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POROUS LIMESTONES UNDER DIFFERENT ENVIRONMENTS – CONDITION ASSESSMENT OF MONUMENTS IN RABAT, MALTA AND CAEN, FRANCE

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Abstract

In the framework of the EU-HORIZON Project STECCI (Stone Monument Ensembles and the Climate Change Impact), cultural assets made of various types of limestone in 14 European sites have been studied. This contribution presents part of the results from the condition assessment activities at the Domus Romana in Rabat, Malta, and the Cimetière Saint Jean in Caen, France. The monuments at both sites are made of porous, biogenic limestone types. In situ tests and analyses, including damage mapping, water uptake measurement using the contact sponge method, Reflectance Transformation Imaging (RTI), and the "brush-off test", were employed along with microscopic investigations in the laboratory to assess the current state of preservation and to identify the primary mechanisms contributing to deterioration. Local climatic conditions were of particular interest in understanding the stones' behavior in response to external weathering parameters. While some damage patterns, such as biological colonization and alveolization, were observed at both sites, their intensity and distribution varied due to site-specific climatic conditions. The Domus Romana, being more exposed to wind and heat, exhibited damage primarily linked to these factors. In contrast, the site in Caen, characterized by a wet and semi-protected environment, showed damage typical of such exposures. Consequently, while in Malta, the dry, windy Mediterranean climate and wind-driven salt are key factors in stone degradation, in Caen, near the Atlantic, higher, more consistent rainfall and abundant vegetation along with some damaging salt accelerate stone deterioration. The findings emphasize the necessity for tailored conservation strategies that address the specific environmental pressures affecting each site.

Keywords: porous limestone, deterioration, condition assessment, climate impact

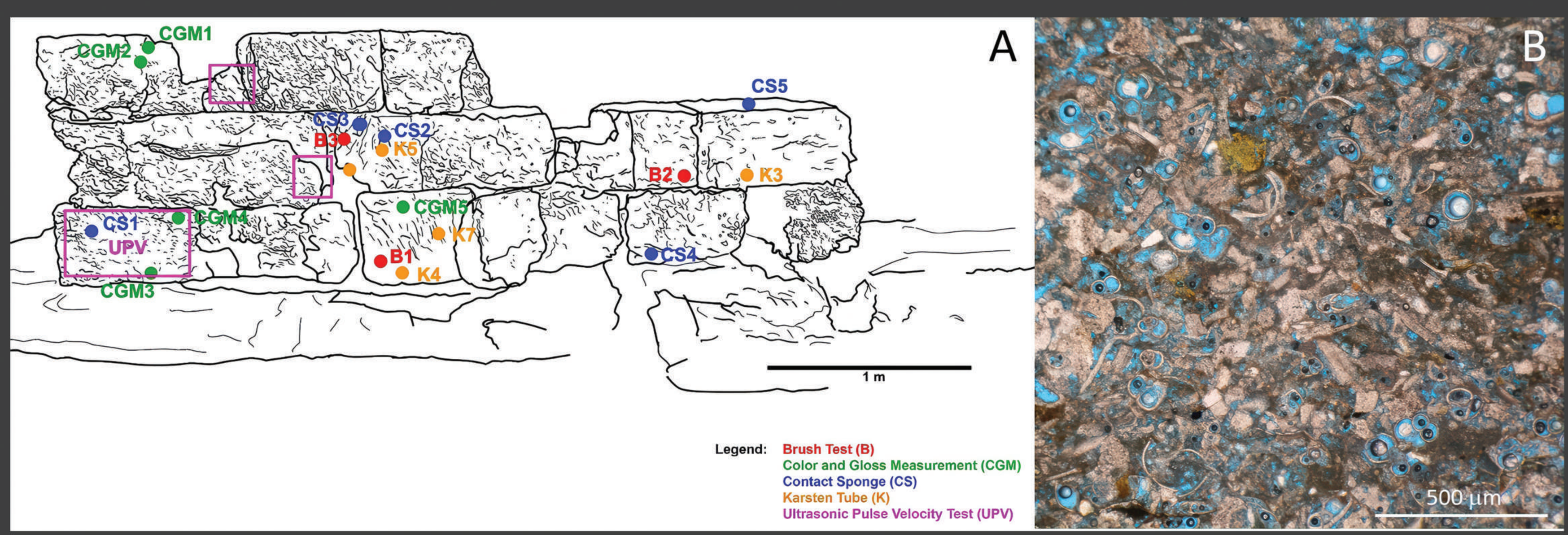

Figure 1: Mapping of in situ tests, masonry at the Domus Romana, Rabat-Malta (A), and micrograph of the Globigerina limestone showing a porous microtexture (B), OM-PPL

