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

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Introduction

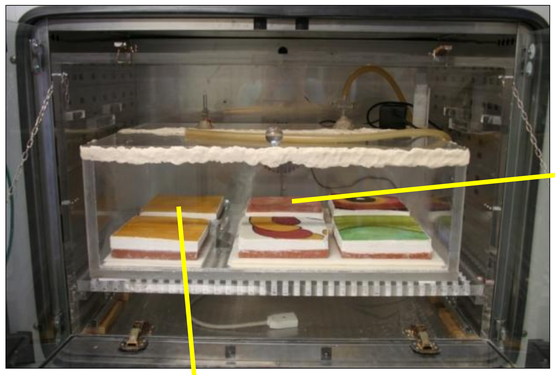
Rock and painted surfaces of the Roman catacombs, carved underneath the suburbs of Rome (Italy) since the 2nd century AD, are frequently covered by calcium carbonate crystallizations, which can create thick coverage and incrustations, even in some cases speleothems. Such crystallization processes actually represent a non-negligible issue for their impacts on the readability of the paintings. New cleaning methods are currently tested, with interesting results obtained during the laser-based restorations carried out in Santa Tecla catacomb (Mazzei, 2010).

Nevertheless, conservation strategies aimed at the prevention of crystallizations are needed, especially in the perspective of public opening. Sanchez-Moral et al. (2005) have already studied the influence of visitors on rock and artificial building materials deterioration in the Roman catacombs of Domitilla and Saint Callixtus, also finding evidences of microbial activity involved in the formation of metastable calcium carbonate mineral phases (Sanchez-Moral et al., 2003). Undoubtedly, the abiotic processes leading to crystallizations are strictly dependent on the availability of calcium sources (in the present case, lime-based mortars of the frescoes) and local microclimate parameters, among which the variations in CO_2 concentration in the air over time.

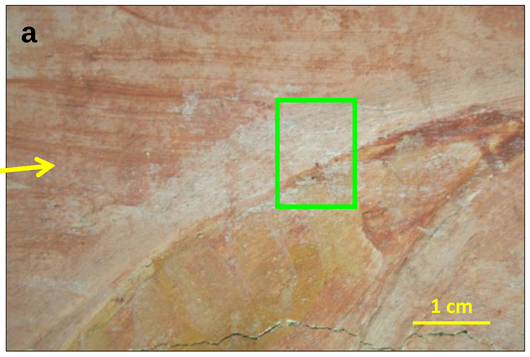
To understand past/recent dynamics of carbonate precipitation in Roman catacomb and how the microclimate can influence the morphology and the degree of crystallinity of the precipitated carbonates, the two-year pilot study **HYPOGEA** has been recently activated in the framework of co-operation between the Institute for the Conservation and Valorization of Cultural Heritage (ICVBC - CNR) and the Pontifical Commission for Sacred Archaeology, Vatican, also benefitting of the experience gained after laboratory simulations by Tapete (2007).

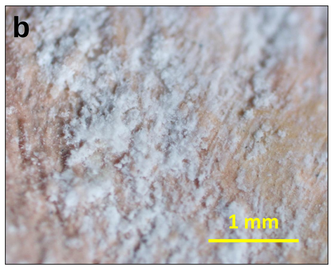
Background laboratory-based research

Combined analyses by means of microchemical and minero-petrographic techniques carried out on fresco and a secco paintings exposed within a simulated hypogean environment, under high and constant pressures of CO_2 and a constantly controlled profile of RH reaching up to 100%, have highlighted the formation of calcium carbonate phases, with different morphologies and degree of crystallinity, spanning from pure calcite to vaterite, even amorphous phases.

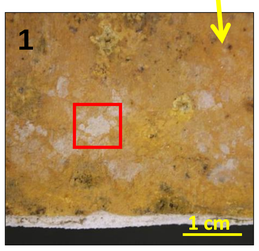


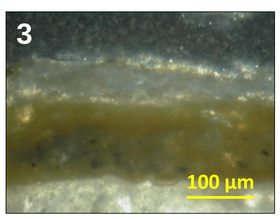
Constantly conditioned simulation box reproducing an hypogean environment, with fresco and a secco painting samples.

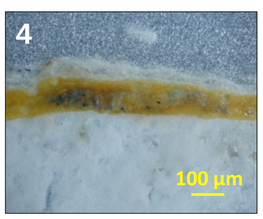


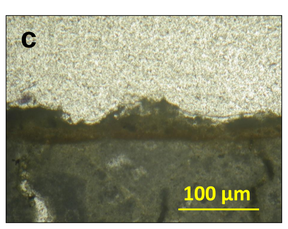


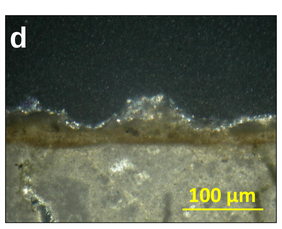
Fresco sample with calcium carbonate crystallizations (a) in form of covering white crystal clusters (b; OM VIS, 40x). PLM (c-d; Nicols // and +, 25x) and OM (e-f; VIS 10x and 20x) observations on thin section show a coverage of micritic calcite above the painted layer. FT-IR analyses confirm they are mainly calcite (g).

