* and the *Route géologique transpyrénéenne* (trans-Pyrenean geological road) (Fig. 35 and 36).

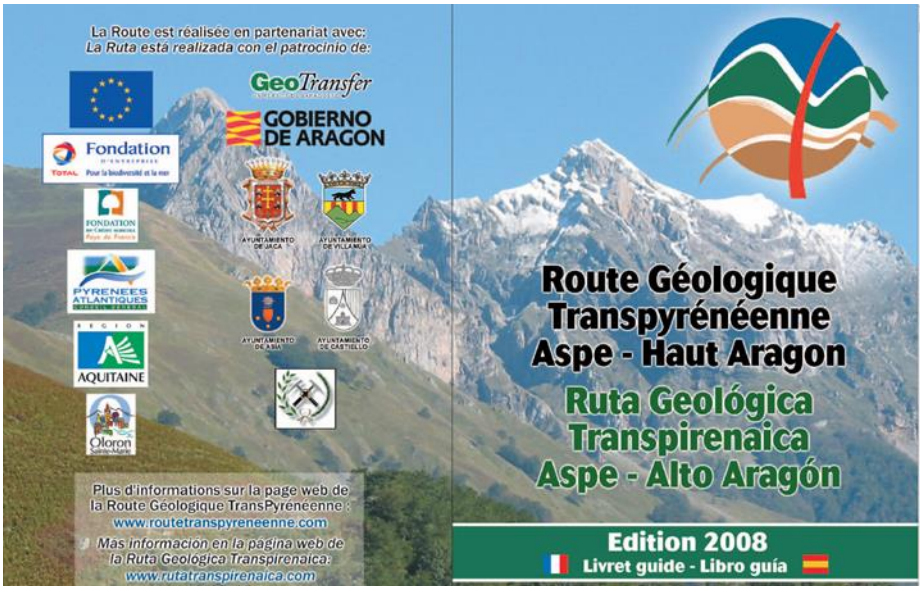

Fig. 35. **Cover of the guidebook of the *Route Géologique Transpyrénéenne.***

Fig. 36. Example of explanatory signboards made for the *Route Géologique Transpyrénéenne.*

The proliferation of national and international meetings related to the geological heritage and its touristic development (geotourism) is another effect of the dynamics of the current dynamics of this discipline, including the *Declaration of Arouca* (Portugal), and geoheritage sessions at many national and international conferences, even including the global International Geological Congress held in Brisbane, Australia in 2012.

Geoheritage can also be used to support local sustainable development and enhancement of a territory by involving the other types of heritage present. This idea is the basis of the concept of Geopark, a label supported by UNESCO. A new Geopark has been recently created in France, which has now five (Ardèche, Chablais, Luberon, Massif des Bauges, Réserve Géologique de Haute Provence).

Valuation of the inventory in international programs

In 1995, the International Union of Geological Sciences (IUGS) launched a project called Global Geosites to produce an inventory of sites of international relevance for conservation and to build a database of these global geosites, in connection with UNESCO. A working group (Global Geosites Working Group) was then established. But after a few years, the project was shelved by IUGS and UNESCO. In 2010, this project was reactivated; the IUGS created a new working group dedicated to geoheritage (Geoheritage Task Group). One of the purposes of the working group is to develop a database of international geosites (http://geoheritage-iugs.mnhn.fr/).

Geosites identified and validated in France at the national level in the National Inventory program, and considered of international relevance, may, for example, be transferred to the international database, similarly to those already identified in other countries (Netherlands, Portugal, Spain, etc.)

Conclusion

Despite an long interest in what we would now call geoheritage (with a first inventory compiled in 1913 by Martel), this topic has been generally poorly regarded in France. For years, only a few people and bodies were making a true effort in geoconservation, through a specific protection programme, the *Réserves Naturelles de France*.

A decade ago, a law was enacted and put the inventory, and therefore geoheritage in general, on the front stage (proscenium). A methodology was developed through wide collaboration and the inventory was launched some seven years ago. Such an inventory is a prerequisite for the identification and understanding of outstanding geological sites, and to assess their heritage value and their protection needs. But there is also the relevance of this 'new' concept of heritage fir the promotion and development of territories, alongside other more familiar types of heritage (cultural, architectural, industrial, etc.).

