



Speleothems of French Limestone Caves, Outstanding Records of Karst Processes and Archives of Palaeo-climates

*File of nomination for inscription on the list of
World heritage of UNESCO as a natural property*



Volume 1

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Volume 1 **General presentation**

The official nomination file has been written in French; however, it was deemed useful, in the prospect of the assessment, to make an English version of the general presentation (vol. 1); the French version remains the reference version.

Volume I: general document of the proposition

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EXECUTIVE SUMMARY

State party

France

State, province or region

Three regions in the South of France: Midi-Pyrenees, Languedoc-Roussillon, Rhône-Alpes.

Name of property

The speleothems of French limestone caves, outstanding records of karst processes and paleoclimates.

Geographic coordinates to the nearest second

The geographic coordinates are those of the main entrances of 18 subterranean sites constituting the property.

Element number of each site	Name	Latitude in degrees, minutes and seconds of the site (WGS84)	longitude in degrees, minutes and seconds of the site (WGS84)
01	Grotte Amélineau	N 44° 12' 08"	E 003° 19' 24"
02	Grotte de Choranche	N 45° 04' 15"	E 005° 23' 54"
03	Aven Armand	N 44° 13' 21"	E 003° 21' 20"
04	Grottes des Demoiselles	N 43° 54' 28"	E 003° 44' 41"
05	Balme del Pastre	N 43° 43' 21"	E 002° 59' 25"
06	Grotte de l'Aguzou	N 42° 45' 41"	E 002° 05' 32"
07	Grotte du Lauzinas	N 43° 28' 46"	E 002° 44' 28"
08	Grotte du TM 71	N 42° 45' 23"	E 002° 05' 09"
09	Réseau de Cabrespine-Lastours	N 43° 21' 34"	E 002° 27' 25"
10	Gouffre d'Esparros	N 43° 01' 50"	E 000° 19' 48"
11	Grotte de Pousselières	N 43° 28' 21"	E 002° 52' 37"
12	Grotte de Clamouse	N 43° 42' 34"	E 003° 33' 10"
13	Réseau Lachambre	N 42° 36' 01"	E 002° 23' 00"
14	Réseau du Rautely	N 43° 31' 25"	E 002° 54' 41"
15	Aven du Mont Marcou	N 43° 41' 36"	E 003° 00' 21"
16	Grotte de la Cigalère	N 42° 49' 38"	E 000° 54' 25"
17	Aven d'Orgnac	N 44° 19' 12"	E 004° 24' 43"
18	Barrencs de Fournes	N 43° 20' 02"	E 002° 22' 56"

Textual description of the boundaries of the nominated property

It is a set of 18 subterranean sites with speleothems (caves, group of cavities) located in southern France.

Cf. administrative map of France with location with regard to Regions.

A4 size map of the nominated property, showing boundaries and buffer zone (if present)

Cf. map of the South of France with regional administrative limits and location of nominated caves (identification by numbers).

Each of the 18 sites is localized on a map of situation (scale 1/25000) and on a map of the protections showing the central zone and the buffer zones (cf. maps appendix).

Surface of the property and of the buffer zone

The surface of the property is **3 581.36 ha**, the surface of the buffer zone without double count is **51 457.33 ha**.

Justification, Statement of Outstanding Universal Value

The speleothems of the 18 sites in Southern France (caves, group of cavities), owing to the exceptional variety of morphologies and crystal forms, constitute a unique set which represents all the variety of transfer processes (present and ancient) and crystallization deposits in karst cavities. Because of the localisation of the different sites, this group also represents an exceptional opportunity for scientific studies of these phenomena and constitutes a precious record of palaeo-climates. Besides, this group illustrates, on a limited territory, a subterranean patrimony of an exceptional beauty the aesthetic quality of which is unanimously recognized.

Criteria under which property is nominated

The criteria (vii), (viii) which are defined for the natural heritage

The criterion (vii): contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance.

The subterranean karst environments have developed and preserved mineral morphologies unknown in surface: the speleothems. The set of speleothems from the 18 caves of the South of France contains the fundamental elements illustrating the aesthetic diversity and quality of these particular natural objects. The shapes of the speleothems, their colours, their association between each other and with the rock support, finally their location mostly in caves with extraordinary morphologies determine the aesthetic quality of this set.

The criterion (viii): be outstanding examples representing major stages of the history of earth, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.

The speleothems of the 18 French sites constitute an eminently representative set of all the different mineralogical and morphological expressions of chemical desposition in karst systems. This exceptional concentration of remarkable sites is located in a territory with a very rich geologic heritage, marked by the recent climatic history. Owing to the continuous deposition and the sensitivity to the outside environmental evolutions, speleothems can be considered as valuable natural archives of palaeo-climates in continental environments.

Name and contact information of official local institution/agency

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Properties for inscription on the World Heritage List

1. IDENTIFICATION OF THE PROPERTY

1.a Country

France

1.b State, Province or Region

The different components of the property are located in three regions of the South of France, 9 départements, and 24 communes.

Régions	Départements	Number of communes
Midi-Pyrénées	Ariège (09)	1
	Aveyron (12)	1
	Hautes-Pyrénées (65)	1
Languedoc-Roussillon	Aude (11)	8
	Hérault (34)	7
	Lozère (48)	1
	Pyrénées-orientales (66)	2
Rhône-Alpes	Ardèche (07)	1
	Isère (38)	2

1.c Name of Property

Speleothems of French limestone caves, outstanding records of karst processes and palaeoclimates

1.d Geographical coordinates to the nearest second

The property consists of a series of 18 subterranean sites containing the speleothems

Element number of each site	Name	Région	Département	Latitude in degrees, minutes and seconds of the site (WGS84)	longitude in degrees, minutes and seconds of the site (WGS84)
01	Grotte Amélineau	Languedoc-Roussillon	Lozère	N 44° 12' 08"	E 003° 19' 24"
02	Grotte de Choranche	Rhône-Alpes	Isère	N 45° 04' 15"	E 005° 23' 54"
03	Aven Armand	Languedoc-Roussillon	Lozère	N 44° 13' 21"	E 003° 21' 20"
04	Grottes des Demoiselles	Languedoc-Roussillon	Hérault	N 43° 54' 28"	E 003° 44' 41"
05	Balme del Pastre	Midi-Pyrénées	Aveyron	N 43° 43' 21"	E 002° 59' 25"
06	Grotte de l'Aguzou	Languedoc-Roussillon	Aude	N 42° 45' 41"	E 002° 05' 32"
07	Grotte du Lauzinas	Languedoc-Roussillon	Hérault	N 43° 28' 46"	E 002° 44' 28"
08	Grotte du TM 71	Languedoc-Roussillon	Aude	N 42° 45' 23"	E 002° 05' 09"
09	Réseau de Cabrespine-Lastours	Languedoc-Roussillon	Aude	N 43° 21' 34"	E 002° 27' 25"
10	Gouffre d'Esparros	Midi-Pyrénées	Hautes-Pyrénées	N 43° 01' 50"	E 000° 19' 48"
11	Grotte de Pousselières	Languedoc-Roussillon	Hérault	N 43° 28' 21"	E 002° 52' 37"
12	Grotte de Clamouse	Languedoc-Roussillon	Hérault	N 43° 42' 34"	E 003° 33' 10"
13	Réseau Lachambre	Languedoc-Roussillon	Pyrénées-Orientales	N 42° 36' 01"	E 002° 23' 00"
14	Réseau du Rautely	Languedoc-Roussillon	Hérault	N 43° 31' 25"	E 002° 54' 41"
15	Aven du Mont Marcou	Languedoc-Roussillon	Hérault	N 43° 41' 36"	E 003° 00' 21"
16	Grotte de la Cigalère	Midi-Pyrénées	Ariège	N 42° 49' 38"	E 000° 54' 25"
17	Aven d'Ornac	Rhône-Alpes	Ardèche	N 44° 19' 12"	E 004° 24' 43"
18	Barrencs de Fournes	Languedoc-Roussillon	Aude	N 43° 20' 02"	E 002° 22' 56"

* The geographic coordinates correspond to the main entrance of every element of the property.

1.e Maps and plans, showing the boundaries of the nominated property and buffer zone

Each of the 18 sites containing the elements of the property is reported on the map of France see below.

Each of the 18 sites is localized on a situation map and on a map of the protections showing the central zone and the buffer zones (cf. cartographic appendix).

For every site (numbered from 01 to 18 according to the scientific criteria), the cartography is also presented in appendix and in the following order:

- A: **Topography of the cavity** (plans, profiles or 3D according to the case)
- B: Transfer of the plan of the cave on the " **BD Ortho** " (**air photo**) except for the caves of Choranche (site n°2) and Aven d'Orgnac (site N 17) where IGN documents are not available. **The limits of the property** and of the **protected zone** (established or planned) also appear on this air photo (both limits often overlies).
- C: Transfer of the plan of the cave on the National Geographic Institute map « Scan 1/25000 », showing the **elevation lines** at the same scale as the "b" map **as well as the limits of the property** and **the protected zone** or in course of protection;
- D: Transfer of the plan of the cave on the cartography National Geographic Institute map «scan 1/25000», showing **the property and the buffer zone** (administrative limit of the commune).

For every map a linear scale is indicated on the document.

1.f Area of nominated property (ha.) and proposed buffer zone (ha.)

Involving a set of separate sites, the surface of the property corresponds to the sum of the surfaces of each of the sites, considering their respective central zones. The karst area needed to insure the integrity of the features in the proposed property is therefore considered as the central zone. These zones benefit of legal protection with adapted regulations.

Buffer zones are also generally separated. The surface of the buffer zone of the property corresponds to the sum of the surfaces of buffer zones of each of the sites, without double count. These buffer zones correspond to the territories of the “communes” containing the central zone.

In every case, the commune limit was chosen as a limit of the buffer zone of the property.

In 7 cases (sites n° 1, 10 to 13, 16 and 17), the limit of the element of the property is partly common with the “commune” boundary.

In any case, the conservation of the property is affected as all the environmental conditions related to the development and conservation of the speleothems were taken into account by the established protections. Indeed, the establishment of the buffer zone was not considered to be necessary because of local configurations: either these limit elements correspond to valley bottoms (sites our 1, 11, 12 and 13), or to limits of water catchment areas (sites our 10, 16 and 17). Further, the risk that industrial activities (quarries) could cause shakes or vibrations is considered as very small and completely under control thanks to existing regulations (environmental impact assessment studies, quarry legislation...).

Element number of the site	Name	Commune(s), n° of département (cf. table 1b)	Coordinates of the site	Surface of the central zone (ha)	Surface of the buffer zone (ha)
01	Grotte Amélineau	Hures-la-Parade (48)	N 44° 12' 08" E 003° 19' 24"	31.37	8 826.74
02	Grotte de Choranche	Choranche, Presle (38)	N 45° 04' 15" E 005° 23' 54"	611.70	3 019.30
03	Aven Armand	Hures-la-Parade (48)	N 44° 13' 21" E 003° 21' 20"	0.89	8 826.74
04	Grottes des Demoiselles	Saint-Bauzille-de-Putois (34)	N 43° 54' 28" E 003° 44' 41"	7.66	1 808.34
05	Balme del Pastre	Mélagues (12)	N 43° 43' 21" E 002° 59' 25"	16.38	4 434.62
06	Grotte de l'Aguzou	d'Escouloubre-les-Bains (11)	N 42° 45' 41" E 002° 05' 32"	232.20	2 881.80
07	Grotte du Lauzinas	Saint-Pons-de-Thomières (34)	N 43° 28' 46" E 002° 44' 28"	43.95	4 055.05
08	Grotte du TM 71	Fontanès-de-Sault (11)	N 42° 45' 23" E 002° 05' 09"	104.00	425.00
09	Réseau de Cabrespine-Lastours	Cabrespine, Trassanel, Fournes-Cabardès, Lastours, Sallèles-Cabardès, Limousis (11)	N 43° 21' 34" E 002° 27' 25"	968.90	4 420.10
10	Gouffre d'Esparros	Esparros (65)	N 43° 01' 50" E 000° 19' 48"	43.65	3 212.35
11	Grotte de Pousselières	Ferrières-Poussarou (34)	N 43° 28' 21" E 002° 52' 37"	13.57	2 587.43
12	Grotte de Clamouse	Saint-Jean-de-Vedas (34)	N 43° 42' 34" E 003° 33' 10"	111.20	1 289.00
13	Réseau Lachambre	Ria-Sirach, Corneilla-de-Conflent (66)	N 42° 36' 01" E 002° 23' 00"	281.20	2 102.80
14	Réseau du Rautely	Olargues, Saint Etienne d'Albagnan (34)	N 43° 31' 25" E 002° 54' 41"	76.63	4 053.37
15	Aven du Mont Marcou	Saint-Geniès-de-Varensal (34)	N 43° 41' 36" E 003° 00' 21"	37.17	1 217.83
16	Grotte de la Cigalère	Sentein (09)	N 42° 49' 38" E 000° 54' 25"	598.50	5 319.50
17	Aven d'Orgnac	Orgnac-l'Aven (07)	N 44° 19' 12" E 004° 24' 43"	379.90	1 804.10
18	Barrency de Fournes	Lastours, Fournes-Cabardès, Limousis (11)	N 43° 20' 02" E 002° 22' 56"	40.39	1 972.00
Total surface of the nominated property with double count*				3 599.25	
Total surface of the nominated property without double count				3 581.36	
Total surface of the buffer zone of the nominated property with double counts**					62 760.68
Total surface of the buffer zone of the nominated property without double count					51 457.33

* double count for the central zone of the sites of Barrency de Fournes and the system of Cabrespine-Lastours

* * two double counts for the buffer zones of two sites:

1) the Amélineau cave and the Aven Armand, 2) Les Barrency de Fournes and the system of Cabrespine-Lastours.

2. DESCRIPTION

2.a Description of the Property

The property is a set of cave deposits (speleothems) considered in their natural environment. All the main types of speleothems are represented on a limited territory and form an exceptional group owing to their quality and variety.

The property consists of 18 subterranean sites in the South of France, illustrating the variety of the mineralogies, the shapes and the colours of the speleothems, this variety is strongly related to the functioning of the karst system, the paleoenvironment and the evolution of the climate.

The elements of the property were selected according to the mineralogical representativeness of the set, to the exceptional quality of their elements and to the particularly illustrative character of the morphologies and the associations of speleothems in the karst natural processes. The numbering was defined according to the following scientific criteria of selection.

