ANALYSIS AND CHARACTERIZATION OF THE MICRO-BIOLOGICAL COLONIZATION OF ROCK SHELTERS WITH PREHISTORIC PAINTINGS IN PORTUGAL

ANÁLISE E CARACTERIZAÇÃO DA COLONIZAÇÃO MICROBIOLÓGICA DOS ABRIGOS COM PINTURAS RUPESTRES PRÉ-HISTÓRICAS EM PORTUGAL

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ABSTRACT

Research on the interface between the lichens and substrates suggests that the weathering of minerals can be accelerated by the growth of some species of lichens.
Under the Project RupScience (PTDC/HIS-ARQ/101299/2008) - "Review of operational chains, Archaeometry and Chronology of rock art paintings. A technological approach to material in contexts of Portugal and Spain", the identification and description of species of lichens in rock shelters with different lithologies associated to rock art in Portugal was carried out.
The micro-bio-mineralogy damage reveals that lichens are the main agents of weathering associated with the paintings.
The field work in rock-shelters with pre-historic paintings in Portugal, allowed the establishment of some correlations between the frequency, diversity, species distribution, climatic conditions variations and forms of deterioration, in particular related with slope and sun exposure of the rock art panels.
The implemented methodology in the identification and description of the lichen species, involved the use of non invasive or destructive techniques (macrophotography and microscope identification).
The interface between the lichens and substrate suggests that the weathering of minerals can be accelerated by the growth of some lichen species, in particular fungal hyphae.

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Preliminary observations indicate a greater representation of crustose species, representing higher penetration into the substrate, resulting in a remarkable acceleration of the fragmentation of rock art panel and consequent destruction of the paintings.

Keywords: Lichenology. Rock art. Micro-Biological Colonization. Prehistoric Paintings.

RESUMO

A investigação sobre a interface entre os substratos e os líquenes, sugere que o desgaste de minerais pode ser acelerado pelo crescimento de algumas espécies de líquenes.

No âmbito do Projeto RupScience (PTDC/HIS-ARQ/101299/2008) - " Análise de cadeias operacionais, Arqueometria e Cronologia das pinturas rupestres: Abordagem tecnológica de materiais em contextos de Portugal e Espanha", Foi realizada a identificação e descrição das espécies de líquenes observados em abrigos rochosos com diferentes litologias associadas à arte rupestre pintada em Portugal.

O dano micro -bio- mineralógico revela que os líquenes são os principais agentes de meteorização associados com as pinturas.

Os trabalhos de campo em abrigos com pinturas pré- históricas em Portugal, permitiu o estabelecimento de algumas correlações entre a frequência, diversidade, distribuição das espécies, da variação das condições climáticas e formas de deterioração, em particular relacionados com a inclinação e exposição solar dos painéis de arte rupestre.

A metodologia aplicada na identificação e descrição das espécies de líquenes, envolveu o uso de técnicas não invasivas ou destrutivas (macrofotografia e identificação ao microscópio ótico).

A interface entre os líquenes e os substratos sugere que o desgaste de minerais pode ser acelerado pelo crescimento de algumas espécies de líquenes, nomeadamente os que possuem hifas fúngicas. As observações preliminares indicam uma maior representação de espécies crostosas, que têm maior penetração no substrato, resultando numa aceleração notável de desfragmentação do painel rochoso e consequentemente na destruição de pinturas rupestres.

1. Introduction

Research has been carried out in western Iberia (OOSTERBEEK, 2008) with the purpose of characterizing the existing bio-colonization in archaeological rock art sites; Developed in the scope of RupScience project (PTDC/HIS-ARQ/101299/2008) – "Review of operational chains, Archaeometry and Chronology of rock art paintings. A technological approach to material in contexts of Portugal and Spain".

Lichens already cover some parts of the rock paintings and other parts will be covered during the future decades and centuries, a characterization of the rock art painting panels was carried out in order to recognize the type of bio-mineralogy damage

in the pre-historic paintings, this diagnosis of establishment enables the definition of measures and policies for the conservation of rock art murals (SEAWARDS, 1999).