The inventory is conducted in such a manner that its data are compatible with other data concerning nature (fauna, flora, etc.). Thus, its results are directly usable by a wide community of geologists, managers and economists for research, education, geoconservation and geotourism – and a large part of the French territory is already covered with the inventory. In conclusion, the absence of an inventory was a handicap in France for a long time, but now that it is established it is revealed as a true advantage, promising a most interesting future for geoheritage across the territory.

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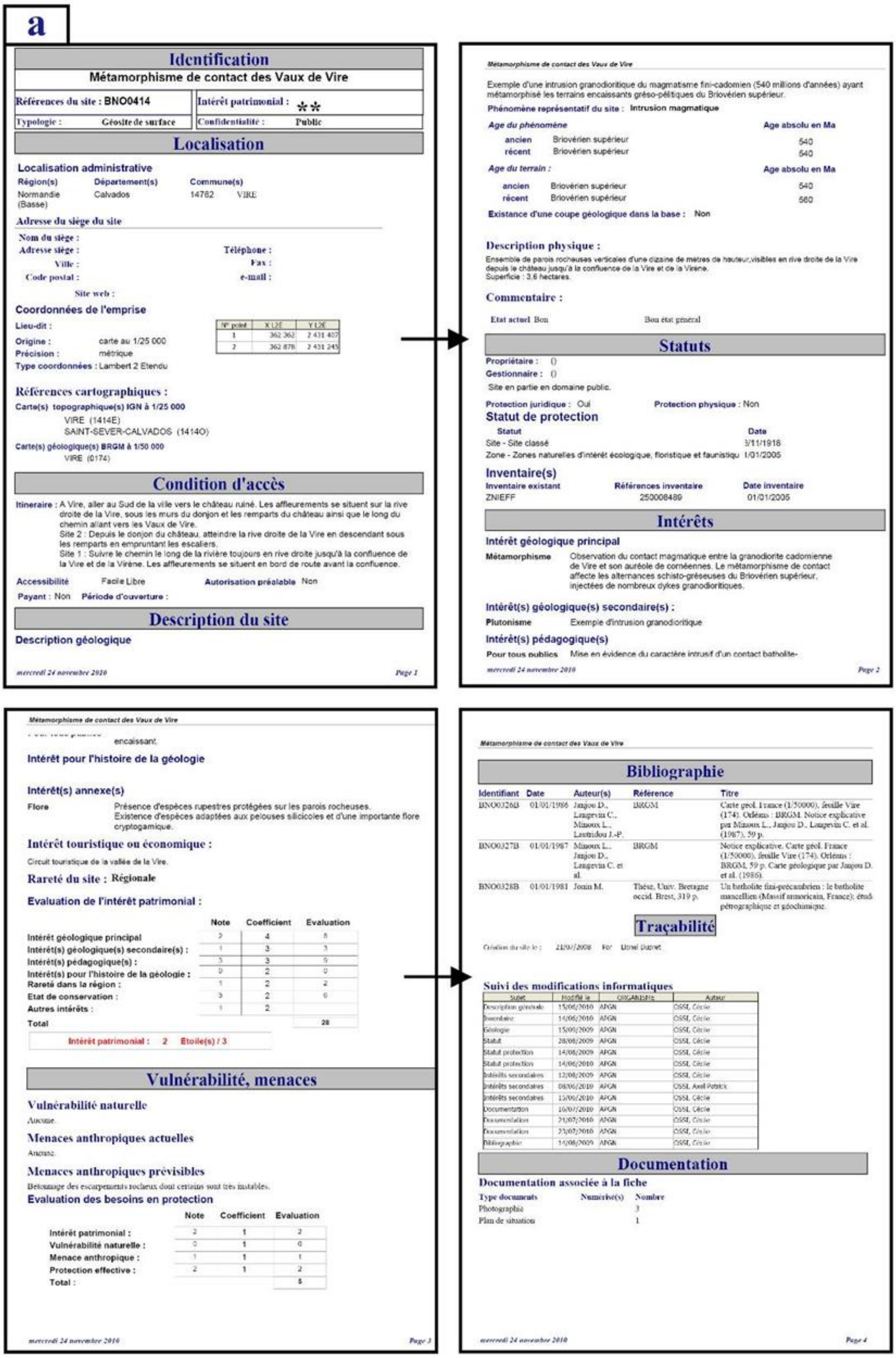
Appendix 1: The French law enacting the inventory of geological inventory: *Article L411-5 du code de l'environnement.*