- Caves with mainly calcite speleothems: 01 - Grotte Amélineau, 02 - Grotte de Choranche, 03 - Aven Armand, 04 – grotte des demouiseselles, 05 - Balme del Pastre, 06 - Grotte de l'Aguzou, 07 - Grotte du Lauzinas, 08 - Cave of the TM 71.
- Caves with white aragonite speleothems of: 09 - Réseau de Cabrespine-lastours, 10 - Gouffre d'Esparros, 11 - Grotte de Pousselière, 12 - Grotte de Pousselière, 13 - Réseau Lachambre.
- Caves with colored aragonite speleothems : 14 - Réseau de Rautely, 15 - Aven du Mont Marcou.
- Cave with gypsum speleothems : 16 - Grotte de la Cigalère.
- Cave with remarkable recording of climatic cycles in speleothems: 17 - Aven d'Orgnac.
- Cave with speleothems presenting diagenesis features: 18 - Barrencs de Fournes.

2.a-1 speleothems, the record of the karst functioning (at the scale of the whole system)

The speleothems of the 18 subterranean sites give evidence of the various aspects of the functioning of the karst system. The nature of rock formations, the present or ancient hydraulic functioning, the history of sites and the relationships with the surface are factors of influence on cave mineral deposition, perfectly illustrated in the selected sites. Nowadays, this correlation opens the road to new scientific perspectives.

2.a.1.1 A set of sites particularly illustrative of karst and its functioning

Karst is both a surface and a subterranean landscape; it holds a special ecosystem and an aquifer with a complex behaviour. The secondary cave mineral deposits (the speleothems), show a unique morphogenesis process strikingly exhibited in the property.

The karst aquifer (Alain Mangin 1975)

karst: from surface to caves

Speleothems are integral components of most karst systems. Karst is a set of original morphologies and landscapes developed in soluble rock formations, mainly limestones.

In surface, landforms generated by fluvial networks are lightly marked or absent because of a mainly subterranean drainage pattern. They are replaced by particular landforms: lapiés, canyons, closed depressions.

In the selected sites, the lapiés of Bentaillou over the Grotte de la Cigalère, the gorges de la Jonte or the gorges du Tarn, the cirque de Choranche illustrates the main karstic land forms.

Gorges de l' Hérault in front of la grotte de Clamouse

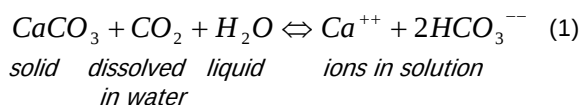
Underground, the drainage pattern develops in networks of interconnected voids, some of which are open to man. In caves, secondary mineral bodies (the speleothems) are deposited by seepage water.

These speleothems contribute to the specificity of the karstic landscapes. The exceptional series of 18 caves with speleothems of Southern France is nominated for the inscription.

The subterranean river of the Grotte de la Cigalère

Water, soil and rock

Karst genesis results from the dissolution of rocks (limestones) by rainwater acidified in grounds, mainly by carbon dioxide of biologic origin. The chemical mechanisms are simplified in the following equation:



Dissolution gradually widens the rock cracks and constitutes therefore a network of interconnected and hierarchized voids. Finally, the main part of rain water seeps in a subterranean hydrographic system in which large flooded volumes constitute water reserves (55 % of French subterranean water reserves are to be found in karst). These waters often resurge in big springs. Some sites present remarkable examples: *resurgence de Couffin and Gournier in Choranche, resurgence du Pestril of the réseau Cabrespine-Lastours, source vaclusienne du Jaur from the system of Lauzinas, the resurgence of Clamouse.*

calcite speleothems along a rock-crack in the Grotte du Lauzinas

The subterranean networks and the organization of karst

Water infiltration in the formerly fissured rock is supposed to be responsible for the genesis and the geometrical organization of the subterranean karst network; in this sense karst is considered as an auto-organized system. The system is constituted by an infiltration zone, the top of which (epikarst) is often occupied by a superficial aquifer; this zone is located over a flooded zone.

Main conduits like subterranean rivers in several sites of the property enable the drainage. *The river of Cabrespine is remarkable as well as the stream of La Cigalère with its 26 waterfalls and the two rivers of the Grotte de Choranche, the confluence of which is a subterranean lake.*

Laterally to these drains, annex void systems including large volumes constitute the water reserves of the karst system. *The remnants of these flooded volumes are exceptionally represented in l'Aven Armand, Grotte des Demoiselles and in the Orgnac cave system.*

Aven of Orgnac – Les salles rouges

Distance of 100 metres between the objective photo and the back of the room

If primary morphologies of caves result from drainage, the complex history of the karsts generated also secondary morphologies: the sequence of fillings and erosion of detritic sediments sometimes develop paragenetic galleries with “*chenaux de voûte*”, and particular corrosions shapes of the walls. The underground streams deposited sedimentary bodies in the caves and left mechanical erosion marks on cave walls. *The Cabrespine-Lastours, Lauzinas or Orgnac-Issirac networks present the main evoked characters.*

Cave mineral deposition in karst evolution

1) The genesis of karst

On the one hand, it requires a preliminary tectonic event responsible for the general fissuring of soluble rock formations, on the other hand a land topography in which hydraulic gradients can be generated under sufficiently rainy conditions. Note that the karstification of limestone areas also requires a soil where the seeping waters can dissolve carbon dioxide and become aggressive for the rock material. The setting up of a karst system is a relatively rapid phenomenon at the geological time scale: 10,000 – 20,000 years, compared with the 450 000 years which are necessary to reach equilibrium for reliefs in surface. Many of the active karsts are recent: the quaternary era or the end of Cenozoic times.

2) The stable phases and the cave mineral deposition

The phases of stability of a karst result from a dynamic equilibrium established in a system open to the outside. In these conditions, evolution inside the physical system is very slow. Seepage water continues the dissolution of limestone with a downward redistribution of the mineral in voids of the infiltration zone which as a consequence tend to seal.

The river and the ceilings of straws from the Grotte de Choranche

Several stable phases can succeed one another in time and mark in bedrock solution features and sediments filling the subterranean space. In our regions, they are related to the effects of the glaciations which considerably modified the outside environment, particularly the plants, the base levels and the rainfall regime of the last million years. The results are polyphase sediments and speleothems. *Analyses in the cave of Clamouse and in Orgnac-Issirac clearly illustrates this phenomenon.*

3) Loss of the functioning or destruction.

The end of karst functioning mainly occurs by decay and stop of the subterranean drainage and finally the sealing of underground voids. The evolution by ablation leads erosion to truncate the cave systems. Anthropological effects (pollutions, inadequate equipments or overcrowding) can also affect seriously the karst environment and mostly the speleothems.

Chemical mechanisms in cave mineral deposition

If the karst subterranean networks are the natural frame of this deposition processes, the characteristics of this particular environment enable to understand the chemical origin of speleothems and enlighten their typology, of which the 18 sites of the property provide the most complete illustration.

Seepage waters of karst pick up ions as they go downward through the rock material and dissolve minerals. A long seeping time shifts compositions close to saturation with dissolved calcium carbonate. In the infiltration zone, the subterranean drainage brings this water, often strongly mineralized with bicarbonates, in large and relatively ventilated subterranean voids. A chemical gradient appears then at the interface between water and the subterranean atmosphere, allowing the release of dissolved carbon dioxide. The chemical balance (1) is then moved leading to the supersaturation of waters in calcium carbonate which precipitates and crystallizes into the form of speleothems *(most of those presented)*. At the outlets of underground streams, the same phenomenon can form travertine. *The big tuff constructions of "resurgences de Couffin et Gournier" in the "cirque de Choranche" supply spectacular examples.*

The tuff structures in the cirque of Choranche

Evaporation is also at the origin of the supersaturation of water and mineral precipitation; it is the main phenomenon when crystals of gypsum form from waters containing dissolved sulfate (*exceptional speleothems of la Grotte de la Cigalère*). Evaporation is also an active process in the crystallization of carbonates (*aragonites, hydromagnésites of the Grotte de Clamouse and the Réseau Lachambre*).

helictite of aragonite and hydromagnesite over calcite in Réseau Lachambre

2.a.1.2 The mineralogy of the speleothems of the property : illustration of the variety of a geologic heritage

The speleothems of the property, through their mineralogies and colors illustrate all the geological richness of the territory characterized by the variety of composition and organization of "parent rocks".

A rich geologic heritage

In the 18 sites, the property offers a remarkable variety of natural conditions owing to the coincidence of a particularly rich geologic heritage, a situation in an active tectonic zone and a strong impact of the recent climatic history. This territory includes different geologic ensembles: the southern Central Massif, the Pyrenees and the Alps; these have a complex recent tectonic history which is that of the alpine orogeny initiated in Eocene times (40 million years) in the Pyrénéo-Provençal domain and is still going on. These movements raise finally the important reliefs of the Pyrenees and the Alps. Since Oligocene (30 million years), this region also underwent strong climatic variations contrasted by the proximity of the mountain massifs which many times carried important glaciers (quaternary glaciations of the last two million years) and of the Mediterranean Sea which underwent an almost total drying with a fall of the sea level of more than 1500 metres during the messinian crisis (6.8 to 5.3 million years). It is interesting to notice that, from the point of view of the biodiversity, the region of Pyrénées-Cévennes-Alps is also exceptional by its high rate of endemism.

Karst is mainly developed in limestones, dolomitic limestones or dolomites. The calcite mineral CaCO_3 constitutes limestones, dolomite $\text{MgCa}(\text{CO}_3)_2$ constitutes the dolomites; dolomitic limestones are associations of both minerals. However, these rocks contain other soluble minerals: metal sulphides, sulfates. After dissolution, the mineral content of waters, although mainly bicarbonated calcic, varies in composition (variations of Mg/Ca ratio, occurrences of ions S and trace elements Ni, Cu etc.). The cave mineral deposits reflect these water chemical differences through the variety of the mineral species such as calcite, aragonite, gypsum for the main part, or rarer minerals and their colours. Trace elements are identified in speleothems where they constitute local chemical markers: *arsenic in the aragonites of the grotte de Cabrespine*.

According to Gèze 1973, modified 2005

Minerals forming the speleothems

The mineralogical representativeness of the whole series was one of the main criteria of choice of the sites. If calcite is ubiquitous, rarer minerals constituting speleothems (aragonite, gypsum), are represented in reference sites of the series.

Calcite and aragonite are the most frequent minerals constituting the speleothems; they are two polymorphs of the calcium carbonate, that is with the same chemical composition but with different structures. Calcite crystallizes in the rhomboedric system; it is the most stable mineral and it constitutes the greatest proportion of speleothems. Aragonite is orthorhombic, it is rarer and less stable; although common in the animal kingdom, forming shells or pearls, it doesn't occur in geologic formations or fossils because it inverts to calcite on long periods. It is dolomitic limestones or dolomites (rich in Mg) that hold the totality of caves with aragonite speleothems. A shared explanation is that the abundance of the magnesium in solutions favours the crystalline growth of aragonite.

Calcites from « la galerie des fleurs » in the Grotte de l'Aguzou
Aragonites from the « Grotte de Cabrespine »

Gypsum (sulfate of hydrated calcium) is rarer; it is related in the selected sites to the leaching of sulphide minerals and displays very particular crystal forms. Other minerals (carbonates, sulfates, oxides and sulphides) are rare or exceptional in caves and precipitate in very special conditions.

*Grotte de Pousselière-**Needles of Aragonites**Barrencs de Fournes- Aragonite in
«chappelet de boules»*

Several sites of the property were selected for their mineralogical contents (mineral species or crystal forms) which make each of them a unique reference at the world level. The Réseau Lachambre is an exceptional site for the aragonite and the hydromagnesite (carbonate of hydrated magnesium) but also for the quantity and the quality of its crystallizations; particular crystal forms of aragonite and calcite are present in the Gouffre d'Esparros (crystals with curved faces); exceptional or unique morphologies ("chapelets de boules", aragonites speleothems with symmetries 2-3-4) are found in the sites of Barrencs de Fournes and Pousselières.

Mineral succession calcite-aragonite-gypse in the Grotte de la Cigalère

“La Grotte de la Cigalère” is a world reference for the speleothems of gypsum; besides, this site contains extremely rare speleothems of pyrite and blende and cave deposits made of limonite, hématite and goethite. Unusual minerals: the hydromagnésite and the huntite (carbonate of magnesium and calcium anhydre) are found in the cave of Clamouse.

The colours of the speleothems

The colour of speleothems has also been a criterium of choice for the rarities of tints which often mark special geochemical heritage and for the aesthetic quality of the mineral associations.

The concretions are often coloured; while the three main minerals which constitute them (calcite, aragonite and gypsum) are clear and colorless when pure. The origins of tints can be different: the polycrystalline fine grained texture often gives the white colour and the opaqueness, the milky white aspect is due to the dispersal of the light by micro-inclusions of water, while the yellow, orange-coloured or brown classic pigmentations result from the presence of organic acids. *Thus a complete palette of these tints from the strongest browns or reds to the most clear ochres are illustrated in an exceptional way in the site of Lauzinas.*

The draperies of the “Grotte du Lauzinas”

Peculiarities of the bed rock produce very varied and rare colourings by integration or replacement of metal elements in the crystalline network of speleothems : the copper gives beautiful blue to green tints to calcite and aragonite. *The blue aragonites in Barrencs de Fournes, those from the TM71, the Réseau de Rautely or La grotte de l'Asperge (associated in this site with green calcite), are among the finest known examples of coloured associations.*

Réseau de Rautely - Aragonite Coralloïde colored in Blue
(Grotte de l'Asperge)

More rarely, the nickel (green), the iron, the cobalt (lilac) or the chromium also give particular colours, *such as the green aragonites from the Mont Marcou with 1 to 2 % nickel (content).*

Speleothems of Aragonite colored in green from the Aven du Mont Marcou

Iron and manganese hydroxides give gypsums a strong rust or black colour in the Grotte de la Cigalère.

2.a.1.3 The morphologies of speleothems as a disclosure of the different drainage conditions in caves.

The rate and the way water is drained in caves drives mineral precipitation and constrain the mineral arrangements (structures), the textures of the deposits as well as the growth dynamics of speleothems. Different seepage regimes also produce contrasted types of speleothems. The property illustrates this aspect of mineral morphogenesis with a mostly complete series of speleothem types.

The straws

The straws show off the regularity and the durability of water seepage in caves, the overlying rock formation works as a hydraulic filter.

The straws are delicate translucent tubiform speleothems whose diameter is determined by the equilibrium size of the droplet which deposits the mineral (calcite or aragonite) in the form of an accretion ruff in its extremity. The straws are generally monocrystalline; they develop close to vertical, and indicate a balance between water inflows and dripping or evaporation. The development of very long straws requires a long lasting regulated hydraulic regime.