Prieto et al. (1998) studied the biodeterioration of granite monuments using Fourier transform Raman (FTR) spectroscopy to analyze the effects of lichens on 20 churches around Galicia, Spain. FT Raman spectroscopy was selected because of it "non-destructively" analyzes small samples, and/or, *in situ* organic materials. This technique was also used by edwards et al. (1993) to examine deterioration induced by lichens on 16th century Renaissance frescoes at the Palazzo Farnese located in Caprarola, Italy.

Research on the interface between the lichens and substrates suggests that the weathering of minerals can be accelerated by the growth of some species of lichens.

The 1st step's processing of rock by lichens is evidenced by the increasing physical disintegration, by penetration of hyphae of lichens and through chemical decomposition of the complex (DANDRIDGE; MEEN, 2003).

Morphologically, lichens are formed by a few distinct characters, the most obvious kind of lichens that form (thallus) followed by shape is that the ranks several families. Lichens survive in very different environmental conditions, due to its adaptability to different habitats and substrates; they are pioneers colonizers of rocks exhibiting colours of lichens depending on their location in the panel.

Variations in humidity, light and natural competition between lichens influences the micro-bio-mineralogy development (CLARKE, 1976).

Lichens are symbiosis between algae and fungi, if the association is made with a cyanobacterium, the lichen can fix atmospheric nitrogen. For this reason, some scientists admit that lichens have been the first multicellular forms to colonize terrestrial environments, producing nitrogen compounds that have become part of the soil (DANDRIDGE; MEEN, 2003).

2. Regional setting

The region is an area where three main geomorphological landscape units of western Iberia meet: the Portuguese Central Cordillera (Hesperian massif), the Estremenho Limestone Massif and the Cenozoic Lower Tejo basin. (Figure 1) Although these landscape units are well characterized, they do not allow an in-depth

understanding of the relationships between the landscape and human settling mechanisms (OOSTERBEEK 2008).

Figure 1: Simplified geologic map of the Iberian Peninsula.

Modified from Gutierrez-Elorza, 1994.

Regional geomorphological features are strongly controlled by the lithology and structure of the substrate (MARTINS et al., 2009). Crests and gorges are linked with synclinal structures and resistant quartzite lithologies; deeply entrenched valleys are associated with a metamorphic and granite basement; small plateaus, fluvial terraces and alluvial plains occur in areas with a soft Cenozoic soft substratum; and karstic morphologies can be found in limestone areas located to the west of the study area. Lower and Middle Palaeolithic sites are mainly associated with fluvial terraces and less commonly with limestone cave infillings. Upper Palaeolithic sites are found mainly in karstic cave contexts. Neolithic and Chalcolithic sites are found mainly in colluvial deposits, and Megalithic monuments tend to be located in metamorphic bedrock areas.

Karstic cavities in the limestones of the Estremenho Massif include the oldest dated occupation in the Almonda cave system (240 ka: TRINKAUS et al, 2003), and various Middle and Upper Palaeolithic layers as well as important records of the Holocene cultural phases (mostly burials) (e.g. OOSTERBEEK, 1994; 1997, 2008). Some rock art engravings attributed stylistically to the Gravetian (Upper Palaeolithic) have been identified in the region (BATISTA, 2001).

The selection of sites results from the intensive research in the Iberian Peninsula. Some of the studied paintings are part of the Tejo valley rock art complex, reported since 1971. (ABREU, 1990) The rock art shelter of Pego da Rainha is the located in the Municipality of Mação (Alto Ribatejo, Central Portugal. Others are located in the

Extremadura region, Spain (La Calderita) (COLLADO, 2000, 2005, 2007, among others).

3. Methodology

The implemented methodology involved the use of non invasive techniques in archaeological sites. The identification and description of species of lichens in rock shelters with different lithologies associated to rock art in Portugal was carried out. The bio-colonization samples were macro-photographed *in situ* and ulteriorly identified with a binocular microscope and taxonomic manuals Samples of lichens identified in quartzite, schist's, granites and limestone were analysed.

When it was not possible to identify to the higher possible taxonomic level.

Lichens are informally classified by growth form into (DANDRIDGE; MEEN, 2003): crustose (paint-like, flat), (e.g., Caloplaca); filamentous (hair-like);foliose (leafy); fruticose (branched); leprose (powdery); squamulose (lacking a lower cortex), gelatinous lichens, (the cyanobacteria produce a polysaccharide that absorbs and retains water).

Crustose lichens – a type of lichen species that adheres tightly to the substrate and does not have a lower cortex attaching itself to the substrate by hyphae from the medulla (JAHNS, 1973).