http://www.legifrance.gouv.fr/affichCodeArticle.do;jsessionid=366CEC157AF9A6141272A572476FA595.tpdjo14v_1?cidTexte=LEGITEXT000006074220&idArticle=LEGIARTI000022495736&dateTexte=20120831&categorieLien=id#LEGIARTI000022495736

I. - L'inventaire du patrimoine naturel est institué pour l'ensemble du territoire national terrestre, fluvial et marin. On entend par inventaire du patrimoine naturel l'inventaire des richesses écologiques, faunistiques, floristiques, géologiques, minéralogiques et paléontologiques.
L'Etat en assure la conception, l'animation et l'évaluation. Les régions peuvent être associées à la conduite de cet inventaire dans le cadre de leurs compétences. En outre, les collectivités territoriales peuvent contribuer à la connaissance du patrimoine naturel par la réalisation d'inventaires locaux, ayant notamment pour objet de réunir les connaissances nécessaires à l'élaboration du schéma régional de cohérence écologique mentionné à l'article L. 371-3 .
Le préfet de région, les préfets de départements et les autres collectivités territoriales concernées sont informés de ces élaborations.
Ces inventaires sont conduits sous la responsabilité scientifique du Muséum national d'histoire naturelle.
Lors de l'élaboration d'un plan, programme ou projet, le préfet communique à la commune ou à l'établissement public de coopération intercommunale compétent toutes informations contenues dans ces inventaires utiles à cette élaboration.
II. - Les dispositions de la loi du 29 décembre 1892 sur les dommages causés à la propriété privée par l'exécution des travaux publics sont applicables à l'exécution des opérations nécessaires à la conduite de ces inventaires. Ces dispositions sont également applicables à la connaissance du sol, de la végétation et de tout renseignement d'ordre écologique sur les territoires d'inventaires.
III. - Il est institué dans chaque région un conseil scientifique régional du patrimoine naturel. Ce conseil est constitué de spécialistes désignés intuitu personae pour leur compétence scientifique, en particulier dans les universités, les organismes de recherche, les sociétés savantes, les muséums régionaux. Il couvre toutes les disciplines des sciences de la vie et de la terre pour les milieux terrestres, fluviaux et marins.
Ses membres sont nommés par arrêté du préfet de région après avis du président du conseil régional.
Il élit en son sein un président.
Il peut être saisi pour avis par le préfet de région ou le président du conseil régional sur toute question relative à l'inventaire et à la conservation du patrimoine naturel.
Un décret en Conseil d'Etat définit sa composition, ses domaines d'intervention et précise les conditions dans lesquelles il est saisi.

Appendix2: An example of information provided for a site belonging to the inventory. A typical report has between 3 and 10 pages,at least one ma, and several pictures.


a

Identification

Métamorphisme de contact des Vaux de Vire

Références du site : BNO0414 | Intérêt patrimonial : **
Typologie : Géosite de surface | Confidentialité : Public

Localisation

Localisation administrative

Région(s)	Département(s)	Commune(s)
Normandie (Basse)	Calvados	14762 VIRE

Adresse du siège du site

Nom du siège :
Adresse siège : Téléphone :
Ville : Fax :
Code postal : e-mail :
Site web :

Coordonnées de l'emprise

Lieu-dit :
Origine : carte au 1/25 000
Précision : métrique
Type coordonnées : Lambert 2 Etendu

