Report on the international symposium in Paris concerning Lascaux and preservation issues in a subterranean environment: ways of approaching multi-faceted and multi-scaled rock art conservation problems.

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The French Ministry of Culture and Communication organized a two-day symposium (26 and 27 February, 2009) in Paris to address ongoing concerns about the adverse effects that micro-biological activities have on the Paleolithic rock paintings within Lascaux Cave. Chaired by Jean Clottes, the Lascaux symposium featured the French Minister of Culture and Communication, 12 scientific presenters who have worked within the cave and 18 international expert discussants from various countries around the globe. The roughly 200 attendants in the audience included rock art and conservation specialists as well as interested media and concerned members from the public.

What follows is an account of my personal impressions gained during the two days that I acted as an expert discussant at the symposium. This account likely contains some factual errors and omissions due to a number of reasons, one being that I've never visited the cave in person and the other that I do not understand French (in spite of valiant efforts by the two interpreters to keep up with the scientific terms etc.). A thorough and proper background and condition assessment requires more time, effort, and direct observation than what I could manage under the circumstances.

Located slightly southwest of France's center, the dark zone Lascaux Cave was reputedly first discovered in 1940 when four local boys allegedly followed their dog into a small gap left by a tree tip-up on a hill slope. Fairly recent discussions with the surviving octogenarian explorers have elicited more nuanced recollections, however. One less romantic version of the discovery, for example, is that people from the nearby Montignac community have already been using the partly sunken cave entrance to dispose of animal carcasses. Even if found not to be entirely true, this account nonetheless suggests that the cave was not necessarily hermeneutically sealed from the outside world after the paintings were done at least 15,000 years ago; fungi and other micro-organisms might have been dormant within for millennia.

As is the case of most other rock art sites, Lascaux Cave is surrounded by a wider natural and cultural milieu. This milieu is not only multi-faceted in terms of natural variables and cultural attitudes, but also multi-leveled in terms of spatial and chronological units of assessment and measurement. As far as cultural context is concerned, often expressed in idiosyncratic ways, a French symposium attendant compared Lascaux Cave to a *pâté de foie gras*, for example. According to the Frenchman, both the cave and *pâté* can last for an unexpectedly long time as long as they are sealed. However, once opened wide for human consumption, deterioration can be expected to set in fairly quickly (for a variety of reasons, comparatively open rock shelters with prehistoric rock paintings and/or engravings do not respond adversely to human visitation in the same way as narrow caves do, partly as a result of having been open all along and partly due to not being subjected to overcrowding as much). Signs of deterioration did eventually start showing up within Lascaux not long after it was formally opened for public visitation in 1948. By 1955, an average of 30,000 visitors has entered the cave per year to view the spectacular paintings (at this time conservators have already detected excess levels of carbon dioxide within the cave).

The reason for the cave's almost universal appeal is perhaps easier to grasp once it is realized that the larger than life and dynamic depictions of extinct aurochs, wild horses, and bison rotating in a vortex-like fashion against the walls and ceilings of the cave invoke powerful emotional responses among first-time visitors, driving many to tears. Most likely due to the artificial widening of the entrance and increased human visitation since the late 1940s, by the early 1960s green algae and white accretions were noticed within the cave. This infestation of micro-biological growth was part of what became known as the first bioclimatic crisis, dating roughly to between 1955 and 1983. The French Minister of Culture responded by closing the cave to public visitation, allowing only small groups of people to enter at pre-calculated intervals. Between 1963 and 1965, conservators treated the cave's interior surfaces with antibiotics and formalin to eradicate the algal growth. During this time a new cooling system was also installed which worked by convection with the cave's natural air currents.