The straws of the Grotte Amélineau owing to their number (several thousands), their density and their sizes (up to 4 metres long) constitute the finest known association. The property contains also the remarkable example of the long straws from the Grotte de Choranche in a splendid landscape of subterranean lake.

Straws (4 metres long) in the Grotte Amélineau

Stalactites, stalagmites and other “classic” speleothems

The classic speleothems stalactites, stalagmites, columns, flowstones develop under conditions of active water flows. The mineral deposition is controlled by the flow rate from feeding cracks and by the CO₂ concentration gradient between water and subterranean atmosphere.

Galleries in the cave system of l'Aven Orgnac (Height 15 metres)

Stalactites are by far the most frequent types. They are generally conic-shaped. Water flowing on their surface loses excess carbon dioxide to the cave atmosphere and precipitate calcite which increases at the same time the diameter and the length of the speleothem. The internal structure appears layered as a consequence of seasonal deposition episodes and also when impurities are rhythmically interbedded between layers of pure calcite. The stalactite is generally associated with a **stalagmite** which gets a part of the potential of precipitation of dripping water. The stalagmites grow vertically in shapes of column, cone or dome; their annual laminated structures are precious chronological markers. *Although these speleothems are widely represented in all the sites of the property, associations between these morphological types are particularly numerous and spectacular in the réseaux d'Orgnac-Issirac. Morphological peculiarities are exemplified in monocrystals with triangular section in which growth extends the calcite crystalline motive whose 3 order axis is vertical; this case is perfectly illustrated in the caves of TM 71 and l'Aguzou.*

The helicoidal development of some stalagmites is another example of remarkable peculiarity in the Grotte Amélineau.

The helicoidal stalagmites in the room of the Straws, Grotte Amélineau

When the rock support is oblique, the water drips and flows along the direction of the steepest slope and develops sometimes translucent **draperies**. Some also show parallel strips from growths variously pigmented in yellow, orange-coloured or brown-tinted by the organic matter trapped in calcite. Therefore these rhythmic structures are typical records of the relationships with the surface environment dynamics. *It is in the Grotte du Lauzinas that the most pedagogic examples are known.*

The massive speleothems

Large sized speleothems like pillars, organ pipes or « cascades de calcite » are deposited by abundant flowing water.

Accretion of calcite deposits from important inflows of supersaturated water and without active hydraulic filter are the main conditions for massive speleothems construction. When the flow rate is abundant or unstable, stalactites lose their simple conical shapes and become massive or complex. *These big formations are particularly well represented in the site of la Grotte des Demoiselles or the Aven d' Orgnac.*

Grotte des Demoiselles Organs Height 15 metres

Grotte des Demoiselles La grande draperie double Height 20 metres

Cave shields

Shields result from powerful water jets activity occurring in conditions of hydraulic load. Shields are in fact double discs of calcite developed on both sides from a central crack the orientation of which is independent from the wall or from the vertical line. The shield formation is interpreted by symmetric calcite deposition of calcite from water emitted under pressure from a feeding crack. The deposition zones are equidistant from of the centre of water discharge and build shield structures thank to peripheral increase. Often, during the evolution of the deposit, the lower shield loaded with dripstones growth falls down. *Shields are exceptionally developed in the réseau de Cabrespine-lastours, Lauzinas, as well as in the zone of "la discotheque" in the réseau d'Orgnac-Issirac with a remarkable density.*

The shields in the network of the Aven d' Orgnac

2.a.1.4 Karst polyphase records in cave deposition

The dynamic balance between inputs and outputs in karst systems provides the physical stability which characterizes the subterranean environment. However, every change in the outside environment (*modification of base levels, evolution of vegetation, climatic changes*) brings the environment on a different level of stability which is characterized by a new state of balance underground. The polyphase structures are related to the succession in time of different equilibrium stages. *At the scale of the subterranean networks, caves as Gouffre d'Esparros are marked in their morphology and their topography with successively abandoned networks of drainage in different levels of galleries. The cave system of the Grotte de Choranche shows patterns clearly connected with stages of the alpine tectonics.*

The cave deposit contains the finest and the richest proxies of the evolutions of the environment. In the subterranean landscape, the succession of the types of speleothems, the continuous evolution of the shapes, lacunes, corrosions or new growth, but also the colours of the speleothems record these changes. More precise analysis also finds these evolutions in the changes of structures or internal textures and mineralogical or chemical compositions resulting from modifications in water compositions.

Speleothems like the calcified clay mushrooms from the Grotte du Lauzinas represent a spectacular example of the imprint of the evolution of environmental conditions. More simply, the huge tilted concretions (the "vaisseau fantôme" of l'Aven d'Orgnac) and their stalagmitic new growths testify of very different periods in the subterranean functioning. In the galerie d'aragonite of the Gouffre d'Esparros, the distribution of crystals under a horizontal level is interpreted by the selective growth of crystals on clay coating left by ancient flooding of the gallery which indicates a situation very different from present. This "stratification" is also present in the réseau Lachambre, in the Lauzinas cave and with gypsum speleothems from the Grotte de la Cigalère. Other remarkable polyphase examples are seen in particular speleothems like the "verseur à pastis" (Cabrespine), the "cymbales" (TM71).

The calcified clay mushrooms of la Grotte du Lauzinas

« Le verseur à Pastis » from the Cave of Cabrespine Les "cymbales" a welt from the cave of TM 71

The analysis of mineral textures indicates that after an initial deposit, recrystallisation can occur in the mass of the concretion. *The duration of this diagenesis is assumed inferior to 2 000 years by dating at 300 BP the site of Barrencs de Fournes, as it is a former mine.*

2.a-2 Cave mineral deposition as a result of local constraints in the subterranean environment.

Local constraints as the presence of water pools, the sealing of cracks, the height of ceilings, the nature of the ground, or the state of confinement of a cavity also drives the shapes of the speleothems. These constraints define a supplementary morphological variety of the speleothems represented in a remarkable way in the property.

2.a.2.1 Water pools and associated speleothems

Every part of subterranean networks has a hydraulic function (drainage, reservoir...) which can evolve during time. However the infiltration zone of a karst remains a place of water transfer. Sometimes held in small volumes, water gives very particular cave deposits which are represented in an exemplary way in the property.

Gours

They are natural water pools limited by successive dams of calcite where water overflows. In active cave systems or in the infiltration zone of the karst, permanent or temporary drainages form rivers, lakes or small stretches of water. The loss of CO₂ oversaturate the waters which deposit carbonates around the edges or on singular points of the drainage, these mineral accumulations at the water surface build the edges of gours. *The cave system of Orgnac contains very spectacular and large rimstone dam complex (les grands gours), but also smaller and very delicately crystallized gours from the remote room "Salle des treize". An exceptional gour of aragonite supplied with water can be seen in the Barrencs de Fournes.*

The green lake of the Grotte du Lauzinas

Pool Crystals

Crystals also develop on walls and bottom of pools of oversaturated water, forming cave crystals. Their growth in water allows the free development of crystalline faces, internal symmetries of the calcite material are expressed with frequent scalénoèdres crystal terminations. Crystals are often beautifully assembled in bunches over large surfaces. *The pool crystals of l'Aguzou cave are remarkable examples through their forms and sizes furthermore, their assemblage structure vary from a gour to the other one. The cave system of Orgnac-Issirac contains large quantities of these crystals and cauliflower-shaped speleothems formed in pools with clay sediments.*

The pool crystals of the Grotte de l'Aguzou

When the water levels remain constant, horizontal growths of calcite follow the surface. *The small cups of the cave of Cabrespine show very fine examples.* The cave rafts crystallize on the surface of pools in the form of very thin films of carbonates confined on water surface plan, floating thanks to the surface tension. They are often temporary.

Calcite cave rafts from the Grotte du Lauzinas

The hollow triangles are another surprising expression of the crystals of gour. *In the beautiful examples of the caves of Lauzinas and Aguzou, they are interpreted as a response to the microvariations of water level in pools.*

Hollow triangles of calcite in the Grotte de l'Aguzou

The caves pearls

These pearls are pisolithes made by concentric accretion of calcite from a nucleus, usually a small little stone. Pearls develop in small shallow pools, under dripping or flowing water with strong enough energy to put them in movement, they remain therefore separated from their support allowing their concentric growth. These pearls get organized in layers, nests or in isolated individuals. *Balme del Pastre (Aven des Perles) is the reference site with thousands of pearls on the ground. Pearls of an exceptional size, 8 cms in diameter were found in the cave system of Choranche. There are very numerous pearls in the réseau Lachambre, no longer with water.*

A nest of pearls from the caves of Balme del Pastre

2.a.2.2 The large subterranean volumes, the context of original speleothem formation

Even if the rock volume does not generally consist of more than 1 or 2% of subterranean voids, some cave systems or rooms have a gigantic size. Curiously, these volumes host some particular types of speleothems, not only because of their size, but rather because of the shapes of the stalagmites. The property contains the most striking examples of these morphologies.

Some speleothems types are hosted in caves with very high ceilings and rooms ventilated with fresh air. They are interpreted as resulting from the energy of water drops splashing at the impact with floor releasing immediately the dissolved CO₂ and precipitating carbonate. Lateral spatters explain the construction of successive rims into “piles d’assiettes” of several metres high and of stalagmites with richly shaped lateral growths (“les feuilles de palmier”). *The most impressive association of these stalagmites “en pile d’assiettes” is the room of Aven Armand owing to the size and density of speleothems. The rooms of Orgnac are also remarkable for the variety, the size and the association of unique speleothems : le palmier, “la pomme de pin”.*

La pomme de pin from l’Aven d’ Orgnac Les feuilles de palmier de l’Aven d’ Orgnac

When the flow rate is more important, impressive massive flowstone speleothems form in these big volumes (*grotte des Demoiselles*).

2.a.2.3 The deposits of confined cavities : the crystal caves

Some subterranean sites, or parts of sites, protected from the direct influence of the outside environment, host crystals caves. In these caves, the speleothems, particularly impressive, form extraordinary but very fragile subterranean landscapes. The property contains unique examples which are considered as world references.

Speleothems with crystalline shapes (spar crystals) and efflorescences

If all the speleothems are made of crystallized material, they rarely display the characteristic geometric shapes of the crystal habitus. Nevertheless, some caves (grottes geodes), host quantities of macroscopic individual or aggregated crystals growing on vaults, walls or grounds. These sites are generally confined, that is protected from flowing or dripping waters and receive only weak contributions through microcracks, porous walls or through wall coatings of silty clay. The solutions crystallize then in the form of mineral efflorescences (frostwork) fed by capillary films. The low level of mineral supply is revealed by mineral successions as a consequence of the chemical evolution of the solutions with crystal growths: *Calcite, aragonite, hydromagnésite successions in the réseau André Lachambre and in the cave of Clamouse with the huntite.*

frostwork of aragonite in the Gouffre d'Esparros

In the Clamouse cave, dripping rates of 0.00035 ml/min were measured on speleothems of aragonite in growth, from solutions the report Mg/Ca of which is superior to 1.1. Supersaturation grades, lengthy degassing and evaporation are the other determining conditions for the development of such mineral structures and also explain the modifications of the habit in the course of growth. When mineral supply is sufficient, moderate growth rates allow development of crystal faces at the origin of large spar monocrystals, some of them close to euhedral. *The magnificent crystallizations of gypsum of "La Cigalère" are great examples of the possibilities of development of monocrystals up to 53 cm long for 5 mm in thickness and arrow-head twinned crystals of exceptional size.*

Different mineral crystal forms can develop due to the variety of nucleation conditions and of crystalline growth. The aragonite is especially rich in particular crystal forms: *the Gouffre d'Esparros host crystals of aragonite with curved faces. The aragonite is often needle-shaped (grottes de Cabrespine, blue needles of la Grotte de l'Asperge) but calcite can also show habitus of this type (Réseau Lachambre, Aven d'Ornag, Grotte du Lauzinas).*

Grotte de la Cigalère - arrow-head twinned crystals of gypsum

Even if it is not simple crystalline forms, the coralloid aragonites from the cave of Cabrespine or in “chapelets de boules” from the Barrencs de Fournes forms in similar conditions, it is the same exceptional aragonites in “tiges d'encrines” of les Barrencs de Fournes which record in their morphology the cyclic modifications of the water feeding rates.

The eccentric or helictites

The competition between several mechanisms which drives crystalline growth leads to changes in the direction of the growth axis or to branching in erratic directions which take away the concretion from the vertical line, consequently forming an eccentric. *Some ceilings in Orgnac are decorated with panels (several tens of square meters in surface) of eccentric speleothems exceptional for their quality and size with locally huge and translucent individuals. Similar deposits are also observed in Lauzinas and in Aguzou. The eccentrics of blue aragonite from Barrencs de Fournes, l'Asperge and TM71 are particularly beautiful and rare because of their mineralogical nature and their colour.*

2.a-3 The speleothems records of palaeo-environments

Speleothems develop in karst systems open to outside environment but stable and protected. Constituted by more or less continuous deposits, some speleothems (stalagmites, floor desposits etc.) have recorded, during their growth, the evolution of the local, regional or global environments. The possibility of precise dating with radiometric methods makes speleothems valuable palaeo-climatic, multi proxy records equivalent to ice cores or sea and lake sediments. Beyond the interest of the results collected in several sites, the property, through the variety of the speleothem types, the diversity of the environments and the current scientific activity, takes on an exceptional interest owing to its remarkable potential for the analysis of palaeo-environnements and especially palaeo-climates.

2.a.3.1 karst, open systems and cave deposition

The composition of seepage waters in limestone caves results mainly from dissolution of the carbonate bedrock in which they pass through. However, the water is also chemically marked by the outside atmosphere and by its transfer into soils where it becomes weakly acidic in reaction with abundant CO₂, but it also carries isotopic signatures from the biologic activity, related to surface climatic conditions. Seepage waters also transport relicts of the vegetation: pollen grains or organic acids. Therefore, cave deposits hold the chemical isotopic characteristics of waters which gave them birth; they can also contain true fossils and fluids inclusions contemporary with the deposits.

*Section of a stalagmite containing macroscopic fluid inclusions
different magnifications showing an air bubble trapped in the fluid inclusion
Photos Dominique Genty*

Some elements are used as geochemical or isotopic tracers (oxygen - $\delta^{18}\text{O}$ -, carbon - $\delta^{13}\text{C}$ -, D, Sr, Mg, U). Indeed, the limestone caves of the temperate zones constitute a depositional environment extremely useful for the analysis, because of its natural protective properties, its humidity, generally close to the saturation, which protects from isotope fractionation with evaporation and its thermic stability at a level similar to the mean annual surface temperature, therefore allowing evaluation of palaeo-temperatures.

