

Internship proposal 2025-2026: 6 months Master 2nd year

Title: Characterization of the Biodeterioration of a Historical Monument

Description of the internship (context, objectives, methodology):

Scientific context

France is particularly rich in historical stone monuments. Despite its greater resistance to all kinds of damage compared to other materials, most stone heritage sites are now severely affected by environmental fluctuations, air pollution, and climate change (Esteban-Cantillo et al. 2024, Wang et al., 2025). Among the dangers these stone monuments face are geological and microbiological phenomena, collectively known as geomicrobiological phenomena. The impact of geomicrobiological phenomena evolves with changes in environmental factors, particularly water activity. A key aspect of the risks to stone exposed to the elements is its microbial colonization in the form of biofilms. This is a multi-species consortium capable of regulating biogeochemical cycles using nutrients primarily from the atmosphere and the colonized substrate, interacting with stone materials to meet their niche needs, and ultimately causing the biodeterioration of stone heritage (Mugnai et al. 2024, Ranaldi et al. 2025). Depending on the stone's bioreceptivity, a broad layer of epilithic biofilm can form on the surface. These frequently photosynthetic biofilms have an aesthetic impact as biocover and, depending on the building's conservation conditions, can have biodeterioration or bioprotection effects. Thus, inactive biofilms could serve as biological coatings to protect heritage stone materials from abiotic attacks when water is biologically unavailable. However, water acts by physically expanding and contracting biofilms in response to hydration/desiccation cycles, and by chemically stimulating salt dissolution and precipitation processes, leading to deterioration (Menendez and Petránová 2016, Lepinay et al. 2018). Chemical antibiofilm treatments applied to stone use biocides that have an ecotoxicological impact on the environment and humans (Romani et al. 2022). Evolving European regulations on the use of biocides and the need for One Health approaches are driving a strong need for the development of innovative treatments based on less toxic natural active ingredients (Ranaldi et al. 2025).

Purpose and Experimental Strategy

This work will consist of a case study (the troglodyte church of “Notre Dame de l’Annonciation” in the city of Haute-Isle in the Vexin region, 70 km north-west from Paris). The church, entirely excavated in chalk, exhibits significant biological growth covering a large portion of the walls and ceiling. The biofilm growth areas appear to be subject to high humidity and intense sunlight. Part of the work will involve establishing a climate data collection system in the church (temperature and humidity readings), mapping the biological growth, and characterizing it using colorimetry. Biofilm samples will be taken from different areas of the biofilm exhibiting varied macroscopic appearances. These samples will be analysed by microscopy at the Cergy Materials Institute's imaging platform using confocal laser scanning microscopy and scanning electron microscopy. They will be cultured on various solid and liquid media to characterize the culturable flora. The isolated microorganisms will be identified using phenotypic and molecular approaches.

This work will require the implementation of various techniques: collection of samples under aseptic conditions, culture of microbial species (bacteria, moulds, microalgae and cyanobacteria), microbial identification (staining, biochemical tests, morphological analyses, DNA extraction, targeted PCR amplification of ITS sequences, of gene sequences encoding 16S and 18S RNA, bioinformatics analysis), imaging (confocal laser scanning microscopy, scanning electron microscopy), colorimetry (portable spectrophotometer).

The research project is part of the Horizon European project CHARM and will continue with a PhD thesis in collaboration with the Laboratory of Biology of Algae at the University of Rome Tor Vergata.