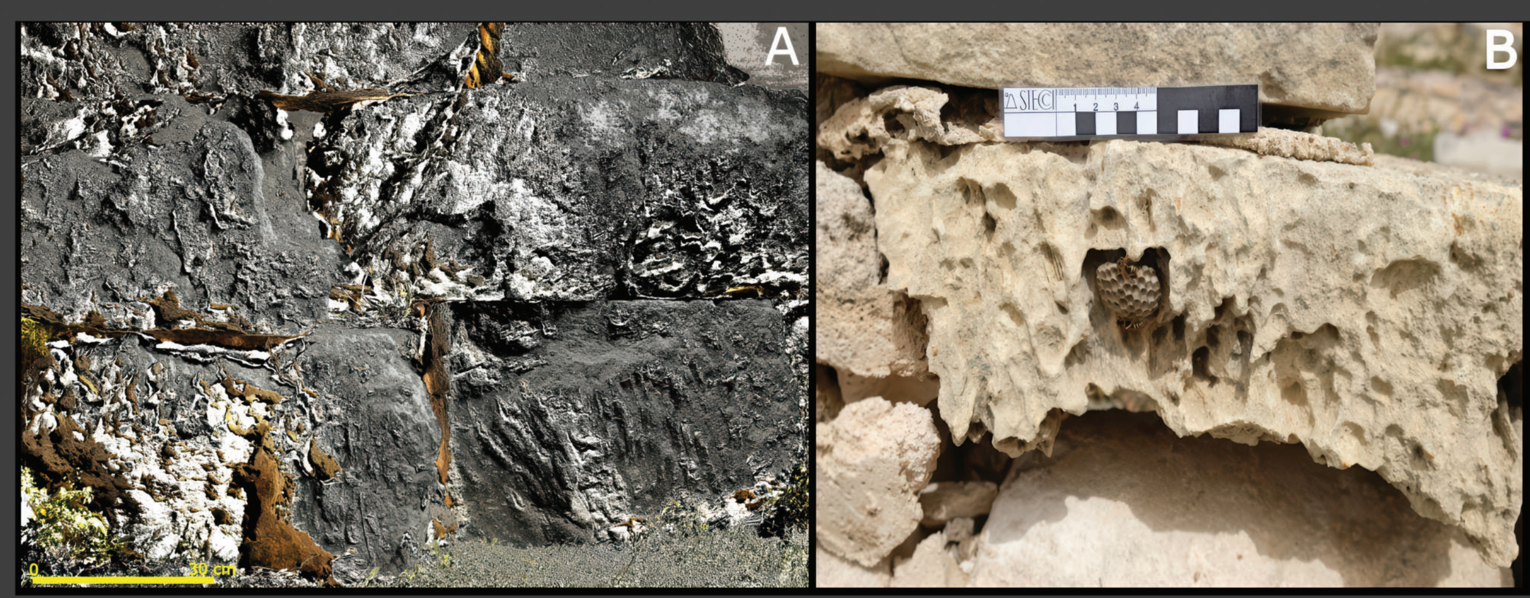

Figure 2: Characteristic alveolar weathering pattern on the surface of stone ashlars (A: RTI, B: digital photography)