The internal structure of the speleothems reveals deposition mechanisms and can also be interpreted as an environmental marker. That is why the study of laminae (variations of thicknesses or compositions) allows investigations at the seasonal time scale and detection of global events (climatic modifications, changes in atmospheric circulation), or local changes (modification of vegetation, evolution of the seeping rates or modifications in the cavity). The growth hiatus are sometimes associated with non functional phases of the karst occurring in response to climate variations.

So several climatic parameters, as mean temperature, rainfall variability, evolutions of vegetation or atmospheric circulation patterns at the time of the deposit, can be estimated from the analysis of the speleothems, on a scale of the last four climatic cycles (about 500,000 years).

The speleothems also are mechanically sensitive and can record the geologic history of the cave (seismic movements or sediment fillings in response to environmental variations). Broken speleothems are associated with major earthquakes whose impacts are also searched in surface morphology.

Results from speleothems analysis are interpreted at various scales:

- **at the level of the speleothem** or the association of speleothems, they provide information on the local conditions of matter transfers in the cavity.
- **at the level of the whole site**, the issue is the functioning of the karst natural system. Often difficult to establish, its evolution can be very slow, the order of a million years, but it can react very quickly and record very short events on the order of a few years.
- **at a general level, because** speleothems are highly sensitive to climatic evolutions and events. Consequently, the geochemistry and the analysis of laminae growths allow to identify events of very different scales of time: from the seasonal cycle to the glaciation periods and open the field of the palaeo-climatic studies.

2.a.3.2 Speleothems as chronological markers.

Datings on a stalagmite from the cave of Clamouse

15 datings showing gaps of growth

Photography by Valérie Plagne.

The calcite deposition is generally continuous but the growth rate of speleothems is variable (average from 0.01 to 1 mm/year) and obeys the principle of superposition on the same object. The possibility of precise dating of the calcite deposits yields a chronological basis to the environmental indicators sealed in the mineral deposit and can therefore provide palaeo-climatic data. The different methods of dating are: the Carbon 14, until approximately 40,000 years and the Uranium-Thorium which, thanks to recent technical improvements, gives precise dating until 500,000 years. Additional methods as paleomagnetism, palynology or counting of annual laminae are also used to correlate variations in the deposits. The development of the seismic markers is another possibility.

With regard to these methods, the advantage of speleothems material is at first the high quality of the information and the resolution of dating which is better than on lake sediments, peat or even on ice cores which supply the reference series. The possibility of sampling the speleothems at a very fine scale (millimetre-length or inframillimetre) gives high resolution data for the reconstitution of continental palaeo-environments, on an absolute chronological scale which has no equivalent in the other archives. *The pioneer works of J.C. Duplessy which applied the radiochronology to the speleothems took place on the site of the Aven d' Orgnac in 1967. A new research programme with speleothems dating is now in progress in Orgnac, (In the programme of the Opération Grand Site). Similar research programs are carried out in the property on speleothems from the cave of Clamouse, la Grotte des Demoiselles and Choranche cave system.*

The problem of palaeo-environments will be developed in part 2b "history and development".

2.a-4 The speleothems as major aesthetic elements of subterranean landscapes.

The landscape value of the subterranean environment is only attached to its natural constituent, and more particularly to the minerals (animals are infrequently visible and plant life is rare or unknown, except at the cave entrances); it is also strongly related to the presence of speleothems, often qualified as decoration of caves.

The peculiarity of the cave mineral growths and the property of this environment which shield fragile mineral objects from destruction caused by surface processes explain the rarity and the specificity of some underground morphologies. The relationship between the material and the forms of these objects arouses the aesthetic emotion and the feeling of strangeness. In 18 subterranean sites, the aesthetic value of speleothems or groups of speleothems is shown in an exceptional way through their forms, their colours, their associations between them and with the rock support.

Human incursion in the subterranean environment remains relatively rare because of the physical constraints (difficulty of access, darkness, humidity). Nevertheless, caves are obviously exceptional sites which hold a considerable place in the imagination of civilizations. Beautiful, strange or frightening, cave environment does not leave people indifferent and has remained a stimulant of human thought since the most remote ages.

Caves and their speleothems are exclusively mineral subterranean landscapes. The aesthetic value of objects and subterranean sites is associated with the extraordinary and the strangeness of shapes. The development of some speleothems morphologies goes against intuition, as far as the most complex shapes have equivalents only in the living world.

Crook and Flower of Gypsum of the Grotte de la Cigalère

The relationship between the mineral matter and its shapes is certainly at the origin of the visual pleasure in these caves.

The feeling of strangeness seems to have objective reasons. The relationship between the visitor and the landscape is influenced by numerous factors: the anomalic composition of its atmosphere, the exclusive mineral nature of the environment and especially the total absence of light. Through the artificial lighting, the observer himself reveals the subterranean objects and creates the landscape.

Calcite monocrystals with curved faces deposited on the surface of a stalactite in the Gouffre d'Esparros

Mushroom of calcified clay from the Grotte du Lauzinas

Another reason is that the physical and chemical processes at the origin of the subterranean landscape have often no visible expression outside: they play no part, or a small one, in the dynamics of surface because, as they gather few energy, they are often supplanted by more active phenomena (crystal growth, dissolution processes are active in caves while mechanical erosion dominates in surface).

The shape of the speleothems is doubtless the most striking aesthetic element of cave landscapes. Numerous constraints bring about an infinite variety of shapes which can be individually analyzed through one or several dominant processes which drive the mineral deposition.

Hélictites of 1 m height from the Grotte du Lauzinas

The clear expression of symmetries in the shapes of speleothems is a remarkable aesthetic element. These symmetries are present in the physical processes driving mineral deposition: for instance, gravity is obviously materialized in the vertical associations of stalactite, stalagmite, and columns. Cave deposits in which mineral growths are horizontal planes generally fossilize former water level surfaces. On a smaller scale, the geometrically perfect terminations are the expression in the crystals outer shapes of internal symmetries present in the crystalline network.

In other cases, the symmetry gets lost. The aesthetic effect is then strengthened by the development of shapes going against common intuition. A typical instance is given by the eccentric which growth in various directions of the space and puzzles the observer. Some stalactites or more often stalagmites have also a broken symmetry by divergent, lateral or coalescent growths.

The presence of fractal morphologies (in crystal branching patterns) and the associated scale invariance, preventing any estimation of the real size of crystals or speleothems without any scale mark, also partake of the impression of strangeness of this environment.

The presence of particular shapes appeals to imagination and has led speleologists to give some exceptional concretions a name, sometimes humorous and inspired by the shape (*the pine cone and the lobster nippers from the Aven d' Orgnac, le verneur à pastis (pour-through stopper) from Cabrespine, the mushrooms of Lauzinas, the cymbals of the TM 71*) or anthropomorphic projections (*La vierge et l'enfant from the grotte des Demoiselles*).

La vierge et l'enfant from the Grotte des demoiselles

Light and colours

This naturally dark world sends back ceaselessly to the importance of the light brought by visitors. One of the most striking effects is the sparkling of thousands of faces of calcite crystals in a landscape of speleothems, disclosing at once its mineral nature. Speleothems show rarely the transparent or translucent properties of the pure calcite or aragonite, and their look mainly results from texture effects (size, shape, arrangement of crystals).

Drapery at the foot of «l'escalier des géants» of the Grotte du Lauzinas

While adaptation to darkness is often a loss of pigmentation in the living kingdom, subterranean mineral environment is surprisingly generally coloured. The tints of the massive concretions are often remarkable owing to their nuances from the blacks or dark red to orange, yellow and very pure whites, however some aragonite crystals present exceptional *blues (Grotte de l'Asperge) or greens (Aven du Mont Marcou)*.

Associations between bedrock, water and speleothems also play an aesthetic role in underground landscapes and micro-landscapes. The contrast appears between rock walls dug or corroded with sometimes aesthetically rich internal structure (bedding, fractures networks, fossils inclusions, colourings), record of forming process and evolutions, and the cave deposits formed more recently which contrast by prominent shapes, often visible crystalline textures even remarkable optical properties transparent or translucent. Associations between crystals sometimes create extraordinary structures *as "les fourrures d'hermines" in the Grotte de la Cigalère*.

The "fourrures d'hermine » from "La galerie du septième ciel", Grotte de la Cigalère

The relations with water also generate a particular aesthetics, connected with the nature or the position of objects: cave pools, immersed or floating crystals or, more frequently, images mirroring on stretches of water. The association of mineral morphologies with water is often a supplementary element of aesthetic interest: the waterfalls springing from gours covered with crystals, water reflections adding more richness, the unique drop suspended at the end of the straws, the droplets on aragonite or calcite needles (*the aiguillettes of the Aven d' Ornac*) underline the relationship between the crystalline world and the original liquid medium. Speleologists name "live speleothems" the active ones.

The size of the mineral objects is used as a criterion to decide the interest of a cave deposit and its remarkable character. The height of columns, the length of the speleothems, even their volume or their weight are often mentioned. For crystals, the criterion is even stronger: the big size is synonymous with scarcity and outstanding character. *The long needles of gypsum of the Grotte de la Cigalère are a particularly fine example.*

It is therefore possible to consider the nominated group of caves as a magnificent illustration of the aesthetic richness of the morphology of speleothems, of their associations, reciprocally or with the cave, and of their outstanding characteristics.

Because of the importance and peculiarities of the series, further information is separately given for each one of the 18 sites: i) a description of the elements of the property, ii) a comprehensive documentation, iii) main present data about management.

2.b History and development

The main forming processes of speleothems have been explained in the description of the property; the history of the discovery, the exploration and in some cases the equipment of every cave, are described in the separate documentation given for each one of the 18 elements of the series.

This part deals with a new interest of speleothems: their quality of archives of palaeo-climates. Speleothems became, these last years, valuable objects in the context of the scientific challenge of the assessment of the human-induced climate change and its impacts. The property, due to the variety of the deposits and of the natural conditions of functioning, are from this standpoint of exceptional interest.

These fragile sites need a relevant protection and the management of the property has to take into account its natural functioning. Experimental operations including scientific works were carried out on several elements of the proposed property. Their aim is to improve the general knowledge on these objects, to base decisions of management, and to follow the evolution of the environment on the long term. They also help make the public aware of the protection of the subterranean environment.

2.b-1 From palaeo-climates to questioning on the present-day climate

The possible occurrence of a human-induced climatic change renewed the interest for the study of palaeo-climates and for dynamics of the ancient climate evolutions. These last years, the concretions were recognized as the best palaeo-climatic archives of the continents, and allowed to reconstruct the variability of the ancient climate evolutions during the last climatic cycles (about 500,000 years). The objective of the current developments of palaeo-climatology is a better understanding of the climatic processes and an assessment and refinement of the models for future climatic evolution. Speleothems, as much as the ice cores and sea sediments, bring about precious data to this issue and gives the property, through the diversity of the cave deposits, an outstanding patrimonial value.

2.b.1.1 The problem of the climate change

The climate warming recorded during these last decades and the consideration of the human-induced additional greenhouse effect led all the models to predict a global climate change. However, the quantitative and temporal modalities of these modifications remain at present widely speculative, as well as the impacts on the natural systems and on the economic and social activities. In this context, it is not possible to propose credible solutions.

The necessity of anticipating the effects of such changes thus imposes a global understanding of the functioning and the evolution of the climate of the planet and is one of the most important scientific challenges humanity ever had to face.

The intergovernmental panel on climate change (IPCC) thus recommended in its last report (2001) « *to accelerate progress in understanding climate change on an international scale* ».

Marker materials of palaeo-climates are numerous but their qualities are quite different. The speleothems are one of the most promising of all.

2.b.1.2 recent contributions from the studies of speleothems and perspectives

Speleothems are at present the best archives of palaeo-climates on the continents.

The continuity, the high resolution, the sensitivity of recording of climatic events by several physico-chemical indicators produces high-quality multi-proxy data. The cave mineral deposition is a specific recording different from sedimentation in large oceanic basins and from ice accumulation, and supplies independent chronologies. The possibility of correlating the information from speleothems in various continental areas documents the spatial variability of palaeo-climates. Correlations with reference series of ice cores also allows to introduce a new chronological accuracy into the modalities of the fast changes (events of Dansgaard-Oeschger on a millennium scale and of thermic amplitude reaching the dozen degrees in surface). So the studies on speleothems integrate a precious regional and global value into the fine reconstruction of the climatic effects. Another quality of the speleothems material is to supply direct information from the hydrological systems. All these elements contribute to the historic knowledge of climate change and to the construction of a new generation of climatic models and justify the current works in several sites of the property (*Aven d' Orgnac, Grotte de Clamouse, Grotte de Choranche, Grotte des Demoiselles*).

2.b-2 The protection of the subterranean environment

The protection of caves with speleothems deals with a complex environment open to surface. The water and air transferred in cave systems leads to a dynamic equilibrium situation which has to be maintained. It is under this condition that the physical integrity of the environment could be preserved and it is under this condition that the fragile speleothems or prehistoric vestiges are kept. The robustness of this environment, attested by extraordinary examples of long term conservation, is only apparent and modifications which would seem minor could have destructive consequences. So, the whole property benefits from a protection strengthened and adapted to its specificity.

Marking off in the “gallerie d’aragonite” in the Gouffre d’Esparros

The aesthetic interest of the speleothems is largely at the origin of the development of cave tourism. The cave deposits being fragile and not renewed over human life time scale, it is therefore necessary to protect them against damages, voluntary or not. Legal rules exist against any destruction in the protected property following landscape or nature protection regulations (*natural reserves: art. L. 332-1 sq. of the code of the environment, classified sites: articles L. 341-1 sq.*). Such is the case for all the elements of the property which will be protected by procedures of classification as classified sites or natural reserves. Besides, these regulations imply specific management provisions, notably for all the caves classified in compliance with art. L. 341-1 sq., for which management committees has been set up (*cf. Example of order in appendix and box on the statutory protection infra.*).

Consequently, any damages, voluntary or not, caused by inadequate equipments (changes in the openings, or in surface conditions), over-frequentation or accidental pollutions, could be avoided.