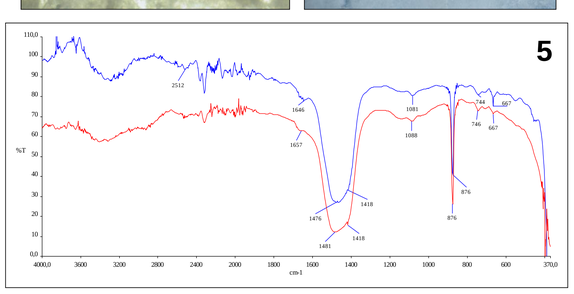




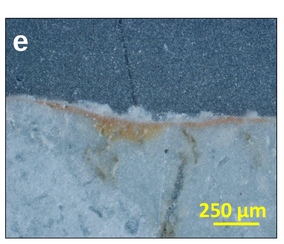


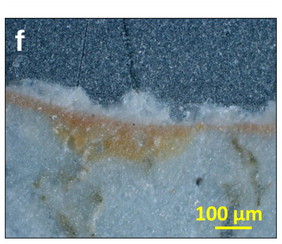


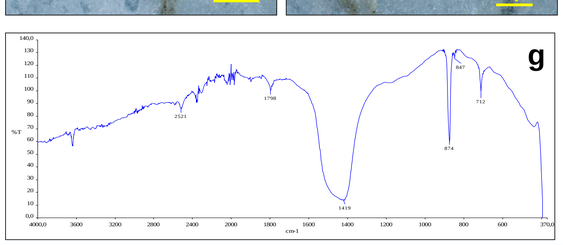




A secco painting sample with calcium carbonate crystallizations distributed as a totally covering drop-shaped crust (1), which strongly adheres to the painted surface (2). PLM (3; Nicols +, 25x) and OM (4; VIS 20x) observations on thin section confirm the thickness of the crust, which is predominantly constituted by vaterite, secondarily calcite (5).

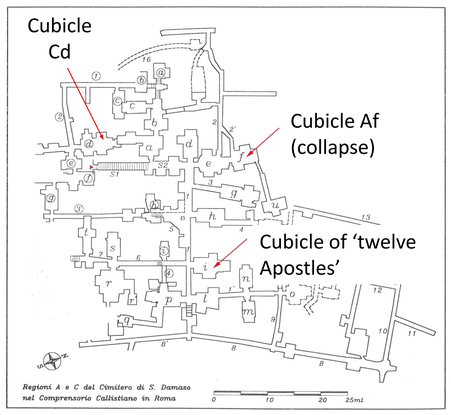






Case study

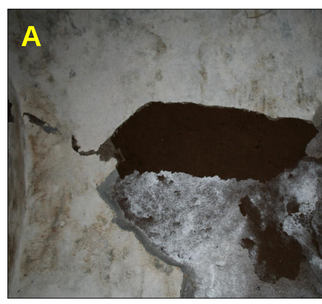
The test sites selected for the HYPOGEA project are the cubicles and corridors of the catacombs of Saints Mark, Marcellian and Damasus, located close to the Saint Callixtus catacombs, in an area between *Via Appia Antica* and *Via Ardeatina*, south of Rome (Italy). These catacombs are nowadays closed to the visitors and several historical archive documentation testifying the conservation history of the site is preserved.



Plan of the Regions A and C, with indication of the three chambers on which diagnostic analyses are ongoing.

White coverages with appearance of salt efflorescence and incrustations are clearly visible on both bare rocks and painted surfaces. They are likely still active and continuously growing, as testified by the apparently fast re-growing of crystallizations in correspondence to areas previously affected by collapses and detachment of the plasters.

Cubicle Cd where spot microclimate measurements performed in October 2011 highlighted an average CO_2 concentration not less than 4000 ppm.



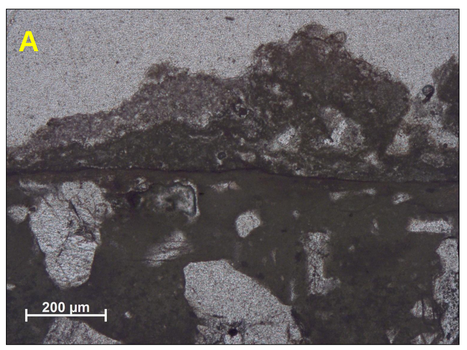
A) Detail of a bare rock surface exposed after a plaster collapse with active crystallization phenomena; B) totally covering and thick incrustations affect rock surfaces weakened up to exfoliation and surface detachment; C) detail of the painted vault of the central arcosolium in the Cubicles of 'twelve Apostles', partially covered by white crystallizations.

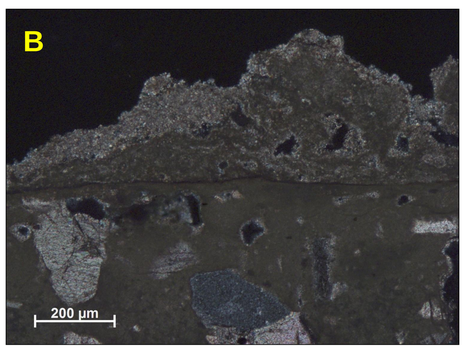
Project phases and aims

The HYPOGEA project foresees the following activities:

- **Diagnosis:** Complete characterization of the crystallizations affecting the archaeological surfaces, to be compared with the findings of the background laboratory-based research. Such phase is currently ongoing.
- **Instrumental microclimate monitoring**: Installation of a monitoring system measuring the microclimate parameters (e.g., T, RH, CO_2 concentration)
- **Surface pattern monitoring:** design and implementation of a procedure of monitoring by means of standardized methods of photographic documentation and digital micro-photogrammetry for change detection of both:
  - painted surfaces and ancient plasters
  - test areas purposely realized by applying fresh lime mortars on the bare rock, simulating the original surfaces
- **Microclimate back-analysis**: analysis of the stratigraphic sequence by mutually correlating morphology, degree of crystallinity and thickness, to draw a hypothesis about the time frames and microclimate conditions related to crystals formation.

Sample from the plaster damaged by the collapse occurred in the Cubicle Af. The PLM observations on thin section highlight the presence of a thick multi-layering sequence of calcium carbonate crystallizations covering the plaster surface (A-B; Nicols // and +, respectively, 10x).





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