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Calcium carbonate crystallizations on hypogean mural paintings: a pilot study of monitoring and diagnostics in Roman catacombs

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One of the deterioration processes affecting mural paintings and rock surfaces within manmade hypogea consists in the formation of calcium carbonate crystallizations, which can create thick coverage and incrustations, even in some cases speleothems. These chemical reactions necessarily require the availability of calcium sources, which can be also of anthropogenic origin (e.g., lime-based mortars). Microclimate parameters also represent environmental forcing factors, on which the morphology and the degree of crystallinity of the precipitated carbonates depend.

Understanding past/recent dynamics of carbonate precipitation implies a deep knowledge of the relationships between the exposed surfaces and the microclimate conditions, the impacts of external factors (e.g., groundwater infiltration and percolation from the overlying soil) and how they change over time. This is particularly fundamental for the preservation of hypogean sites which have not comparison with other typologies of environment due to their uniqueness, such as the ancient catacombs carved underneath the suburbs of Rome (Italy), since the 2nd century AD.

In this paper we present the multidisciplinary methodological approach designed for the instrumental monitoring of the microphysical environment of the Catacombs of Saints Mark, Marcellian and Damasus, in the framework of the co-operation between the Institute for the Conservation and Valorization of Cultural Heritage and Pontifical Commission for Sacred Archaeology, Vatican, on the project HYPOGEA.

Temperature inside the catacomb and on the surfaces, air relative humidity and CO_2 concentration are the main of the parameters continuously measured by means of data loggers installed within the cubicles. Contemporarily, standardized methods of photographic documentation and digital micro-photogrammetry are used for change detection analysis of the painted surfaces and ancient plasters, as well as of the test areas purposely realized by applying fresh lime mortars simulating the former surfaces. Parallel laboratory investigations (e.g., diamond anvil cell FT-IR spectroscopy, X-ray diffraction, thin section observations under polarized light microscope, conventional microbiological investigations) are complementarily employed to characterize the calcite crystallizations, in terms of compositional, textural and mineralogical properties. Hence, it is expected to find a correlation between the microclimate conditions and the degree of crystallinity and morphology of the incrustations developed on the surfaces of the fresh samples.

A specific study of the stratigraphic sequence of the calcite crystallizations already formed on the ancient surfaces is also included, to perform a back-analysis of the microclimate variations inside the cubicles through centuries of use and abandonment. In this regard, the precise knowledge of the conservation history of the monitored cubicles is adopted as a temporal guide to hypothesize the time frames, to which the observed strata are presumably to be referred.

The main outcome of this pilot study is the establishment of a methodological approach suitable for the monitoring of crystallization phenomena inside catacombs, to be potentially exported to similar contexts. The findings of the research will also constitute the scientific base for the design of the most appropriate measures of environmental conditioning, also in the perspective to open the catacombs to visitors.