The awareness of the fragility of the subterranean environment and of its contents is largely linked to the damages in the famous prehistoric painted caves of Lascaux, Niaux or Altamira. A scientific work on the conservation of vestiges and subterranean environment was initiated and is still going on, the Laboratory of Moulis (CNRS) being one of most implied French structures. The aim of this work was to identify the natural functionings of caves in distinguishing them from disturbances related with cave equipments and tourist frequentation. The insight was to identify particular sensitivities, physical stability thresholds and acceptable levels of frequentation. With a monitoring on relevant parameters, environmental surveys were set up on several sites. They also supply helpful elements for improving cave management or equipments.

In the Aven d' Orgnac this approach drove the new equipment project towards sustainable, non aggressive solutions, like the removal of impermeable car park areas and the reopening of the natural entrances. The sinking of a shaft for the installation of a lift was realized in respect with aerodynamic constraints of confinement of the remote rooms of the cave and with the objective of limiting equipments to the previously visited zones. A same original method of environmental evaluation and survey was applied in the Gouffre d'Esparros to a preliminary study, to the equipments installation works and to the phase of touristic exploitation. This is the first instance of a preliminary operation for a subterranean equipement.

The survey of these two sites is integrated into the visit with a presentation of the operating devices for sensitization of the public to the protection of subterranean environment. A research work on the subject of cave conservation is in progress using data recorded on these reference sites (Aven d' Orgnac, Gouffre d'Esparros).

The techniques of speleology integrate nowadays the marking off, the cleaning if needed, the protection of grounds and speleothems; acetylene torches are now replaced by electric light. *The organization of the speleological visits of Orgnac cave systems and of the Grotte de l'Aguzou is exemplary and pedagogic. Today, the main galleries of all the caves of the property are marked out to allow visits controlled by speleologists. In the case of the caves of Esparros and Lauzinas, grounds were locally restored according to the recommendations of the IUCN.*

If the studies on caves mineral deposition processes are of scientific interest, it is also necessary to be careful about the resulting risks of destructions. As these sites are of exceptional patrimonial value, the sampling for analysis is made with the highest caution and with guarantees concerning as well the quality of the scientific method as the quality and the volume of the samples. The sampling for dating are presently made from naturally broken speleothems or by means of core samplings. These takings are based on the principle of the least possible damages to the aesthetics of the place and to avoid any significant impact to the potential for future studies which the predicted refinement of analysis techniques would allow.

3. JUSTIFICATION FOR INSCRIPTION

3.a Criteria under which inscription is proposed (and justification for inscription under these criteria)

Criteria vii), viii).

The criteria held for the justification of the registration result from a reflection involving international experts in several scientific meetings (Orgnac 2003, Lipica 2004). The scientific interest of the property was privileged regarding the criterion of natural beauty, even if this criterion is also proposed. The criteria *vii* and *viii* are thus clarified here in the order recommended by the format of UNESCO.

Criterion (vii): contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance.

The karstic subterranean environments are the places for the expression and conservation of mineral morphologies unknown in surface: the speleothems. The speleothems of the 18 caves of the South of France gather the main elements illustrating the aesthetic richness of these particular natural objects. The shapes of speleothems, their colours, their associations, mutually and together with the rockwalls, finally their location in caves with often extraordinary morphologies determine the exceptional aesthetic quality of this series, which is also recognized for its touristic interest in sites open to visit. Publications also revealed the very particular beauty and the interest of this patrimony. The bibliography and photos attached to the file allow to appreciate these qualities.

The shape of the speleothems is the most striking aesthetic element. A morphological profusion results from the development of symmetries, from their distortions, successions or associations during the process of mineral deposition. Unknown in the surface environment, these mineral shapes have no equivalent except in the living world, bestowing strangeness to these objects. The relationship between mineral matter and shapes is certainly at the origin of the visual pleasure. Morphologies result from interactions between various physical factors related to the environment (*gravity, superficial tension, quality and position of water inlets, water flow regimes, occurrence of pools, composition of the subterranean atmospheres*) and those related to the material (*symmetries of the crystal networks, nucleation and crystal growth processes*). These various constraints produce an infinite variety of shapes which remain individually analyzable through one or several dominant processes which drive the whole morphology of the deposit.

Some occurrences of high **colours** in this dark environment is astonishing. The speleothems rarely show the properties of transparency of pure calcite or aragonite. It is mainly an effect of texture (*size, shape, arrangement of crystals*) that controls their aspect. The colours of some deposits result from the presence of particles impurities, from elements or chemical components brought in solution in the water and trapped in the speleothem. For others, (*blues and greens*) they mark a very special geochemical context.

Associations between rock-walls, water and speleothems contribute to the esthetic quality of underground landscapes or micro-landscapes. The contrast between dug or corroded rock-walls bearing prominent, geometrically shaped speleothems is also marked by the symmetry and the tints which often contrast with the walls. The relationship with water also generates a particular

aesthetics by the nature or the position of objects: gours, immersed or floating crystals or more usually by the reflection effects on water.

Criterion (viii): be outstanding examples representing major stages of earth history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.

The speleothems of the 18 French sites constitute an exceptional set, particularly representative of all the different mineralogical and morphological expressions of the chemical sedimentation active in karst systems (not including hydrothermal karsts). The continuity of the deposits and the sensitivity to outside environmental variations justifies the use of speleothems as palaeo-climatic archives of the continents.

The speleothems result from a redistribution of dissolved mineral by drainage of meteoric water in subterranean voids belonging to karst systems.

The karst, developed in weakly soluble rocks (*mainly limestones or dolomites*), is characterized by dissolution shapes in surface and in depth by a hierarchical network of subterranean voids. Open to outside, auto-organized natural system, it reacts sensitively and quickly (on a geologic time scale) to the evolutions of its environment (*variation of the basic levels, evolution of the vegetation, hydrological changes etc.*). **The genesis and the diversity of speleothems record the functioning and the evolutions of the karst systems.** The speleothems form in the infiltration zone of karst. The surface waters, after their transit through soils, when they exist, penetrate and percolate in the cracks network of the bedrock where they dissolve mineral matter and sometimes drag solid particles. When the drainage reaches a subterranean cavity, the physico-chemical equilibrium is modified; mineral precipitation occurs, generating cave deposits.

The diversity of the water chemical compositions, of flow rates, of transfer and emergence conditions and of the quality of the subterranean atmospheres generates the mineralogical diversity (*different crystal species, crystal form and morphologies*). In other situations, the stability of subterranean drainage regimes allows regular, periodic or continuous and chronologically organized deposits; speleothems are in that way similar to sedimentary series.

Because karst systems are open to exterior, all these secondary mineral deposits trap inclusions of matter, fossil fluids and contain geochemical tracers recording the marks of palaeo-environments.

The possibility of accurate dating of the mineral deposit by radio-isotopes or simply with laminae counting gives the speleothems **their status of archives of palaeo-climates for continental environments**. Records from speleothems correlate and complete those of the sea sediments and icecaps.

The objective of these studies is the understanding of the fundamental climatic mechanisms in order to estimate the consequences of the additional greenhouse effect and the anthropologic climatic change.

3.b Proposed Statement of Outstanding Universal Value

The speleothems of the 18 sites of the South of France (caves, cave groups, cavities), through the exceptional variety of morphologies and crystal forms, constitute a unique series representing all the diversity of the transfer processes (present and ancient) and of deposition by crystallization in limestone caves. Owing to the location of the sites, this series has an

exceptional interest for scientific studies of these phenomena and contains precious archives of palaeo-climates. Besides, the series illustrates a subterranean patrimony of an exceptional beauty, the aesthetic quality of which is unanimously recognized.

This series of cave speleothems is an **outstanding testimony of the functioning of complex and sensitive natural systems : karsts**. The genesis of this series, unique through its diversity, results from the conjunction on a limited territory (at the junctions of the Alps, the Pyrenees, the Central Massif and the Mediterranean bank) of environmental conditions active and varied in surface, complex and compatible with preservation in depth. Indeed, the mineral chemical deposition in caves depends at the same time on surface dynamics, on dissolution phenomena and on transfers in the subterranean voids. The genesis of speleothems result from a slow and regular mineral deposition, sometimes as annual laminae growth. Speleothems contain archives of natural and anthropological processes having marked the continental environments.

Besides, the speleothem types, their situations in contrasted sites (heights, vegetations, rock types, ages of karst systems) on a limited territory give this series **a paleoenvironmental value**, whose only a part of the potential has been investigated at present day. The memory of speleothems extends the data collected for example in icecaps and so participates to the knowledge of the particularly important climatic evolutions of the last million years.

Besides, **the aesthetic value** of this series is characterized by remarkable or very original shapes, colorations and associations of speleothems. The nominated series contains the most representative examples of the morphological variety of the mineral deposited in caves, some of them as world references. The landscape interest of these sites is also attested through the different protections and established legal designations and through the 4.5 million annual visitors of the 107 French tourist caves. France is the third country visited for this type of patrimony, after China and the United States of America. The 8 tourist caves which are part of the group of nominated sites receive 700,000 visitors each year. It has to be noticed that the series of sites was mainly selected on the basis of scientific criteria and that conditions of access and visit of the subterranean patrimony are very particular.

3.c Comparative analysis (including state of conservation of similar properties)

Out of the 812 properties included on the world heritage list, 160 are natural properties among which only 4 were held for the exceptional quality of the subterranean environment: Mammoth Cave (United States), Aggtelek caves (Hungary) and of the karst of Slovakia, the Skocjan caves (Slovenia) and the national park of the Carlsbad caves (United States). Other natural properties from the world heritage list contain caves but the justification of inscription does not concern exclusively this part of the property (Gunung Mulu Park in Malaysia, National park of the subterranean river of Puerto Princesa in the Philippines, Pyrenees Mont Perdu in France and Spain). 10 subterranean sites, caves or sets of caves, have also been inscribed as cultural properties for the vestiges they contain (for example painted caves from the valley of Vézère in France or Yungang in China).

Apart from for sites inscribed on the list of the world heritage, numerous karst areas in countries like China or Indonesia host subterranean sites of high interest, but these are isolated sites, distant from comparable places. So, the subterranean patrimony still remains under-represented at the world level. This situation can be explained however by the fact that speleological investigations are relatively recent and not very developed in some countries, or more simply by the physical difficulty of access to this environment.

From the point of view of the nature of the property, the closest site inscribed under the same criteria used for the nominated property (criteria *i* and *iii* corresponding now to criteria *vii* and *viii*) is the National park of the caves of Carlsbad with the incomparable crystallizations of Lechuguilla cave. The quality of the speleothems in this site is the result of exceptional subterranean conditions, in particular the important occurrence of sulfur and of speleothems, qualified as "biothems", the formation of which is due to the action of bacterian colonies.

The series proposed for inscription concerns the same objects (speleothems with exceptional characteristics) but mostly from different types, resulting from remarkable cave deposition in gravific karsts which testify of an open system connected with the surface environment. In the proposed series, a larger mineralogical and morphological variety results from the variety of current and ancient subterranean contexts; this series thus completes the reference elements of the Carlsbad caves.

Classic shapes of speleothems are also present in Aggtelek cave, as well as in the Skocjan caves and in Mammoth Cave; however the speleothems do not constitute in none of these sites a central patrimonial element. Finally, still from the point of view of the mineral deposition, the proposed set contains, on a restricted area, a wider variety of types, colours and associations of speleothems than in the sites of Slovakia and Slovenia. It is this variety and its scientific interest which justify the proposition.

To sum it up, compared with the other existing properties inscribed on the list of the world heritage, the value of the present proposition is characterized by the multiplicity of interests from different points of views:

- from the point of view of the functioning of the karst systems. Carlsbad cave can be considered as a unique type, belonging to a different and local karst setting. In the systems of Aggtelek and Slovakia, the speleothems hold a relatively less important place, less representative of the geologic processes. In the 18 caves set, the very wide

variety of cave deposits represent to an unequalled level the relationships with the whole karst functioning;

- from the point of view of the knowledge of palaeo-climates, the geographic and climatic distribution of 18 caves gives an accurate and very diversified sight of recent events on a territory bordering three mountain sets (the Pyrenees, the Central Massif, the Alps) and on two maritime spaces (the Atlantic Ocean, the Mediterranean Sea) the proximity of which have affected the geology in different ways;
- finally, from the aesthetic point of view, the 18 French caves complete a morphology present in Carlsbad or in other places, but here at a higher level by its very wide variety.

Although the comparative analysis has to report on the value and the representativeness of the whole series, it is important to underline that some sites among the 18 French caves, (Réseau André Lachambre, Aven d' Ornac, Aven Armand or Grotte de la Cigalère), individually present an exceptional quality.

It is thus possible to establish comparisons by types of speleothems.

*If **straws** are frequent in caves worldwilde, the very long straws are rare: those of the Grotte Amélineau are exceptional owing to their length, their number and their density.*

*The **Mushrooms** of Lauzinas are unique in the world for their perfect shape and their size of 1.25 m height, even if smaller mushrooms were found in Cueva Grande of Santa Catalina in Cuba.*

*If speleothems of **aragonite colored in blue** are known in caves of Sardinia, the blue aragonites of the French caves are large-sized, totally intact and the blue needles in Réseau de Rautely (Grotte de l'Asperge) seem to be unique.*

***Aragonite colored in emerald green** is extremely rare, it was indicated in a cavity of South Africa but the quality of the deposit of the Mont Marcous is unique.*

*The **pearls of the caves** which are more numerous in some caves (Mexican ones) were often plundered (Cave of Carlsbad on 1929). The cave of the Balme del Pastre (Aven of pearls) is a remarkable set from the polite, the shape, the appearance, the number and the concentration of pearls; its quality is to have been entirely protected.*

*If **gypsum** is very present in the cave of Lechugilla in the USA, the Grotte de la Cigalère contains this mineral in very important quantities but in a completely different context.*

*The property contains **speleothems with unique shapes** : crystals of calcite and aragonite with curved faces of Esparros, speleothems of pyrite and blende of la Cigalère, aragonite "en tige d'encrine", corraloid aragonite with symmetries 2, 3, 4 of the Barrencs de Fournes, stalagmites with equilateral section of the cave of l'Aguzou and TM 71. The tubes of ringed aragonite of the Réseau de Rautely (cave of the PN 77) are unique too.*

***Stalagmites "en piles d'assiettes"** are known in l'Aven Armand and in l'Aven d' Ornac; there are some rare exemples in the aven de la salamandre (Gard), in the caves of Frassassi (Italy) and in the cave of Zhijin in China.*

*For **polyphase speleothems**, their exceptional density and variety in the whole property seems unequalled in the world.*

If in numerous caves in the world, there are scientific works on the subterranean environment, the current studies on two sites of the property (Aven d'Ornag, Gouffre d'Esparros) aim, through accurate measurements, at a better understanding of the functioning of karst systems. Both sites have become experimental sites for conservation of the subterranean natural patrimony.