Hyphae – fungal filaments which help secure the lichen body to a substrate; and which may or may not serve as a conduit for nutrients and/or water (after JAHNS, 1973; ST. CLAIR, 1999).

Squamulose lichens – intermediate form between crustose and foliose lichens.

Elongated lobes can be attached to the substrate by the entire lower surface or the margin may be free and ascending (JAHNS, 1973).

4. Results

Lichen growth is extremely common on the quartzite rock outcrops in this area.

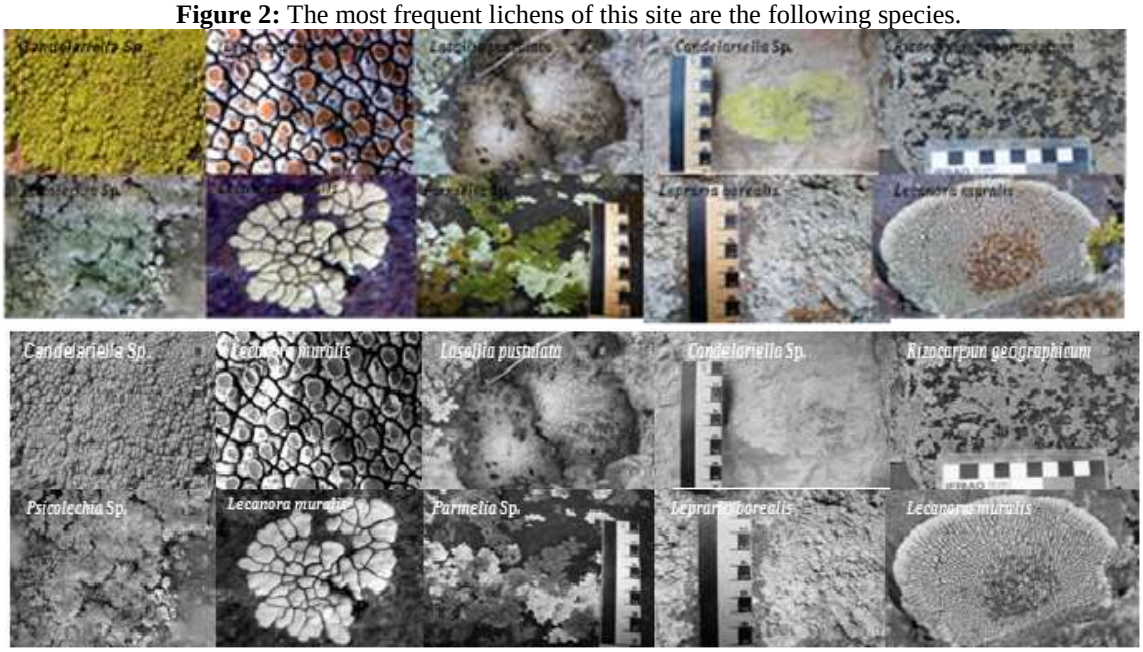
All exposed quartzite outcroppings observed, demonstrated an abundance of live lichens.

No fruticose lichens were identified in this research. Identification of lichen species was attempted but not possible for all.

The most frequent lichens of this site are the following species (Figure 2):

ex. *Xanthoparmelia* sp.; *Parmelia saxatilis*; *Lecanora muralis* Lasallia *postulate* and *Lepraria nivalis*; *Crysoteix* sp., *Candelariella* sp.; *Aspicilia calcarea*; *Placynthin nigrum Limonacea* sp.; *Strigula* sp.; *Crysoteix* sp., *Bacidea egenula*; *Crysoteix* sp.; *Psilochia lucida.*

Figure 2: The most frequent lichens of this site are the following species.



Legend: *Xanthoparmelia* sp.; *Parmelia saxatilis*; *Lecanora muralis* Lasallia postulate and *Lepraria nivalis*; *Crysoteix* sp., *Candelariella* sp.; *Aspicilia calcarea*; *Placynthin nigrum Limonacea* sp.; *Strigula* sp.; *Crysoteix* sp., *Bacidea egenula*; *Crysoteix* sp.; *Psilochia lucida.*

Preliminary observations indicate a greater representation of crustose species, with higher penetration into the substrate, resulting in a remarkable acceleration of the fragmentation of rock art panels and consequent destruction of paintings. The micro-bio-mineralogy damage reveals that lichens are the main agents of weathering associated with the paintings.