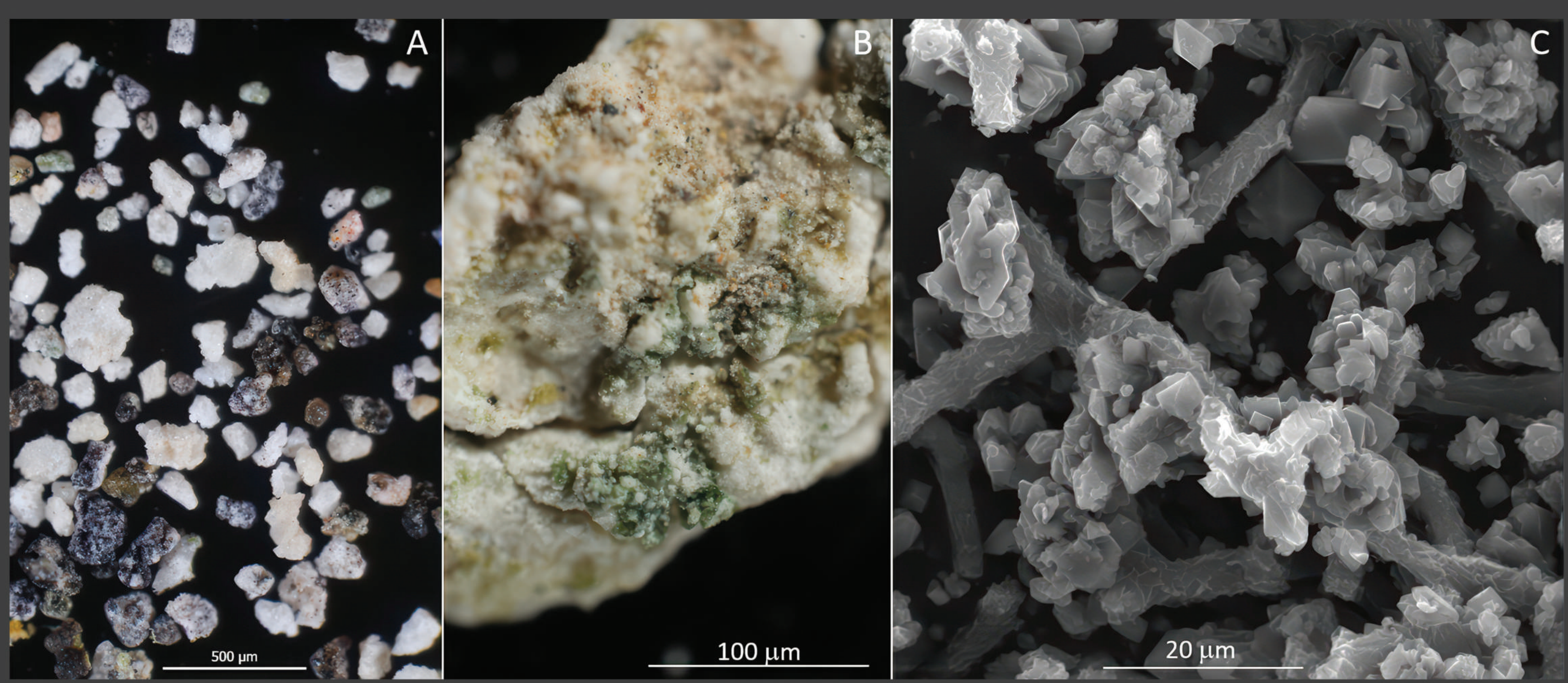

Figure 3: Loose mineral grains and biogenic components collected by the brush-off method (A); surface of a larger grain from the stone´s surface with green algae and possible traces of Ca-oxalate (B); SEM-SE image of biogenic residues and Ca-oxalate crystals (C)

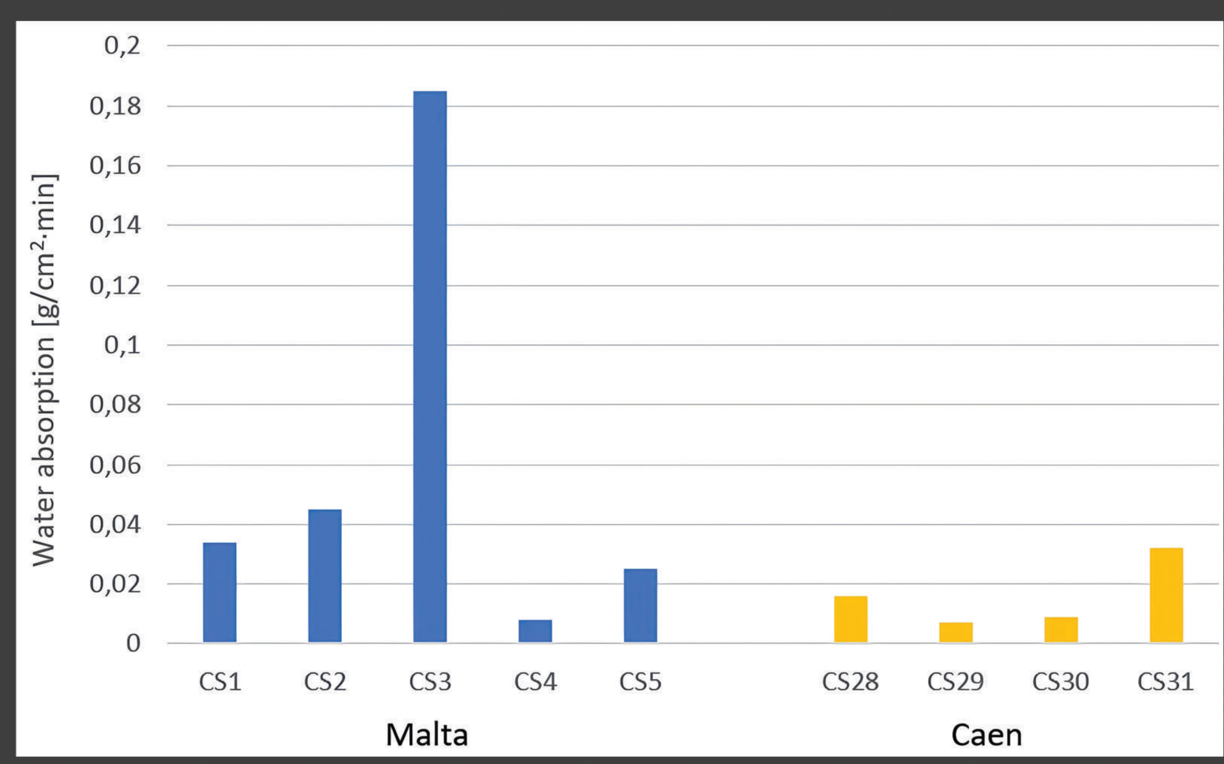

Figure 4: Water absorption measured by the contact sponge method. State of preservation of the surfaces: CS1: fairly good condition, some salt damage; CS2: good condition, patina; CS3: alveolization, salts, flaking; CS4: good condition, patina; CS5: good condition, black lichens; CS28:sound surface, algae; CS29: heavily decayed, scaling: CS30: scaling; CS31: loose crust, sulphation. For the position of measuring points see Fig. 1a and 6c