- Esteban-Cantillo O.J., Menendez B., Quesada B. Climate change and air pollution impacts on cultural heritage building materials in Europe and Mexico, *Science of The Total Environment*, 2024, 921, 170945, <https://doi.org/10.1016/j.scitotenv.2024.170945>.
- Wang L., Huang J., Sanmartín P., Di Martino P., Wu F., Urzi C.E., Gu J.D., Liu X. Water determines geomicrobiological impact on stone heritage, *Nature Geoscience*, 2025, 18, 108–111. <https://doi.org/10.1038/s41561-024-01631-x>.
- Mugnai G., Borruso L., Wu Y.L., Gallinaro M., Cappitelli F., Zerboni A., Federica Villa. Ecological strategies of bacterial communities in prehistoric stone wall paintings across weathering gradients: A case study from the Borana zone in southern Ethiopia. *Science of The Total Environment*. 2024. 907, 168026, <https://doi.org/10.1016/j.scitotenv.2023.168026>.
- Ranaldi R., Gabriele F., Rugnini L., Di Martino P., Agniel R., Scuderi F., Braglia R., Canini A., Spreti N. Essential oils in hydrogel for microalgal biofilm removal: Application strategies for stone heritage preservation, *International Biodeterioration & Biodegradation*, 2025, 203, 106128, <https://doi.org/10.1016/j.ibiod.2025.106128>.
- Menéndez B., Petráňová V., Effect of mixed vs single brine composition on salt weathering in porous carbonate building stones for different environmental conditions, *Engineering Geology*, 2016, 210, 124-139, <https://doi.org/10.1016/j.enggeo.2016.06.011>.
- Lepinay C., Mihajlovski A., Tournon S., Seyer D., Bousta F., Di Martino P. Bacterial diversity associated with saline efflorescences damaging the walls of a French decorated prehistoric cave registered as a World Cultural Heritage Site. *International Biodeterioration & Biodegradation*. 2018. 130: 55-64. <https://doi.org/10.1016/j.ibiod.2018.03.016>.
- Romani M., Warscheid T., Nicole L., Marcon L., Di Martino P., Suzuki M.T., Lebaron P., Lami R. Current and future chemical treatments to fight biodeterioration of building materials and associated biofilms: moving away from ecotoxic and towards efficient, sustainable solutions. *Science of The Total Environment*. 2022. 802: 149846. <https://doi.org/10.1016/j.scitotenv.2021.149846>.
- Ranaldi R., Gabriele F., Rugnini L., Di Martino P., Agniel R., Scuderi F., Braglia R., Canini A., Spreti N. Essential oils in hydrogel for microalgal biofilm removal: Application strategies for stone heritage preservation, *International Biodeterioration & Biodegradation*, 2025, 203, 106128, <https://doi.org/10.1016/j.ibiod.2025.106128>.

Host structure

CY CERGY PARIS UNIVERSITÉ

The Master project is a collaboration between two laboratories located in the same building on the Neuville-sur-Oise site, Cergy-Pontoise, France.

Laboratory 1: ERRMECe Laboratory Biofilm group (BCMI), Cergy Paris University

Web site: <https://www.cyu.fr/recherche-et-valorisation/structures-de-recherche/laboratoires/errmece-equipe-de-recherche-sur-les-relations-matrice-extracellulaire-cellule>

Laboratory 2: L'Institut des Sciences de la Terre de Paris (ISTeP) UMR 7193 CNRS équipe PRISME (formerly called GEC) Cergy Paris University

Mailing address: Maison Internationale de la Recherche (MIR) 1 RUE DESCARTES 95000 NEUVILLE-SUR-OISE

Web site: http://istep.upmc.fr/fr/les_equipes/prisme-2.html

Both host facilities belong to the Institute of Materials (I-MAT) of Cergy Paris University.

Contacts/ internship supervisors

■ *Contact 1:* Patrick Di Martino, Professor of Microbiology ERRMECe laboratory

Phone: +33 1 34 25 66 06

e-mail: patrick.di-martino@cyu.fr

■ *Contact 2:* Beatriz Menendez, Associate Professor of Geosciences UMR 7193 CNRS équipe PRISME

Phone: +33 1 34 25 73 62

e-mail: beatriz.menendez@cyu.fr

Applications (CV and cover letter) should be sent to:

patrick.di-martino@cyu.fr and beatriz.menendez@cyu.fr