It was found that identical kinds of lichens proliferate in similar lithologies.

In quartzite panels the micro-biological colonization is similar; lichens identified are the same species, showing different stages of development, dependent on sunlight and humidity (CARDOSO, 2003; COLLADO, 2000, 2005, 2007).

5. Discussion

It is possible to establish some correlations between the abundancy, diversity, species distribution, climate conditions, and forms of deterioration, slope and sun exposure of the panels.

Preliminary observations indicate that the crustose species are more represented, with greater penetration into the substrate, resulting in remarkable acceleration of the fragmentation and destruction of the panels containing pre-historic rock paintings. The micro-bio-mineralogy damage reveals lichens as major agents of weathering associated with the paintings.

A small scale experiment was carried out. A foliose and crustose lichen, respectively, were removed by using a mechanical method. The foliose lichen such as *Lasallia pustulata* and species were easily removed, not so easy was the removable of the crustose lichen.

The microscopical hyphae of most crustose lichens are firmly attached to their substrate and in many cases penetrating between the mineral crystals. When the thallus of a crustose lichen is growing over a rock painting, it is impossible to remove the crustose lichen mechanically (by erasing) without causing a severe damage to the underlying painting (VANSKA, 2002).

Most foliose lichens grow ca. 2-3 mm in a year. The foliose lichen *Lasallia pustulata* is able to grow still faster in suitable moisture. Most crustose lichens grow a millimetre in a radial direction in a year. In suitable moisture the growth rate of the crustose lichens can reach 1 mm in a year depending on the species (VANSKA, 2002).

Through many decades, lichens have been removed from rock carved surfaces at various places in Portugal. The few facts available from the first half of the 1900s, indicate that this took place in some places beginning in the 1930s. The motivations for removal of lichens appear to have been multiple and varied over time, but originally the rock surfaces were cleaned in connection with documentation of the carved figures and consideration of the public's understanding and experience. At a later point problems associated with preservation of rock surfaces came into the picture. These were based on general knowledge about the acid producing attributes of lichens that lead to selective disintegration of minerals and therefore the disappearance of harder minerals, and about the ability of lichen hyphae for expansion and contraction in the rock

resulting in additional weakening of the weathering surface (see HAUGEN, 1994; DANDRIDGE; MEEN, 2003).

6. Final Remarks

The field work in archaeological sites with pre-historic paintings in Portugal and Spain, allowed the establishment of some correlations between the frequency, diversity, species distribution & climatic conditions, and forms of deterioration, slope and sun exposure of the rock art panels.

This work intends to investigate the contribution of "lichenic" substances in the degradation of the rocks, adding several factors: climate, topography, biological action, among other parameters that contribute to the maintenance and preservation of rock art murals.

In quartzite panels (Pêgo da Rainha and La Calderita) the micro-biological colonization is similar); the identified lichens are the same kind (crustose and foliose), showing different stages of development, dependent on sunlight and moisture. E.g. Xanthoparmelia Sp.; Parmelia saxatilis; Lecanora muralis and others…

This study allowed determining that the mostly representative lichens are crustose and pulverous species; Investigations on the interface between the lichens and rocky substrates suggest that the weathering of minerals can be accelerated by the growth of some species (crustose) of lichens.

The biggest representation of crustose species, with higher penetration into the substrate, resulting in a remarkable acceleration of the fragmentation of rock art panels and consequent destruction of paintings.

These results help us to generate conservation policies and measures to apply in rock art sites.

References

ABREU, M. S. DE; FOSSATI, A., JAFFE, L., (1990) - Rupestrian Archaeology: Techniques and Terminology: a methodological approach: Petroglyphs Valcamonica, Brescia: Cooperativa Archeologica "Le Orme dell'Uomo".

BAPTISTA, A. M. (2001) -The Quaternary Rock Art ofthe Côa Valley. In Carvalho, A. F., ed. - Les premiers homes modernes de la péninsule ibérique (Actes du COlloque de Ia Commission VIII de I'UISPP. Vila Nova de Foz Côa, 22-24 Octobre 1998). Lisboa: IrA, p. 237-252.