N° point	X L2E	Y L2E
1	362 362	2 431 407
2	362 878	2 431 245

Références cartographiques :
Carte(s) topographique(s) IGN à 1/25 000
VIRE (1414E)
SAINT-SEVER-CALVADOS (1414O)
Carte(s) géologique(s) BRGM à 1/50 000
VIRE (0174)

Condition d'accès

Itineraire : A Vire, aller au Sud de la ville vers le château ruiné. Les affleurements se situent sur la rive droite de la Vire, sous les murs du donjon et les remparts du château ainsi que le long du chemin allant vers les Vaux de Vire.
Site 2 : Depuis le donjon du château, atteindre la rive droite de la Vire en descendant sous les remparts en empruntant les escaliers.
Site 1 : Suivre le chemin le long de la rivière toujours en rive droite jusqu'à la confluence de la Vire et de la Virène. Les affleurements se situent en bord de route avant la confluence.

Accessibilité Facile Libre Autorisation préalable Non
Payant : Non Période d'ouverture :

Description du site

Description géologique

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Métamorphisme de contact des Vaux de Vire

Exemple d'une intrusion granodioritique du magmatisme fini-cadomien (540 millions d'années) ayant métamorphisé les terrains encaissants grèso-pélitiques du Briovérien supérieur.
Phénomène représentatif du site : Intrusion magmatique

Age du phénomène		Age absolu en Ma
ancien	Briovérien supérieur	540
récent	Briovérien supérieur	540

Age du terrain :		Age absolu en Ma
ancien	Briovérien supérieur	540
récent	Briovérien supérieur	560

Existance d'une coupe géologique dans la base : Non

Description physique :
Ensemble de parois rocheuses verticales d'une dizaine de mètres de hauteur,visibles en rive droite de la Vire depuis le château jusqu'à la confluence de la Vire et de la Virène.
Superficie : 3,6 hectares.

Commentaire :

Etat actuel Bon Bon état général

Statuts

Propriétaire : ()
Gestionnaire : ()
Site en partie en domaine public.

Protection juridique : Oui Protection physique : Non

Statut de protection

Statut	Date
Site - Site classé	3/11/1918
Zone - Zones naturelles d'intérêt écologique, floristique et faunistiqu	1/01/2005

Inventaire(s)

Inventaire existant	Références inventaire	Date inventaire
ZNIEFF	250008489	01/01/2005

Intérêts

Intérêt géologique principal
Métamorphisme Observation du contact magmatique entre la granodiorite cadomienne de Vire et son auréole de cornéennes. Le métamorphisme de contact affecte les alternances schisto-grèseuses du Briovérien supérieur, injectées de nombreux dykes granodioritiques.

Intérêt(s) géologique(s) secondaire(s) :
Plutonisme Exemple d'intrusion granodioritique

Intérêt(s) pédagogique(s)
Pour tous publics Mise en évidence du caractère intrusif d'un contact batholite-

mercredi 24 novembre 2010 Page 2

Métamorphisme de contact des Vaux de Vire

encaissant.

Intérêt pour l'histoire de la géologie

Intérêt(s) annexe(s)
Flore Présence d'espèces rupestres protégées sur les parois rocheuses. Existence d'espèces adaptées aux pelouses silicicoles et d'une importante flore cryptogamique.

Intérêt touristique ou économique :
Circuit touristique de la vallée de la Vire.

Rareté du site : Régionale

Evaluation de l'intérêt patrimonial :

	Note	Coefficient	Evaluation
Intérêt géologique principal	2	4	8
Intérêt(s) géologique(s) secondaire(s) :	1	3	3
Intérêt(s) pédagogique(s) :	3	3	9
Intérêt(s) pour l'histoire de la géologie :	0	2	0
Rareté dans la région :	1	2	2
Etat de conservation :	3	2	6
Autres intérêts :	1	2	
Total			28

Intérêt patrimonial : 2 Etoile(s) / 3

Vulnérabilité, menaces

Vulnérabilité naturelle
Aucune.

Menaces anthropiques actuelles
Aucune.