The set of speleothems, through its unique or extremely rare characteristics of numerous elements of the property, and through the representativeness of the whole, completes in an original way the previous inscriptions.

3.d Integrity and/or Authenticity

The conditions of integrity are fulfilled for all the sites concerned in the sense where the whole subterranean network is included in the proposition of inscription and where this perimeter includes the caves and karst system which host them. The property contains all the necessary elements to express its exceptional universal value.

The protections of French subterranean sites in conformity with art. L. 341-1 sq. of the “code de l'environnement” (former law of 1930) were only concerning the subsoil. The consideration of the karst natural system containing caves and its functioning widened the protection to land parcels in surface. Each site has therefore a sufficient size to include the whole characteristics and processes which express the importance of this property.

All the proposed sites are authentic in the way that the cave deposits which are proposed were neither provoked nor influenced by human activity and remain the expression of only natural processes. Among all the proposed cavities, the only site which is an exception (les Barrenes de Fournes), is an ancient mine where the human intervention is widely responsible for the digging of cavities. For this site, the mineral deposition forming the speleothems takes place after the end of the exploitation works little before Christian era, and results from a natural process.

4. STATE OF CONSERVATION AND FACTORS AFFECTING THE PROPERTY

Although the state of conservation is completely satisfactory for the whole property, the elements of the property are in contrasted situations and present very different sensitivities from caves with a "mass tourism" (*Grotte de Choranche, Demoiselles, Clamouse, Aven d'Ornac*) up to sites visited exceptionally because of their sensitivity (*Réseau de Rautely, Barrenc de Fournes, Grotte Amélineau*). A global reflection was nevertheless the mainspring of the policy of protection of all these sites, it takes into account the peculiarities of each one.

4.a Present state of conservation

The current state of conservation is exemplary for all the elements of the proposed property; measures are undertaken to maintain and insure a monitoring of the state of the property .

On the occasion of the implementation of every statutory protection, a photographic inventory was or will be realized; it notably concerns the most exceptional zones for speleothems.

In some tourist caves (Gouffre d'Esparros, Aven d'Ornac for example), fragile or difficult to protect, environmental surveys are realized by monitoring several physical parameters, to verify the stability of the environment in front of disturbances induced by the tourist visits or by the equipment. In some caves or parts of particularly sensitive caves frequentation threshold are imperatively applied. In other cases, simple visits allow to report on the quality of the natural environment and to identify particular sensibilities of the site.

4.b Factors affecting the property

I) Development Pressures (for example, encroachment, adaptation, agriculture, mining development)

The protections established according to environmental conditions necessary to form and conserve speleothems guarantee a complete preservation of these places. Besides, near these sites, for the control of industrial activities apt to cause shocks or vibrations in the environment (quarries), this risk was considered as very small (sites difficult to reach) and completely under control thanks to environmental legal rules (environmental impact assessment studies, legislation on quarries).

ii) Environmental pressures (e.g., pollution, climate change, desertification)

The legal protections provide a complete control on the activity in the land, at the surface and inside cave systems. The protection limits (sites classés or réserves naturelles) were established taking into account the hydrogeologic functioning of the karst (see below summary of French legal protections). These protections are for some sites close to finalisation and safety measures could, in the intervening time, be implemented (instances de classement). Considering the collaboration of the local participants and the weak human pressure in these zones, it does not seem that the conservation of the property could be threatened.

Legal protections

Following the kind of patrimony, a cave is liable to be protected by one of the four following laws:

- law of 31. December 1913 : concerning the protection of historic monuments, this law encompasses the whole field of Prehistory and History. Caves such as Lascaux, Niaux etc., are protected on this basis. This law allows also to protect ancient mines, very numerous on the French territory. The property includes the ancient mine of Barrencs de Fournes, dated 1,000 BC (protection under way). All the works concerning archaeological vestiges have to be authorized by the ministry of culture.

- law of 2. May, 1930 (art. L. 341 sq., code de l'environnement) : concerning the protection of natural monuments and sites, allows the protection of subterranean landscapes of national interest, either speleothems or cave galleries with typical morphologies (Esparros, Orgnac, Aven Armand...). 120 French caves or cavities are protected on this basis.

- law of 27. September, 1941: concerning archaeological excavations, allows the protection, as soon as they are discovered, of all the sites with archaeological vestiges. According to this law, it is forbidden to anybody, either its owner or not, to make a boring or excavations in any land which could be of archaeological interest. Judicial decisions have provided precisions about this prohibition:

1. the law concerning archaeological excavations applies to all the sites with palaeontological remains, even when there is no trace of human settlement, provided that these sites are contemporary with the appearance of man on earth. From this respect, all the sites of the Quaternary Period are taken into account (there are numerous instances of decisions, the main one being the case of the looting of bones of cave bears found in a cave of Ariège);

2. this same law applies to all ancient mine vestiges: all the mines and their wastes, as well as the buildings contemporary with the exploitation, when the mine's owner has given up the concession. This text was completed by the law concerning the preservation of public collections against ill-intentioned actions (15. July 1980), forbidding any destruction of land including archaeological vestiges without the preliminary and necessary excavations and required authorizations.

- law of 10. July, 1976: concerning nature preservation, allows the creation of "réserves naturelles" (art. L. 332-1 sq., code de l'environnement) and the passing by the préfet of specific regulations for the protection of biotopes. In particular, it allows to take into account the mineralogical, geomorphic or biological interests of a cave. It foresees the management of a "réserve naturelle" with dedicated financial ressources and a management committee with all the interested parties (proprietors, elected representatives, administrations, associations). Among the 133 French "réserves naturelles", three are directly dealing with subterranean environment: one of them protects minerals, the other two protect bats.

A special and more simple procedure gives the owner of the land the possibility to ask for a protection of his patrimony as a voluntary "réserve naturelle". Today, there are 150 "réserves naturelles" of this kind in France; about thirty are of subterranean interest (mineralogical and biological).

Today, 250 caves or cavities are protected either as historic monuments, sites or nature preservation; the law concerning archaeological excavations applies in a general way to all the sites already discovered, either subterranean or not.

The present 18 caves being a natural property, the laws of 1930 (sites classés) and 1976 (réserves naturelles) are the only relevant texts.

iii) Natural disasters and risk preparedness (earthquakes, floods, fires, etc.)

In this zone of the South of France, earthquake hazard is not equal to zero. However during the earthquake of Arette (1967) speleologists who progressed in caves close to the destroyed village did not notice the event. It seems that the property has little sensitivity to these phenomena.

The risks of flooding are part of the natural functioning of this type of property (at least for some cavities). A recent episode following a 100-year rainfall event was observed in the Aven d'Orgnac in 2002; it has flooded the low parts of the cave system but did not cause any significant modifications.

The fires can have an impact on water infiltration, but only the complete loss of the vegetation could be harmful.

This type of the property is generally well protected against natural disasters.

(iv) Visitor/tourism pressures

Some caves, or parts of cave systems, are open to tourist visit without any threshold as Orgnac, Choranche, les demoiselles; in other ones like le gouffre d'Esparros, limits are imposed on the number of visitors. Some caves are only open to speleological visit with visitors quotas (Lauzinas, Lachambre, Aven des Perles). In some parts of the caves, visits are prohibited (Septième ciel of la Cigalère, galleries of Orgnac IV, gallery of aragonite in Esparros). Finally, for a unique case, visits are restricted to scientists only: Barrency de Fournes. Thus, on the whole, all kinds of possible managements exist, according to the fragility of the patrimony.

Element number of the site	Name	Cave	Open to tourist visits	Cave safari	Open to speleologists	Zone in which no visits are allowed
01	Grotte Amélineau	Grotte Amélineau	No	No	exceptionnally	No
02	Grotte de Choranche	Grotte de Choranche	Yes, about 120,000 visitors per year	No	yes	No
03	Aven Armand	Aven Armand	Yes about 100,000 visitors per year	No	Authorization necessary for the descent of the shaft	No
04	Grottes des Demoiselles	Grotte des Demoiselles	Yes about 100,000 visitors per year	No	Yes with the speleologic group of the University of Montpellier	No
05	Balme del Pastre	Aven des Perles	No	No	Restricted to 6 groups of 10 persons per year	No
06	Grotte de l'Aguzou	Grotte de l'Aguzou	No	Yes, about 1100 persons per year.	yes	No
07	Grotte du Lauzinas	Grotte de Lauzinas	No	No	Restricted to 20 groups of 10 persons per year	No
08	Grotte du TM 71	Grotte du TM 71	No	no	Restricted to 12 groups of 10 persons per year	No
09	Réseau de Cabrespine-Lastours	Grotte de Cabrespine Grotte de Trassanel Grotte de Limousis	Yes, about 90,000 visitors per year No Yes, about 25,000 visitors per year	Yes, about 900 persons per year No No	Yes Yes Yes	No No No

Element number of the site	Name	Cave	Open to tourist visits	Cave safari	Open to speleologists	Zone in which no visits are allowed
10	Gouffre d'Esparros	Gouffre d'Esparros	Yes Restricted to 300 persons per day About 30,000 visitors per year	No	Junction excursion from the natural entrance to the tourist zone is restricted to 12 visits of 10 persons per year	Galerie d'Aragonite : no visits allowed except with a special authorization "réserve intégrale" (2005)
11	Grotte de Pousselières	Grotte de Pousselières	No	No	Visit restrictions projected	No
12	Grotte de Clamouse	Grotte de Clamouse	Yes about 100,000 visitor per year	No	About 2 visits of 10 persons per year	No
13	Réseau Lachambre	Réseau Lachambre	No	No	Yes restricted to 12 visits of 10 persons per year	Special visit authorization is needed for the visit of the second sector of "les Canyons Blancs"
14	Réseau du Rautely	Grotte de l'Asperge	No	No	Yes, visit restrictions projected	No
		Grotte du PN 77	No	No	Yes, Visit restrictions projected	No
		Grotte du Rautely	No	No	Yes	No

Element number of the site	Name	Cave	Open to tourist visits	Cave safari	Open to speleologists	Zone in which no visits are allowed
15	Aven du Mont Marcou	Aven du Mont Marcou – Partie sportive Aven du Mont Marcou – La géode Verte	No No	No No	Yes Restrictions to 12 visits of 6 persons per year.	No No
16	Grotte de la Cigalère	Grotte de la Cigalère	No	No	12 Km of galleries – restriction to a yearly 3 to 4 weeks speleo camp in summer with 20 persons per week	Special visit authorization is needed for 4 fragile zones
17	Aven d'Ornac	Aven d'Ornac	Yes about 120,000 visitors per year	yes	Yes	Special visit authorization is needed for Ornac IV
18	Barrenes de Fournes	Barrenes de Fournes	no	no	Non	« Réserve intégrale » exclusively for scientific studies

Among the proposed series, some touristic caves are equipped for visiting in acceptable safety and comfort conditions. Facilities give access to the zones of interest (tunnels, lifts), others help and channel the visitors (banisters, bridges, stairs, and protections). In these sites, the equipments are considered as respectful of the integrity of speleothems and of the environment in general. There are significant differences due to the history of each site. *So, the recent equipment of "le Gouffre d'Esparros", which was controlled and in which an environmental survey is still active, cannot be compared with that of la Grotte des Demoiselles which has been visited from 1890, equipped for tourism from 1929, and in which the original equipment has been kept.*

In all the other cavities, no modification that could affect the site or its speleothems has occurred and only speleological equipments necessary for progression in the cave (fixed ropes, ladders, toe clips, handles etc.) or equipments for physical protection were added (fences, door, marking off material). Lastly, some caves or caves portions are completely closed to visit, including speleological visit, and are under complete protection: *Barrenes de Fournes, system IV of Orgnac, gallery d'aragonite du Gouffre d'Esparros.*

V) Number of inhabitants within the property and the buffer zone

Element number of the site	Name	Number of inhabitants	
		In the central zone of the property	In the buffer zone
01	Grotte Amélineau	0	177
02	Grotte de Choranche	0	219
03	Aven Armand	0	177*
04	Grottes des Demoiselles	0	1140
05	Balme del Pastre	0	102
06	Grotte de l'Aguzou	0	90
07	Grotte du Lauzinas	2	2287
08	Grotte du TM 71	0	4
09	Réseau de Cabrespine-Lastours	10	637
10	Gouffre d'Esparros	0	194
11	Grotte de Pousselières	0	49
12	Grotte de Clamouse	0	1160
13	Réseau Lachambre	5	1552
14	Réseau du Rautely	0	842
15	Aven du Mont Marcou	0	209
16	Grotte de la Cigalère	0	147
17	Aven d'Orgnac	2	341
18	Barrenes de Fournes	0	316*
TOTAL		19	9150

* In double count

With the exception of the following four sites: Grotte du Lauzinas, réseau de Cabrespine-lastours, network Lachambre and Aven d' Orgnac, which number a total of 19 persons, the whole of the property remains uninhabited. In the buffer zone, the total population of the corresponding communes has been numbered.

5. PROTECTION AND MANAGEMENT OF THE PROPERTY

5.a Ownership.

There are three types of land ownership: state, commune and private owners. The table below gives the distribution, without the possibility to provide the exact proportion between the ownerships because of the division of the land or because, for protections in progress, the limits have not been set permanently.

Element number of the site	Name	State property	Commune property	Private property
01	Grotte Amélineau			100%
02	Grotte de Choranche		X	X
03	Aven Armand			100%
04	Grottes des Demoiselles			100%
05	Balme del Pastre			100%
06	Grotte de l'Aguzou	100%		
07	Grotte du Lauzinas		X	X
08	Grotte du TM 71	2%	9%	89%
09	Réseau de Cabrespine-Lastours	X	X	X
10	Gouffre d'Esparros		100%	
11	Grotte de Pousselières		10%	90%
12	Grotte de Clamouse			100%
13	Réseau Lachambre	75%	X	X
14	Réseau du Rautely		X	X
15	Aven du Mont Marcou		75%	25%
16	Grotte de la Cigalère	100%		
17	Aven d'Orgnac		X	X
18	Barrencs de Fournes		X	X

To note, for the following elements:

- 02 : protection in course of an important site situated on two communes;
- 07 : land ownership modifications occurred since the date of the protection act (Recent acquisitions of the municipality of Saint-Pons);
- 09 : protection in progress of an important site (encompassing six communes);
- 13 : large number of properties scattered in two communes;
- 14 : protection in progress on two communes;
- 18 : protection in progress on three communes.