By 1989 lichens started appearing in the cave. Following the break-down of the old convection system, a more powerful unit of temperature control was installed by 2001. Prior to the installation of the new air conditioning system, the deeper recesses of the cave tended to be warmer than the areas closer to the entrance. After the installation these temperature gradients reversed. Air exchange between the front and back of the cave ironically also became more stagnant after the installation of the new unit. Moreover, some people claim that it was during this second installment of a comparatively large air conditioning unit that the cave's entrance was left exposed to exterior rain and temperature fluctuations for a considerable time. These critics moreover claim that one possible reason for the appearance of fungi within the cave roughly around this time is that unsupervised construction workers did not sterilize their boots. However, another scenario is that the long-term, low-level presence of formaldehyde in the cave may have killed off many of the other organisms in the cave that would naturally have checked the expansion of fungi through the cave. It is the particularly the spread of a white fungus, known as *Fusarium solani*, that set off what became known as the second bioclimatic crisis in 2001, and which is still continuing.

The dynamics around and within the cave are complicated, as even the slightest of changes in geology or climate can trigger a chain of unanticipated events. Geological and hydrological studies above and within Lascaux Cave have shown that calcium saturated ground water fills the pore spaces of the caves' limestone walls and ceilings, which is thought to be good from a rock stability point of view. However, elevated levels of humidity soon after the construction of the new air conditioning unit apparently favored the growth of *Fusarium* fungi, whereas artificially induced desiccated conditions thereafter encouraged melanin-like growths to colonize clayey surfaces within the cave (yet anecdotal evidence seems to suggest that water have entered the cave via natural openings on an intermittent basis ever since the cave was re-discovered in 1940 and very likely long before, extending back into prehistoric times).

Between 2002 and 2008 highly trained conservators, wearing protective clothing, have been painstakingly removing fungi from the cave walls and in certain instances from on top of the prehistoric paintings, first with chemicals and then mechanically with sponges and hand-held vacuums. Unfortunately, repeated applications of fungicides and then antibiotics did not appear to be affective in the long term as ostensibly resistant fungi tended to re-appear. The use of ammonium quaternaire and isothiazolinone seems to have been successful in checking the spread of *Fusarium*, however. Most recently *Scolecobasidium* fungus has been the dominant growth within the cave, together with at least 10 species of bacteria. Interestingly, increasing treatment has resulted in an increasing diversity of species (biocides leave traces of carbon that allow those species that have survived to colonize). Of potential concern is *Collimonas* sp. that degrades minerals within the limestone surface but also has the potential advantage of killing other fungi. Meanwhile, bacteria produce acids that are not limestone friendly. *Cladisporium* growth is still a problem too.

A question that arises from the constant monitoring and battling of micro-biological growth is if the site is not being over-treated. Left alone, the fungi and bacteria can perhaps fight and determine the outcome of their own battle. Meanwhile, of obvious concern though, is the damage that these growths can cause; black spots, some as large as human hand, have appeared on some of the prehistoric paintings. Whether these spots are permanent or would eventually fade and disappear is still something that needs to be observed over the very long term. Monitoring the efficacy of rock art conservation treatments is a bit like watching a marathon run in progress; the athlete who is ahead at any one point in the race is not necessarily the winner. Similarly, rock surface stains at Painted Rock in California that looked worse two years after their first appearance have become invisible between 10 and 15 years later.

Concern for Lascaux's predicament has encouraged an independent international committee to propose at the 2008 UNESCO World Heritage meeting that the cave be put on the Endangered Sites List. To my mind this might be an overreaction. In certain ancient cultures people tantalizingly viewed natural and cultural features as sharing characteristics with the human body. Co-incidentally, puffy white spots that allegedly occurred on human skin (according to descriptions reminiscent of *Fusarium solani*) were also believed to occur on the walls of places where people live or visit. It is believed that these white spots are somehow symptomatic of discontent among people, particularly slander and rumor-mongering, even when insinuations turn out to be based on some grain of truth. In such a metaphorical assessment of a situation, it is believed that the white infestations can only be removed once people have decided to address the problem at hand in a spirit of empathy, instead of judging others in a harsh manner or unfairly apportioning blame. Overall, the symposium offered a venue where people came together to discuss innovative ways of assessing and addressing the presence of damaging micro-botanical organisms within the cave