Menaces anthropiques prévisibles
Bétonnage des escarpements rocheux dont certains sont très instables.

Evaluation des besoins en protection

	Note	Coefficient	Evaluation
Intérêt patrimonial :	2	1	2
Vulnérabilité naturelle :	0	1	0
Menace anthropique :	1	1	1
Protection effective :	2	1	2
Total :			5

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Métamorphisme de contact des Vaux de Vire

Bibliographie

Identifiant	Date	Auteur(s)	Référence	Titre
BNO0326B	01/01/1986	Janjou D., Langevin C., Minoux L., Lautridou J.-P.	BRGM	Carte géol. France (1/50000), feuille Vire (174). Orléans : BRGM. Notice explicative par Minoux L., Janjou D., Langevin C. et al. (1987), 59 p.
BNO0327B	01/01/1987	Minoux L., Janjou D., Langevin C. et al.	BRGM	Notice explicative. Carte géol. France (1/50000), feuille Vire (174). Orleans : BRGM, 59 p. Carte géologique par Janjou D. et al. (1986).
BNO0328B	01/01/1981	Jonin M.	Thèse, Univ. Bretagne occid. Brest, 319 p.	Un batholite fini-précambrien : le batholite mancellien (Massif armoricain, France); étud. pétrographique et géochimique.

Traçabilité

Création du site le : 21/07/2008 Par Lionel Dupret

Suivi des modifications informatiques

Sujet	Modifié le	ORGANISME	Auteur
Description générale	15/06/2010	APGN	OSSL Cécile
Inventaire	14/06/2010	APGN	OSSL Cécile
Géologie	15/09/2009	APGN	OSSL Cécile
Statut	28/08/2009	APGN	OSSL Cécile
Statut protection	14/08/2009	APGN	OSSL Cécile
Statut protection	14/06/2010	APGN	OSSL Cécile
Intérêts secondaires	12/08/2009	APGN	OSSL Cécile
Intérêts secondaires	08/06/2010	APGN	OSSL Axel Patrick
Intérêts secondaires	15/06/2010	APGN	OSSL Cécile
Documentation	16/07/2010	APGN	OSSL Cécile
Documentation	21/07/2010	APGN	OSSL Cécile
Documentation	23/07/2010	APGN	OSSL Cécile
Bibliographie	14/08/2009	APGN	OSSL Cécile

Documentation

Documentation associée à la fiche

Type documents	Numérisé(s)	Nombre
Photographie		3
Plan de situation		1

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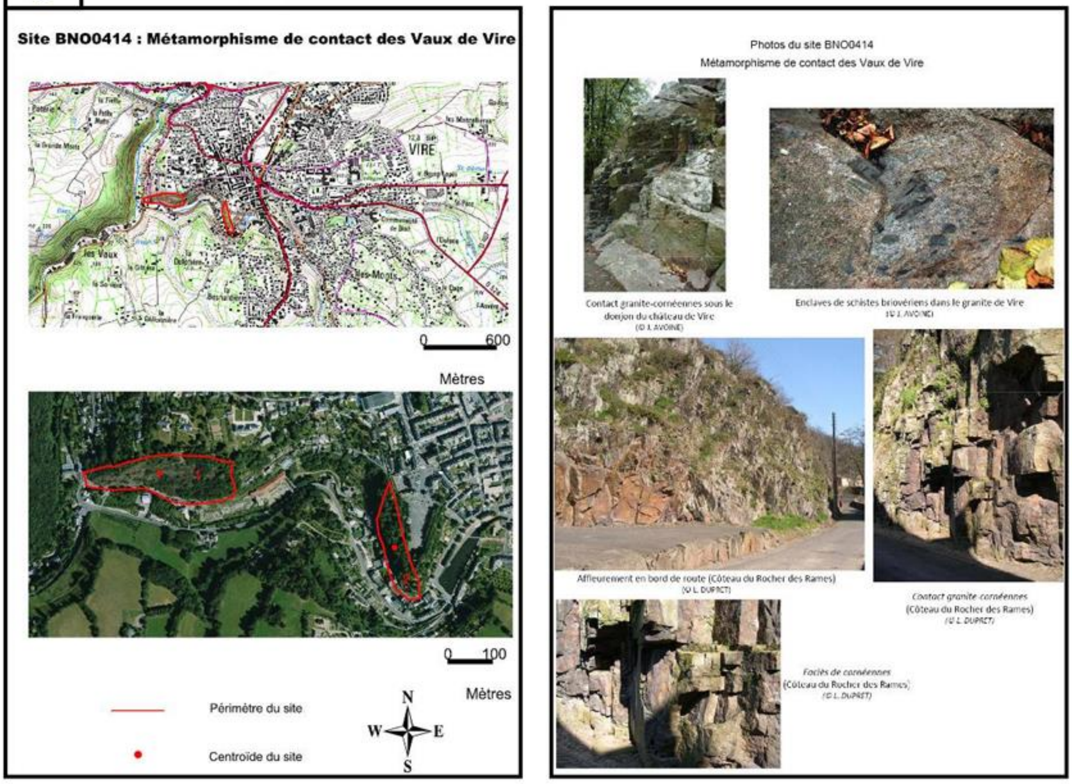
b