5.b Protective designation

As indicated previously, involving a natural property, two types of designations are used: “sites classés” or “inscrits” and “réserves naturelles” (see framed in chapter 4). The table below sums up the state of progress of these two types of designations, as well as the constitution of the management committee at the local level.

Element number of the site	Name	Commune(s), n° of département	Current protection	Protection in progress	local management committee
01	<i>Grotte Amélineau</i>	<i>Hures-la-Parade (48)</i>	<i>The cave is a site classé au 01/02/1990 Gorges du Tarn et de la Jonte : Site classé au 29/03/2002</i>	<i>Protection assured</i>	<i>Yes 10/07/2003</i>
02	<i>Grotte de Choranche</i>	<i>Choranche, Presle (38)</i>	<i>Protection in progress</i>	<i>Classement au titre des sites in progress</i>	<i>Planned</i>
03	<i>Aven Armand</i>	<i>Hures-la-Parade (48)</i>	<i>The cave is a site classé 20/08/1941 Gorges du Tarn et de la Jonte : Site classé au 29/03/2002</i>	<i>Protection assured</i>	<i>Yes 10/07/2003</i>
04	<i>Grottes des Demoiselles</i>	<i>Saint-Bauzille-de-Putois (34)</i>	<i>Protection en cours</i>	<i>Protection in progress au titre des sites. The procedure begins in 2006</i>	<i>Planned</i>
05	<i>Balme del Pastre</i>	<i>Mélagues (12)</i>	<i>Site classé au 26/04/2002</i>	<i>Protection assured</i>	<i>Yes 12/09/2002</i>
06	<i>Grotte de l'Aguzou</i>	<i>d'Escouloubre- les-Bains (11)</i>	<i>Site classé au 01/02/1990</i>	<i>Protection assured</i>	<i>Yes 15/09/2003</i>
07	<i>Grotte du Lauzinas</i>	<i>Saint-Pons-de-Thomières (34)</i>	<i>Site classé au 16/07/1996</i>	<i>Protection assured</i>	<i>Yes 10/01/2000</i>
08	<i>Grotte du TM 71</i>	<i>Fontanès-de-Sault (11)</i>	<i>Réserve naturelle au 17/08/1987</i>	<i>Protection assured</i>	<i>Yes 23/11/1988</i>
09	<i>Réseau de Cabrespine-Lastours</i>	<i>Cabrespine, Trassanel, Fournes-Cabardès, Lastours, Sallèles-Cabardès, Limousis (11)</i>	<i>Grotte de Limousis : Site Inscrit au 10/09/1947 Cave entrance of Cabrespine : arrêté de protection de biotope pour les chiroptères au 13/08/1996</i>	<i>Protection of the whole area in progress</i>	<i>Planned</i>
10	<i>Gouffre d'Esparros</i>	<i>Esparros (65)</i>	<i>Site classé au 30/10/1987</i>	<i>Protection assured</i>	<i>Yes 04/05/1999</i>
11	<i>Grotte de Pousselières</i>	<i>Ferrières-Poussarou (34)</i>	<i>Protection in progress</i>	<i>Protection in progress -</i>	<i>Planned</i>
12	<i>Grotte de Clamouse</i>	<i>Saint-Jean-de-Vedas (34)</i>	<i>Cave: Site classé au 15/02/2005 Vallée de l'Hérault : Site classé au 22/02/2001</i>	<i>Protection assured</i>	<i>Planned for the beginning of 2006</i>
13	<i>Réseau Lachambre</i>	<i>Ria-Sirach, Corneilla-de-Conflent (66)</i>	<i>Site classé au 18/01/1991</i>	<i>Protection assured with an extension of the protected zone in progress</i>	<i>Yes 10/03/1999</i>

Element number of the site	Name	Commune(s), n° of département	Current protection	Protection in progress	local management committee
14	Réseau du Rautely	Olargues, Saint Etienne d'Albagnan (34)	Protection in progress	Protection in progress	Planned
15	Aven du Mont Marcou	Saint-Geniès-de-Varensal (34)	Protection in progress	Protection en cours ; The procedure begins in early 2006	Planned
16	Grotte de la Cigalère	Sentein (09)	Site classé au 24/04/1981	Protection assured	Yes 13/12/1995
17	Aven d'Ornac	Ornac-l'Aven (07)	Site classé et site inscrit au 25/02/1946	Protection assured	Yes 12/4/1999
18	Barrency de Fournes	Lastours,Fournes-Cabardès, Limousis 11)	Protection in progress	Protection au titre des sites in progress ; The procedure begins in 2006	Planned

Eleven caves or groups of caves are under protective designations. For seven other ones, procedures are in progress: for Barrency de Fournes, Grotte des Demoiselles and Aven du mont Marcou, the administrative public inquiry should start at the beginning of 2006, for the Grotte de Choranche, the Cabrespine-Lastours cave system, the Réseau de Rautely and the Grotte de Pousselière, the delineation of protection boundaries are in course of definition; all these procedures will be completed in 2008.

5.c Means of implementing protective measures

The designation “*sites classés*”: articles L. 341-1 sq. of the “*code de l'environnement*” is related to natural monuments and sites for which conservation or present preservation, from the artistic, historic, scientific, legendary or picturesque point of view, is of general interest. The designation “*classement au titre des sites*” implies in particular that they neither can be destroyed, nor modified in their state or their aspect, except by special authorization from the préfet or from the Minister in charge of sites, after advice from the “*commission départementale ou supérieure des sites*”. The designation “*site inscrit*” permits information and intervention of the competent authorities for any project of modification. Considering the specificity of the subterranean environment, the conditions of management of caves designated as “*sites classés*” are specified by government decree.

For the “*réserves naturelles*”, articles L. 332-1 sq. of the “*code de l'environnement*”, it is specified that parts of the territory of one or several communes can be designated as “*réserves naturelles*” when the conservation of fauna, flora, ground, waters, deposits of minerals and fossils and generally the natural environment presents a particular importance or when it is advisable to protect them from any artificial intervention that could damage them... Are considered as such, the conservation of remarkable biotopes, geological formations, geomorphic or speleological features. No modification can be brought to the state or to the use of places without special authorization from the préfet or the minister in charge of the environment, following the case. A “*réserve naturelle*” has a management board, which has to work out a management plan.

The different state administration departments, at central and local levels (*Ministère de l'écologie et du développement durable, préfets, directions régionales de l'environnement,*

services départementaux de l'architecture et du patrimoine...) provide the monitoring and the application of these protective mesures.

5.d Existing plans related to municipality and region in which the proposed property is located (e.g., regional or local plan, conservation plan, tourism development plan)

For each of the 18 elements of the property, actions of promotion exist. Information is made in the premises of public access to the cavity (7 places) and, very often, also available nearby. Besides, within the framework of local management of each element of the property (cf. 5.b), some sites have formalized management plans, related to the tourist activity (e.g. label Grand Site de France at l'Aven d'Ornac), or to a protection designation for the natural environment (e.g. réserve naturelle du TM 71).

Elements of the property	Information et promotion	
	In the hall of reception of the cavity	Other places
01 - Grotte Amélineau		éco-musée (museum of man and the environment) in Huelza
02 - Grotte de Choranche	X	Premises of the parc naturel régional du Vercors
03 - Aven Armand	X	éco-musée (museum of man and the environment) in Huelza. Premises of the Parc national des Cévennes
04 - Grotte des Demoiselles	X	
05 - Balme del Pastre		City hall of Mélagues; premises of the parc naturel régional des Grands Causses
06 - Grotte de l'Aguzou		maison de la réserve naturelle de la grotte du TM 71
07 - Grotte de Lauzinas		Saint Pons's tourist information office. Musée français de la spéléologie in Courniou-les-Grottes
08 - Grotte du TM 71		maison de la réserve naturelle de la grotte du TM 71
09 - Réseau Cabrespine à Lastours	X	Hall of reception of the cave of Limousis
10 - Gouffre d'Esparros	X	
11 - Grotte de Pousselières		City hall of Ferrières Poussarou; Centre des Ecosystèmes d'Olargues; Musée français de la spéléologie in Courniou-les-Grottes
12 - Grotte de Clamouse	X	
13 - Réseau André Lachambre		Premises of the Parc des Pyrénées Catalanes
14 - Réseau du Raulety		centre des Ecosystème d'Olargues musée français de la spéléologie in Courniou-les-Grottes
15 - Aven du Mont Marcou		Musée français de la spéléologie in Courniou-les-Grottes
16 - Grotte de la Cigalère		Project of valuation of the ancient mines of Bentaillou in Sentein. Project of "Maison du monde souterrain" in Moulis near Saint-Girons.
17 - Aven d'Ornac	X	Musée régional de préhistoire in Ornac
18 - Barrency de Fournes		Project of mine museum (studies in course)

For promotion and development actions of the whole nominated property, they are foreseen within the framework of the management structure defined in 5.e.

Consequently, in each element of the property, a structure dedicated to information and promotion should be able to relay, in a harmonized way, the international recognition of the whole property (global presentation, pedagogy, public awareness).

5.e Property management plan or other management system

Management structures

Beyond the necessity of an adapted and specific management board in each property of the world patrimony, the divided territorial characteristic of the series composing this property, scattered on three regions, provide a supplementary justification for a structure of global management of the property.

The objective of this structure is to guarantee the integrity of the property of an extremely fragile kind (any damaged part would be definitively lost), to insure, under conditions, the promotion towards the public and, from the point of view of knowledge, to develop its scientific potentialities.

In this prospect, the proposed structure should contain three parts, guaranteeing the respect of these objectives and the participation of all the actors at each level.

- 1) **A local organization**, the definitive legal form of which has to be found, but which could be at first a preliminary association ("*association de la loi de 1901*"), should be set up at the local level and gather all the operators or, if not possible, representatives of the owners of each of the 18 caves or groups of caves.

Formed of 18 members, its main objective should be to promote the candidacy as well as to share the promotion of the property and management experiments. This association should be helped by different scientific research organizations, by the national Association of the show cave operators (ANECAT) and by the French union of speleology (FFS), according to their respective competences.

A presidency should be organized according to the current regulations in the field of associations and the statutes of this structure should expressly take into account the possibility of taking in new members, if other caves were integrated to the nominated series.

Several meetings have already been held by the end of 2005 and the beginning of 2006, gathering all the actors, who have unanimously drafted a charter in order to commit themselves.

This structure should have its head office and meet periodically in a nearby place of the territory where the cavities are situated.

- 2) **A steering committee**, different from the association, should gather the communities at various levels (communes, départements, regions), the local services of the State, the scientific research bodies, the specialized associations in show caves and caving (ANECAT, FFS), and naturally the members of the association of the developers and/or owners (cf. 1).

This committee, with the coordinating préfet of Languedoc-Roussillon, or his representative, as president, should insure at the local level the protection monitoring and the promotion of the property.

The préfet of Languedoc-Roussillon had been asked by the French ministry of environment (letter of February 15th, 2005), to appoint this local and interregional steering committee; the first meeting was held by the sous-préfète of Lodève on October 12th, 2005.

- 3) Finally, **a coordination at the national level** should be established by a national committee of the subterranean patrimony presently in the making by the French ministry of environment.

This committee should associate representatives from the French ministry of environment, members of the *conseil national de la protection de la nature* (CNP) and from the *commission supérieure des sites, perspectives et paysages* (CSSPP), representatives of other ministries - culture (archaeology) and sports (speleology), and scientific institutions (Centre national de la recherche scientifique (CNRS), Bureau de recherches géologiques et minières (BRGM) and Muséum national d'histoire naturelle (MNHN)). It should also include a representative of the managers of tourist caves (ANECAT), a representative of the speleologists (FFS), as well as representatives of the French sections of the World Conservation Union (IUCN) and from the international council of monuments and sites (ICOMOS).

Among its missions, it should be in charge of a general monitoring and assessment of the management operations in the property, with a special monitoring of protective measures at the national level (finalisation of the last protective designations in conformance with the reserves naturelles or sites, possible extensions, protection operation), and of proposing research orientations.

It should have to work in connection with the local authorities and have the responsibility of the assessment of the management of the property under its different sides.

This global organisation of management of the property (association, steering committee and coordination at the national level) should complete the local organisation of the management of each element of the property.

Each site has its own appropriate management organisation, as described in appendix: management committee of "réserve naturelle or site classé". These committees associate the competent administrative departments, elected members and experts. They propose to the préfet the statutory or police decisions to insure the conservation of the property.

5.f Sources and levels of finance

The structures and the means described in the present document can be considered as sufficient to insure a satisfactory management adapted to each element of the property. Involving the global nature of the property, the ressources to be set up should be specified within the frame of the management structure described above.

The specificity of the elements of the property from the point of view of their difficulty of access, thus making control easier, allow to limit the ressources necessary to preservation. These ressources are modest and mainly provided by the staffs of the State administration dedicated to protection policy; it is in particular the case for the implementation of the statutory measures of protection and management, as well as the few necessary measures of police.

For the promotion, notably for tourism, regardless of the frequentation level, each administrator of tourist cave is preoccupied with this promotion and dedicates the necessary means and ressources, in connection notably with the “offices du tourisme” agencies. These administrators are mostly members of a professional association (ANECAT) which has an Internet site and documentation.

Besides, for the most important tourist sites, the State and the communities participate generally to the management of the property. Some sites already have a formal partnership for the promotion of the subterranean patrimony: it is the case of the Aven d’Ornac, labelled as “Grand site de France” (GSF). This element of the property, one of the most visited, gathered through the partnership, for the improvement of tourist facilities, 5.5 million euros, provided from Europe, the French state, region, department and commune.

More generally, the policy of the grands sites (main national sites) led by the “*Ministère de l’écologie et du développement durable*” supplies the technical tools to face the problems related to tourist visit and in some cases overfrequentation as well as the methodologies for the realization of works respectful of the quality of sites.

Besides, in order to insure the promotion of the whole property, notably the communication, the necessary ressources should be brought without difficulties by the local authorities of the territories on which the caves are situated. These authorities are associated with the steering committee for the management of the whole nominated property (cf. 5.th). Furthermore, as approximately half of the sites are run on an economic basis, by private owners in some cases, a specific partnership has to be established: it is the reason why the global management organization described above has been planned. Consequently, a mixed partnership - public/private - is intended for commercial sites, both with developers and with representatives of economic circles.

The global promotion of the property should be also insured at the national level by communication tools and supported notably by the State concerning all the French properties inscribed on the World Heritage list (projects such as Internet sites, printed documents, organization of a network of administrators of the French sites of the World Heritage).

