In recent years, the problems related to the conservation of rock art in European caves, which represent the first evidence of human artistic expression, have been a subject of debate, not only for the scientific community but also for the society and the media in general.

The conservation of Lascaux paintings received the attention of *Nature* as early as in 1967. There it was already stated that “The problems of Lascaux may be the most extreme that conservators have faced in recent years”. In 1999, *Nature* reported that “scientists and others will be excluded from the Lascaux caves in southern France, renowned for their prehistoric paintings, for at least a year while workers retune the systems monitoring the microclimate”. In fact, a new climate system was installed. Within months, an outbreak of the fungus *Fusarium solani* and other microorganisms covered the floor and banks of the main decorated halls. The climate system soon came under scrutiny as the direct cause of the cave’s climate change and the origin of the fungal outbreak.

The Laboratoire de Recherche des Monuments Historiques in Champs-sur-Marne, France, was charged with developing a research programme to control the microbial invaders of the cave. The application of ammonium quaternary disinfectants and quicklime were recommended, but the results of these treatments were unsuccessful and the microorganisms colonising the walls and paintings remained unclear for years.

Holden (2003) published in *Science* the short comment “Wanted: solution for cave mold” describing the problems of Lascaux, threatened by a stubborn infestation of fungi and bacteria, but scientific data on the origin of the microbial outbreaks were rarely published.

In 2005, Castellani discussed the problems of Lascaux and possible solutions, which led to Allemand and Bahn (2005) to declare that the best way to protect rock art is to leave it alone.

In 2006, an issue of the French magazine *Monumental* was devoted to describe the history and problems of Lascaux. Lascaux curator Jean-Michel Geneste told the Wall Street Journal that there was no danger to the paintings and that the microbial growth had disappeared naturally. But Laurence Léauté Beasley, founder and chair of the US-based International Committee for the Preservation of Lascaux, had a very different opinion. “The fungus is still present in the cave. Art restorers continue to manually pluck the roots [mycelia] of the fungus from the affected paintings. However, as the fungus is removed, dark and grey spots are left,” she said. Léauté Beasley added that new black spots have appeared in large numbers near the entrance of the cave. “To date, they have not been reported by authorities for scientific analysis,” she said (Rinaldi 2006).

Dupont et al. (2007) published a phylogenetic discrimination of the members of the *Fusarium solani* species complex found in the cave.

On 19 February 2008, Laurence Léauté Beasley wrote to the Director of UNESCO: “Today, there is a growing alarm around the world among scientists, academics, NGOs and private citizens about the deteriorating conditions of the painted cave of Lascaux in the Prehistoric Sites and Decorated Caves of the Vézère Valley, World
Heritage site. Lascaux is an exceptional masterpiece of human creative genius: its 17,000-year-old art bears witness to the vibrant culture of our ancient ancestors and is one of the very few tangible evidences left by their vanished civilization. But today Lascaux is in extreme danger, as a new biological invasion threatens to obliterate its priceless heritage. In 2006, a new proliferation of black spots began spreading on the cave’s walls, paintings and engravings. This outbreak continues, eating away at our World Heritage. This letter led UNESCO to warn France that the cave would be included on the List of World Heritage in Danger unless progress was made on the efforts to save the paintings from an invasion of black fungi.

To this end, the French Ministry of Culture and Communication awarded the Project “Microbial Ecology of Lascaux Cave” to the research groups of the Institute National de la Recherche Agronomique, Dijon, France (Claude Alabouvette) and Instituto de Recursos Naturales y Agrobiologia de Sevilla, Spain (Cesareo Saiz-Jimenez). The project was concluded in June 2011 and a final report was delivered to the Ministry. The presentation of this report stated that “Le principal objectif de ce projet était d’étudier l’écologie et les processus de succession microbienne qui se produisent dans la grotte. La grotte constitue un écosystème dynamique, les populations microbiennes évoluent avec le temps et nous avons pu constater à l’échelle de ces derniers 24 mois, que les profiles microbiens sont en train de changer. Au cours de dix dernières années, nous avons assisté à l’invasion par Fusarium solani puis à celle des «taches noires» et actuellement nous observons une évolution au sein des communautés fongiques associées aux «taches noires». Celles-ci ont révélé en 2007, la présence d’une nouvelle espèce de champignon, Ochroconis lascauxensis apparemment originales à Lascaux, et actuellement nous constatons l’apparition de levures noires et d’autres champignons mélanisés. La cause de cette évolution complexe et de cette succession de microorganismes au sein des communautés formant les «taches noires» est vraisemblablement l’utilisation de biocides dont les résidus constituent une source de carbone et d’azote utilisable par beaucoup de microorganismes”. This report (in French) can be accessed at Digital CSIC: http://hdl.handle.net/10261/45124.