CARDOSO, D., (2003) – Pego da Rainha (Mação), *Arkeos – Perspectivas em Diálogo*, nº 14, CEIPHAR, Tomar, pp. 59-72.

CLARKE, J., (1976) A Lichen Control Experiment at an Aboriginal Rock Engraving Site, Bolgart, Western Australia. *ICCM Bulletin* 2(3):15-17.

COLLADO, H., (2000) - Reflexión crítica y conclusiones sobre la interpretación y el encuadre cronológico de la pintura rupestre esquemática en la Extremadura española. Arkeos, nº 7, p. 103-144.

COLLADO, H; GARCÍA A. J. L., (2005) - Arte rupestre en el Parque Natural del Monfragüe: El sector oriental. En: Corpus de Arte Rupestre en Extremadura. Vol I. Ed. Junta de Extremadura, Consejería de Cultura. Algumas considerações de métodos sobre estilos, valoração estética e cronoestratigrafia figurativa, Arkeos - Perspectivas em diálogo, Tomo II, nº 6, Tomar, pp. 197-277.

COLLADO, H; GARCÍA A. J. L., (2007) - Arte Rupestre en La Zepa de la Serrana. En: Corpus de Arte Rupestre en Extremadura. Vol II. Ed. Junta de Extremadura, Consejería de Cultura.

DANDRIDGE, D. E., AND J. K. MEEN, (2003) The Degradation of Rock Art by Lichen Processes. In *American Indian Rock Art*, Vol. 29, edited by Alanah Woody and J. T. O'Connor, pp. 43-52. American Rock Art Association, Phoenix, Arizona.

EDWARDS, H. G. M., K. A. E. EDWARDS, D. W. FARWELL, I. R. LEWIS, AND M. R. D. Encrustations. *Journal of Raman Spectroscopy* 25:99-103.

HAUGEN, R. 1994. Low on rock surfaces in Ostfold. A-S. Hygen (ed.): State Registration, conservation and management of rock carvings in Østfold 1994. Publications issued by the Culture Department, Ostfold County No. 2/1994, Part III, 32-35. Sarpsborg.

JAHNS, H.M. (1973) Anatomy, morphology and development. In: Ahmadjian, V. & Hale, M.E. (eds). The lichens. Academic Press, New York. Lindau, G. (1888) Über die Anlage.

MARTINS, A.A, CUNHA, P.P, HUOT, S, MURRAY, A, BUYLAERT, J.P., (2009). Geomorphological correlation of the tectonically displaced Tejo River terraces (Gavião-Chamusca area, Portugal) supported by luminescence dating. Quaternary International. 199, 75–91.

OOSTERBEEK, L, (1994). Echoes from the East: the western network. An insight to unequal and combined development, 7000-2000 BC. Ph.D. Thesis, University of London, 732 pp.

OOSTERBEEK, L., (1997) - Echoes from the East: Late Prehistory of the North Ribatejo, Tomar, CEIPHAR - Centro Europeu de Investigação da Pré-História do Alto Ribatejo, 304 p.

OOSTERBEEK, L; (2008) - Problems and perspectives of Rock Art in Portugal: a view from the Tagus valley. In: "Man in India": A Quarterly International Journal of Anthropology Vol. 88. Special Issue Rock Art World Main Problems (Dario Seglie, Editor). pp.173- 180.

PRIETO, B., M. R. D. SEAWARD, H. G. M. EDWARDS, T. RIVAS, AND B. SILVA SEAWARD, (1993) - An approach to stone and fresco lichen biodeterioration through fourier transform raman microscopic investigation of thallus-substratum. 1998/1999 - Biodeterioration of Granite Monuments by Ochrolechia parella (L.)

ST. CLAIR, LARRY L. 1999 - A Color Guidebook to Common Rocky Mountain Lichens. M. L. Bean Life Science Museum, Provo, Utah.

TRINKAUS, E, MARKS, A.E, BRUGAL, J.P, BAILEY, S.E, RINKE, W.J, RICHTERE, D, (2003). Later Middle Pleistocene human remains from the Almonda Karstic system, Torres Novas, Portugal. Journal of Human Evolution 45, 219-226.

VANSKA, H., (2002) - A Report to the Nervanderinkatu 13, National Board of Antiquities, Department of Ecology and Systematics, Division of Systematic Biology, Helsinki University, Finland.