Finally, the State is supporting financially the realization of surveys (surveys for the protections of “sites classés” and “réserves naturelles”): environmental survey in Esparros with “commune” level cofinancing, a preliminary survey for the protection of the site of the Réseau de Rautely, as well as the installation of reinforced doors or equipments in other cavities.

5.g Sources of expertise and training in conservation and management techniques.

The table below summarizes, for every element of the property, the competences existing on the site. When caves are not fitted out for the public, speleologist competences are necessary and each cavity is managed by one or several “clubs spéléologiques” at the origin of their discovery and having supported their protection. The site of Barrencs de Fournes (ancient mine in complete reserve) is open to scientists only.

Elements of the property	Show cave	Competences
01 - Grotte Amélineau	No	
02 - Grotte de Choranche	Yes	The director and several guides were formed during a one week training session in the Laboratoire souterrain de Moulis
03 - Aven Armand	Yes	One of the owners is a geologist and several guides were formed during the one week training session in the Laboratoire souterrain de Moulis
04 - Grotte des Demoiselles	Yes	The director is a geologist and several guides were formed during the one week training session in the Laboratoire souterrain de Moulis
05 - Balme del Pastre	No	
06 - Grotte de l'Aguzou	No	
07 - Grotte de Lauzinas	No	
08 - Grotte du TM 71	No	
09 - Réseau Cabrespine à Lastours	Yes	The owner of the part opened to the public of the cave of Cabrespine is a geologist
10 - Gouffre d'Esparros	Yes	
11 - Grotte de Pousselières	No	
12 - Grotte de Clamouse	Yes	One of the owners is a geologist. Several guides were formed during the one week training session in the Laboratoire souterrain de Moulis
13 - Réseau André Lachambre	No	
14 - Réseau du Raulety	No	
15 - Aven du Mont Marcou	No	
16 - Grotte de la Cigalère	No	
17 - Aven d'Orgnac	Yes	The Director and several guides were formed during the one week training session in the Laboratoire souterrain de Moulis
18 - Barrencs de Fournes	No	

The Laboratoire Souterrain of the CNRS in Moulis, near Saint-Girons (Ariège), is specialized in the protection of caves presenting an exceptional patrimony, either archaeological (caves Chauvet, of Niaux, Gargas, Pech Merle) or mineralogical (Esparros, Orgnac). It is headed by Alain Mangin, a world-wide acknowledged specialist of karst systems. The research, fundamental and applied, is directly made on these reference sites. Besides, the Ministry of the Environment has at its disposal a high-level specialist, doctor in geology, in the the fields of the forming and protection of speleothems, Patrick Cabrol.

5.h Visitor facilities and statistics

The table below presents, for every element of the property, data concerning visitor number (on the whole property approximately 700,000 visitors, with high disparities according to places) as well as the different facilities available on sites for visitors

<i>Element number of the site</i>	<i>Name</i>	<i>Open to visit</i>	<i>Number of visitors (2005)</i>	<i>Parking</i>	<i>Nature trails</i>	<i>Shops</i>	<i>Publications</i>	<i>Museum</i>	<i>Restaurant</i>	<i>Toilets</i>
01	Grotte Amélineau	No	15	No	No	No	DVD	No	No	No
02	Grotte de Choranche	Yes	120 000	Yes	Yes	Yes	Yes	No	Yes	Yes
03	Aven Armand	Yes	100 000	Yes	No	Yes	Yes	No	Yes	Yes
04	Grottes des Demoiselles	Yes	100 000	Yes	No	Yes	Yes	No	Yes	Yes
05	Balme del Pastre	No	60	No	No	No	No	No	No	No
06	Grotte de l'Aguzou	Yes (« safari type »)	1000	Planned	Planned	No	No	No	No	No
07	Grotte du Lauzinas	No	200	No	No	No	No	No	No	No
08	Grotte du TM 71	No	120	Planned	Planned	No	No	No	No	No
09	Réseau de Cabrespine-Lastours	Yes	115 000	Yes	No	Yes	No	No	No	Yes
10	Gouffre d'Esparros	Yes	30 000	Yes	No	Yes	Planned	No	Not on the spot, but in 500 m	Yes
11	Grotte de Pousselières	No	200	No	No	No	No	No	No	No
12	Grotte de Clamouse	Yes	100 000	Yes	No	Yes	Yes	No	Yes	Yes
13	Réseau Lachambre	No	120	No	No	No	Yes	No	No	No
14	Réseau du Rautely	No	300	No	No	No	No	No	No	No
15	Aven du Mont Marcou	No	50	No	No	No	No	No	No	No
16	Grotte de la Cigalère	No	80	No	No	No	No	Study in course	No	No
17	Aven d'Orgnac	Yes	120 000	Yes	No	Yes	No	Yes	Yes	Yes
18	Barrency de Fournes	No	0	No	No	No	No	Study in course	No	No

The increasing number of visitors which could be generated by the inscription will be taken into account by an implementation of equipments and facilities for public (cf. charter of commitment of the administrators).

5.i Policies and programmes related to the presentation and promotion of the property.

According to the article 5 of the World Heritage convention, the measures concerning the whole property are the following ones:

- for the general policy of natural patrimony: the initiation of the proposition reactivated a specific general policy for subterranean patrimony (cf. 5.th, national committee); the whole proposed property constitutes the jewel of this type of patrimony in France;
- for the institution of protection services: there has been for a long time in France protection services able to insure the management of the subterranean patrimony; however, the intensification of the protections related to the property was the occasion to improve the existing services (local management committees);
- for the development of studies and scientific research projects: these were already reactivated for the preparation of the proposition file; however, an international acknowledgment would be very important to mobilize resources dedicated to these types of environments;
- for all the legal, scientific measures etc. to insure the protection and the development: there has been for a long time in France adapted protective measures; however, the specificity of the subterranean environments will be better taken into account thanks to an international recognition;
- for the training development: if, on a technical level, trainings of administrators were organized, the management of the property should be the occasion to strengthen the training and to raise the awareness in the circles of speleology; to do it, the French Union of Speleology (FFS) is associated to the structure of management.

All these elements allow thinking that the development and the transmission of this natural patrimony to future generations can be guaranteed, as required in the art. 4 of the convention.

5.j Staffing levels (professional, technical, maintenance)

The table below recaps the data relating to the various categories of employees for each element of the property.

Site	Cave fitted out for visit	Management	Guides	others
01 - Grotte Amélineau	No			
02 - Grotte de Choranche	Yes (Private)	1	4,5 annual full-time equivalent	9,5 full-time equivalent
03 - Aven Armand	Yes (Private)	3	4 guides all the year long + 2 in summer	2 persons all the year + 5 in summer
04 - Grotte des Demoiselles	Yes (Private)	1	4 guides part-time all the year + 6 in summer	2 full-time all the year + 6 part-time in summer
05 - Balme del Pastre	No			
06 - Grotte de l'Aguzou	Yes (Private)	1		1 person in summer
07 - Grotte de Lauzinas	No			
08 - Grotte du TM 71	No			
09 - Réseau Cabrespine à Lastours	Yes (Private)	2	4 full-time + 6 in summer	
10 - Gouffre d'Esparros	Yes (Communal)	1	4	1
11 - Grotte de Pousselières	No			
12 - Grotte de Clamouse	Yes (Private)	1	3 guides all the year + 5 in summer	3,5 persons all the year + 3 in summer
13 - Réseau Lachambre	No			
14 - Réseau du Raulety	No			
15 - Aven du Mont Marcou	No			
16 - Grotte de la Cigalère	No			
17 - Aven d'Ornagac	Yes (Communal)	1	3 guides all the year + 3 in summer for the cave	2 persons all the year + 2 in summer . 3 persons all the year for the museum
18 - Barrenes de Fournes	No			

A great number of tourist cave guides have attended a specialized training during a week in the Subterranean Laboratory of Moulis (Ariège). This training is organized by the National Association of Tourist Caves (ANECAT) and the GRETA of Ariège.

The grotte des Demoiselles, the grotte de Clamouse and the Aven Armand have a geologist in their staff. The directors or the managers of the caves of Choranche and Esparros have attended guide training sessions organized by the ANECAT. The director of the caves of Cabrespine and Limousis is a geologist.

6. *Monitoring*

6.a Key indicators for measuring state of conservation

The speleothems evolve very little at the human time scale. The natural modifications of minerals can be seen only after dozens, hundreds, even thousands of years.

The main modifications that could alter the elements of the property are thus mainly of human origin. It is necessary to distinguish works in surface, over the cave and in its sphere of influence, and direct infringements to the subterranean environment.

The control of works in surface is insured by the management committees and by the various services of the State. The walking of visitors in the cavity is under the responsibility of the administrators, under the control of management committees. Finally, the state of conservation of speleothems is insured by a periodic visual and photographic control.

A daily monitoring of the management of this property by the local management committee is thus the essential element of this control. Assessments made within the global management organization proposed for the property (cf. 5.th) should allow to collect these different informations in order to provide a general overview.

6.b Administrative arrangements for monitoring property

Le "ministère de l'écologie et du développement durable" :

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Le préfet de région Languedoc-Roussillon, préfet de l'Hérault, préfet coordonnateur :

See below (8.b)

Les directions régionales de l'environnement de Languedoc-Roussillon, Midi-Pyrénées et Rhône-Alpes :

See below (8.b)

6.c Results of previous reporting exercises

Pointless.

7. DOCUMENTATION

7.a Photographs, slides, image inventory and authorization table and other audiovisual materials

See particular appendix

7.b Texts relating to protective designation, copies of property management plans or documented management systems and extracts of other plans relevant to the property

See particular appendix

7.c Form and date of most recent records or inventory of property

An inventory of caves should be finalized by the committee in course of creation.

7.d Address where inventory, records and archives are held

Pointless.

7.e Bibliography

The bibliography is constituted:

- 1) Of quotations of works or articles on the general thematic of the proposition (cf. list infra, volume I),
 - 2) Of quotations of works or articles realized from the study of sites or groups of sites constituting the property (cf. lists attached to each of the index maps of sites, volume II).
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A fifty-year climatic signal in three Holocene stalagmite records from Mato Grosso, Brazil. *Quaternary International*, v. 135, n. 1, p. 115-129.

8. Contact Information of responsible Authorities

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8.b Institution or local official agency

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et préfecture du Rhône
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Rhône-Alpes

208 bis rue Garibaldi
69422 Lyon Cedex 03
Tél. : 04 37 48 36 00
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8.c Other Local Institutions

MAIRES :

Midi-Pyrénées :

Maire d'Esparros	André PENE	Village - 65130 Esparros	05 62 39 19 23
Communauté de Communes d'Esparros	Maurice LOUDET	Mairie 65 250 - La Barthe de Neste	05 62 98 21 32
Maire de Mélagues	Jean MILISI	Le Bourg - 12360 Mélagues	05 65 99 53 03
Mairie de Sentein	Guy CARRIEU	Pace de l'Eglise - 09800 Sentein	05 61 96 73 92

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Mairie Fontanès le Sault	Henri Paris	11140 Fontanès le Sault	04 68 20 39 30
Maire Escouloubre	Jacques PETIT	11140 Escouloubre	04 68 20 40 88
Mairie Cabrespine	Mr Antoine MENEN	Rue Six Ponts - 11160 cabrespine	04 68 26 16 56
Mairie Trassanel	Mne Jacqueline BONNEL	Le Village - 11160 Trassanel	04 68 26 11 92
Mairie Sallèles Cabardès	Albert Gendre	Forge 11600 - Salleles Cabardes	04 68 77 04 49
Mairie Limousis	Camille RAMEL	7 Grand Rue - 11600 limousis	04 68 77 15 79
Mairie Fournes Cabardès	Guy CHIFFRE	11 600 - Fournes Cabardes	
Mairie Lastours	Max BRAIL	1 rte Fournes - 11600 Lastours	04 68 77 16 76
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OWNERS AND/OR DIRECT MANAGER OF A CAVITY

1 - Grotte Amélineau	nom	Adresse	Téléphone
Propriétaire et gestionnaire	Armand PRATLONG	Hyelzas - 48150 Hures La Parade	04 66 45 43 68
06 - Grotte Aguzou	nom	Adresse	Téléphone
Conservateur de la grotte de l'Aguzou	Philippe MORENO	Grotte Aguzou - 09460 Mijanès	04 68 20 45 38
08 - Grotte TM 71	nom	Adresse	Téléphone
Gestionnaire de la grotte du TM 71	Philippe MORENO	Grotte Aguzou - 09460 Mijanès	04 68 20 45 38

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Languedoc-Roussillon :

09 - Cabrespine / Lastours	nom	Adresse	Téléphone
Exploitants des grottes touristiques de Cabrespine et de Limousis	Mr Jean Pierre LLORET	Gouffre Géant de Cabrespine - 11160 Cabrespine	04 68 26 14 22 06 85 84 68 74
04 - Grotte des Demoiselles	nom	Adresse	Téléphone
Exploitant :	Guilhem de Grully	Résidence du Parc des Graves G.170 – 1444 route de Mende – 34090 Montpellier	04 67 54 68 62 06 12 19 79 19
12 - Grotte de Clamouse	nom	Adresse	Téléphone
Exploitant	Paul et Nicole DUBOIS	Chemin des Merlets – Rue Grèzes - 34070 Montpellier	04 67 45 01 68
3 - Aven Armand	nom	Adresse	Téléphone
Direction de l'Aven	Jean Paul PIN	1 rue des Magnolia - 31470 Fonsorbes	05 61 06 58 42

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02 - Grotte de Choranche	nom	Adresse	Téléphone
Directeur d'exploitation	Laurent GARNIER	Grottes de Choranche - 38680 Choranche	04 76 36 09 88
17 - Aven d'Orgnac	nom	Adresse	Téléphone
Gestionnaire du site	Joël Ughetto	Aven d'Orgnac – 07150 Orgnac l'Aven	04 75 38 62 51

CLUBS OF SPELEOLOGY INSURING THE MANAGEMENT OF A CAVITY OF THE PROPERTY:

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07 - Grotte du Lauzinas	nom	Adresse	Téléphone
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11 - Grotte de Pousselières	nom	Adresse	Téléphone
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(cf. also 8.a)

9. SIGNATURE ON BEHALF OF THE STATE PARTY

The Ambassador of France, permanent representative of the French Republic to UNESCO.

- Le Ministère de l'Ecologie et du Développement Durable présente ses remerciements tout particuliers à Alain Mangin, directeur de recherche au CNRS, responsable du laboratoire de Moulis, pour ses contributions essentielles au présent dossier.
- Rédaction du texte de la proposition : François Bourges (Géologie Environnement Conseil.)
- Maquette et impression : ALT 92

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