In addition to the report, a few papers have been published since 2009 on this topic. The most relevant data were to decipher the contribution of collembolans in the formation of black stains (Martin-Sanchez et al. 2012a), the discovering and description of two novel species of melanised fungi involved in black stains formation (Martin-Sanchez et al. 2012b), and the paper recently published by the American Chemical Society journal Environmental Science and Technology, on the use of biocides for the control of fungal outbreaks (Martin-Sanchez et al. 2012c). This paper received the attention of Science, section Editor’s Choice, and published on 6th April the comment “Cave of Forgotten Fungi”. A few more papers describing the origin of the black stains on the clayey sediments (Saiz-Jimenez et al. 2012), the amoebae present in the cave (Garcia-Sanchez et al. 2013) and the application of RT-PCR to the quantification of Ochroconis lascauxensis (Martin-Sanchez et al. 2013) can be accessed on-line in the respective journals.

At present, the microbial ecology of Lascaux is disclosed but this complex cave needs frequent surveys and studies to follow the microbial succession along the time. Also the problems originated by the sole use of benzalkonium chloride derivatives during three years in a subterranean environment revealed to be a great error that marked the fate of the microbial microorganisms.
communities in Lascaux Cave. If biocide were to be applied, to avoid microbial resistance, a second biocide or a rotation of different biocides should have been included in the treatment protocol, which was not the case. As stated by Martin-Sanchez et al. (2012c) any biocide treatment should be planned after testing new molecules in laboratory as well as under field conditions in order to find an effective biocide treatment. However, this type of treatment is not recommended for caves with rock art paintings, because the presence of complex biofilms, inaccessible to biocides, and the fast inactivation of the biocides due to biotic and abiotic factors are expected, and the treatment, if not ineffective, can cause further and irreversible damage to the ecosystem.

Acknowledgements
This is a TCP-CSD 2007-00058 paper.

References and recent publications on Lascaux Cave


ADVERSE EFFECTS ARISING FROM CONSERVATION TREATMENTS ON ARCHAEOLOGICAL SITES: THEORY, PRACTICE AND REVIEW.

Natalia Pérez Ema¹,² and Mónica Álvarez de Buergo²

¹CEI Campus Moncloa, UCM-UPM. Edif. Real Jardín Botánico Alfonso XIII, Avda. Complutense, s/n 28040 Madrid.
²Instituto de Geociencias, (CSIC, UCM). C/ José Antonio Novais, 2. 28040 Madrid.

Introduction

Conservation and restoration of archaeological sites developed significantly in the second half of the twentieth century, with greater emphasis in recent decades, which has led to a considerable number of interventions.

Methodology of intervention has changed significantly since more interventionist measures are performed against the current criteria of minimum intervention, although what actually occurs today is a difficult balance between innovation (experimental application of new techniques and products) and minimum intervention. The debate, in the case of archaeological sites, has focused on the actions traditionally more aggressive: cleaning, consolidation or reintegration, as this is where most notable has been the restorative action throughout history.

The restoration, like everything else, has been subject of trends, in relation to the appearance of new products and technologies, and today remains a discipline that widely develops experimental practice. It certainly brings great benefits and constant renewal of criteria and methodologies, but also risks by introducing new compounds that may interact negatively with original substrate, although their effects cannot be checked in the short or medium term. The lack of knowledge of the causes of decay arising from previous interventions has generated a