Site BNO0414 : Métamorphisme de contact des Vaux de Vire
VIRE
0 600
Mètres
0 100
Mètres
Périmètre du site
Centroïde du site
N
W
E
S
Photos du site BNO0414
Métamorphisme de contact des Vaux de Vire
Contact granite-cornéennes sous le donjon du château de Vire
(© J. AVOINE)
Enclaves de schistes briovériens dans le granite de Vire
(© J. AVOINE)
Affleurement en bord de route (Côteau du Rocher des Rames)
(© L. DUPRET)
Contact granite-cornéennes
(Côteau du Rocher des Rames)
(© L. DUPRET)
Faciès de cornéennes
(Côteau du Rocher des Rames)
(© L. DUPRET)

Appendix3: Internet sources for state geosite inventories in Europe.

Czech Republic
Czech Geological Survey(2014). Significant geological localities of the Czech Republic: http://www.geology.cz/extranet-eng/geology-for-all/geological-localities

Denmark
Geological Survey of Denmark(2006). Geosites in Denmark: http://geosites.dk/

Estonia
Geological Survey of Estonia (2014).Estonian Geosites: http://www.egk.ee/about-gse/geological-treasures/geosites/?lang=en

Finland
Finnish Environment Institute (SYKE) (2014). National Inventory of geological formations: http://www.ymparisto.fi/fi-FI/Luonto/Geologiset_muodostumat (in Finnish)

Ireland
Geological Survey of Ireland (2014). Irish Geological Heritage Program: http://www.gsi.ie/Programmes/Heritage+and+Planning/

Italy
Environmental protection and research institute (ISPRA) (2009). The Geosites database: http://sgi2.isprambiente.it/geositiweb/

Lithuania
Lithuanian Geological Survey (2011).Geotops database: http://www.lgt.lt/index.php?page=33&mod_id=69&action=showFull&id=219&lang=en

Netherlands
Netherlands Organisation for Applied Scientific Research (TNO) (2014).Geosites in Netherlands: http://www.geosites.nl/ (in Dutch)

Poland
Institute of Nature Conservation of the Polish Academy of Sciences (2012).Database of Polish Representative Geosites: http://www.iop.krakow.pl/geosites

Slovakia
State Geological Institute of Dionýz Štúr (State Geological Survey of the Slovak Republic) (2014).Important Geological Sites: http://mserver.geology.sk:8085/g_vgl/?jazyk=EN

Spain
Geological Survey of Spain (IGME) (2014).Spanish inventory of sites of geological interest: http://info.igme.es/ielig/ (in Spanish).

Switzerland
Lausanne University Geography Institute (IGUL) (2010). Geosites of national importance-swiss inventory: http://mesoscaphe.unil.ch/geodata/geosites2/

United-Kingdom

Joint Nature Conservation Committee (2008). Geological Conservation review: http://jncc.defra.gov.uk/page-2947