What became apparent during the symposium on Lascaux was the variety of highly specialized and advanced approaches taken to study and address the fungal and bacterial infestations within. On Thursday the 26th of February, 2009, contributing scientists focused on the probable roles that geological and climatic factors might have played in the spread of fungi and other micro-organisms. Although the investigations have been extremely thorough and exact, I am still not sure if the results from the different studies have ever been properly integrated or synthesized. It is only once changes in the surface topography and vegetation cover above the cave, the soil and rock structure and chemistry in-between, the ground water, air flow, temperature, and humidity recorded at more-or-less the same time have been brought together, that one can start proposing and checking hypotheses as to the most likely causal chains of events.

But even of greater importance is to integrate and match the recorded results from the above-mentioned studies with the actual appearance, spread, and decline of micro-botanical organisms within particular sub-areas of the cave. As in the case of the geological and climatological studies concerning Lascaux Cave, the micro-biological research results presented on Friday the 27th of February are based on cutting edge and world class methods and techniques. Once again, however, I was not sure if any attempt has been made to integrate the various results. Also, the likely effects that the conservators' presence and activities within the cave might have had on the presence/absence of micro-organisms are worth recording and integrating into an overall time-line synthesis, if it has not been done already.

The daunting task of integrating vast masses of recorded information can perhaps be simplified by dividing up areas within the cave in terms of natural divisions (e.g., chambers or "panel-like" surfaces) or arbitrary units (e.g., 5-square meter blocks). Data gathered within each area can then be combined for analysis and comparison, knowing that the surface within an area shares more-or-less the same characteristics (i.e., similar slope, texture, and chemistry of rock). The spatial spread of micro-organisms on the rock needs to be photographed and mapped per area. Recorded information can be entered at regular time intervals, such as illustrated in the hypothetical table-like format below. Recorded information can also be presented as graphs or three dimensional maps to visualize, assess, and interpret developments in a systematic and chronological fashion (this can be done using the latest Geographic Information System (GIS) software).

Hypothetical and simplified table-like format to compare different kinds of information.

Area 1	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun
Conservation action						
Humidity						
Temperature						
Air pressure						
Water chemistry on roof						
Water chemistry against ceiling						

Water chemistry against wall						
Micro-organisms present and extent						
Area 2	1-Jan	1-Feb	1-Mar	1-Apr	1-May	1-Jun
Conservation action						
Humidity						
Temperature						
Air pressure						
Water chemistry on roof						
Water chemistry against ceiling						
Water chemistry against wall						
Micro-organisms present and extent						

Micro-climatic data collected by sensors placed within each area can be downloaded by a research assistant after the data has been electronically collected (in this way the presence of a human body does not influence the electronic reading of temperature and humidity levels). **Real-time recordings that are linked in an almost one-to-one fashion with specific rock surfaces and the documentation of presence/absence of micro-organisms are preferable to simulations**. Information can also be collected at different spatial scales. From macrocosm to microcosm these scales can include: the landscape above the cave (i.e., climatic, vegetation, and soil conditions on the roof); the entire cave (i.e., human visitation numbers and activities); and areas within the cave (i.e., once-off chemical and physical analysis of a small rock cross-section sample from within each sampling area). Studied in this fashion, changes at the micro-level can be tied to changes detected on the landscape above, for example. Tying together evidence from different scales might help the investigator to better detect if factors favoring fungal infestation are intra-site only or can be traced back to changes in the wider landscape above.

Perhaps some or all of the above steps have already been taken; I've included them in this informal report primarily as a query. In many ways Lascaux is a sacrificial cave simply because it is the first rock art cave where things happened and interventions were made. Based on the decisions and results at Lascaux, site managers and conservators at caves such as Altamira in northern Spain, to name but one instance, have gone to great lengths not to repeat certain mistakes thought to have been made at Lascaux. Nonetheless, each rock art site has unique characteristics and has to be managed and conserved accordingly, following the conservation principles of minimal intervention, repeatable treatment, and compatible use informed by the input and consensus of all concerned parties and interested stakeholders.