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Effects of microbial biofilms in carbonate rocks from spanish monuments

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In situ microscopy diagnosis was made of the biodeterioration processes occurring in carbonate stones from several Spanish monuments. To explore the possible influence of climate on the microbiota colonizing the stone and their effects, we sampled monuments from regions of different climate such as Alicante (semiarid with 336 mm mean annual rainfall, 1971-2000, and long periods of drought) and Segovia (cold and wet with 464 mm mean rainfall for the same period).The rock samples studied were dolostones and limestones from Biar Castle (Alicante), dolostones and biocalcarenites from monuments in Novelda (Alicante), microcrystalline dolostones from the Church of Vera Cruz (Segovia) and dolomitic rocks from the Convent of Santa Cruz la Real (Segovia). The microscopy and microanalytical approaches used were scanning electron microscopy with back scattered electron imaging (SEM-BSE), transmission light microscopy (TLM), low temperature scanning electron microscopy (LTSEM) and confocal scanning laser microscopy (CSLM).

The composition and effects of the different biofilms found in carbonate rocks from several monuments had several features in common. Lichen colonization was observed on the surface of all the monuments. Cyanobacteria, free-living fungi, algae and heterotrophic bacteria were also frequent components of these biofilms. Biofilm components in the epilithic zones produced de-cohesion and loss of substrate material from the surface of the monuments. Granular disaggregation, flaking and pitting were observed in the areas colonized by these microorganisms.

Microorganisms were observed not only in epilithic parts of the biofilm but also occupying holes and cavities within the rock. This internal biocolonization by cryptoen-

dolithic and chasmoendolithic microorganisms was mainly achieved through discontinuity planes in the stone. Associated with this penetration, geomechanical effects were noted. In monuments from semiarid regions, euendolithic cyanobacteria were also detected in zones lacking lichens. These penetrate the rock to settle in spaces that adopt their shape. Element mobilization and biomineralization processes associated with lichen thalli and cyanobacteria were identified in the biofilms.

In situ microscopy revealed that many of the deterioration processes observed in the monuments were linked to the presence of microbial biofilms in the stone. The diversity of microorganisms as well as the relative contribution of the different components of the biofilm to the biodeterioration processes observed was found to vary according to the climate and the type of the rock. The rock petrofabric (texture and structure) plays an important role in the rate and morphology of bioalterations. Geophysical and geochemical signs produced by the biofilm's endolithic components indicate that, besides the microorganisms we can see on the monument stone, others hidden beneath the surface layer also contribute to the biodeterioration process. The combined action of epilithic and endolithic components of the microbial biofilm has the final consequence of degrading the stone.