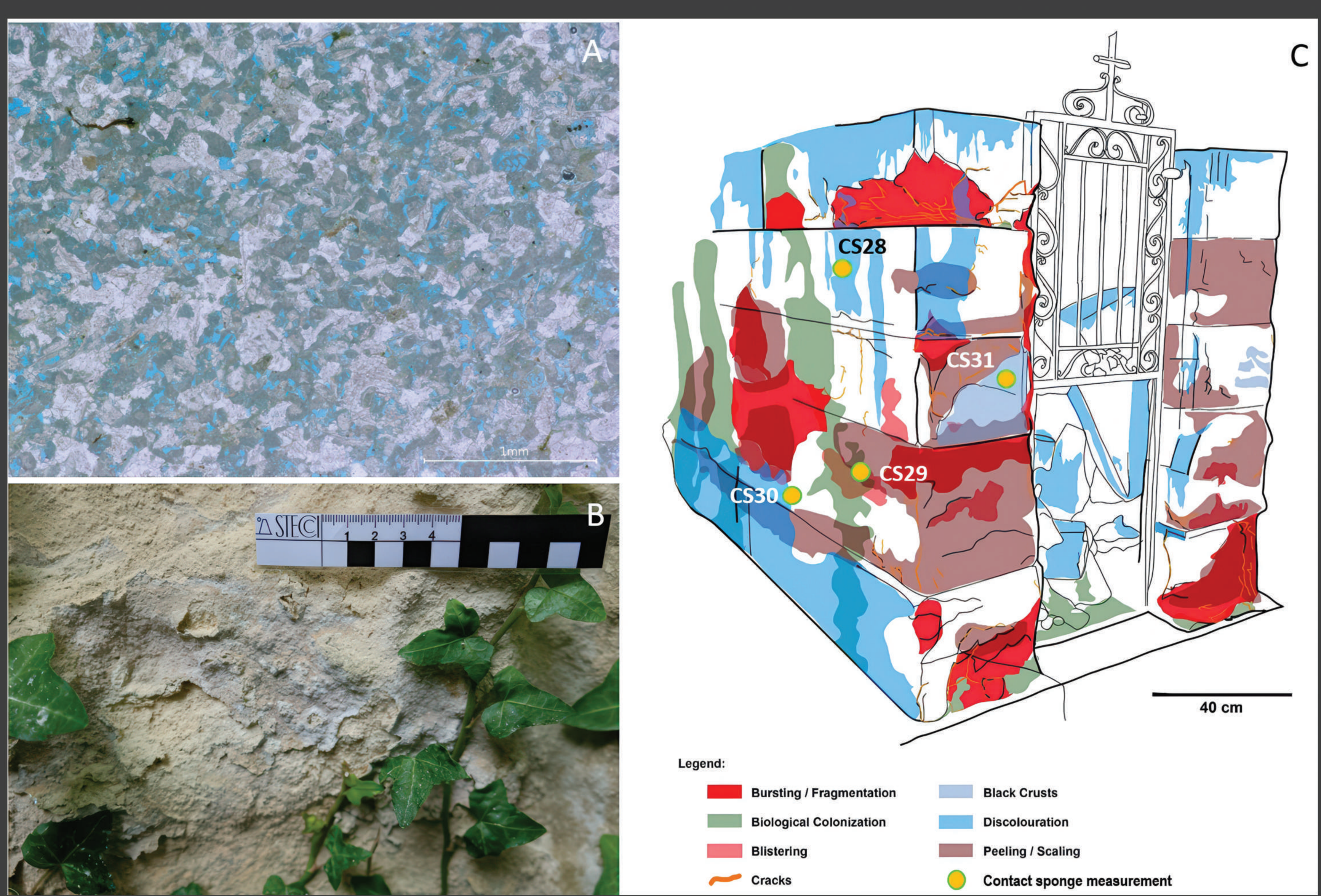

Figure 5: Micrograph of the Caen stone with residues of foraminifera cemented with sporadic calcite (OM-PPL)(A); characteristic damage patterns: peeling and scaling (B); Damage Mapping of a crypt with the positions of contact sponge measurements (C)

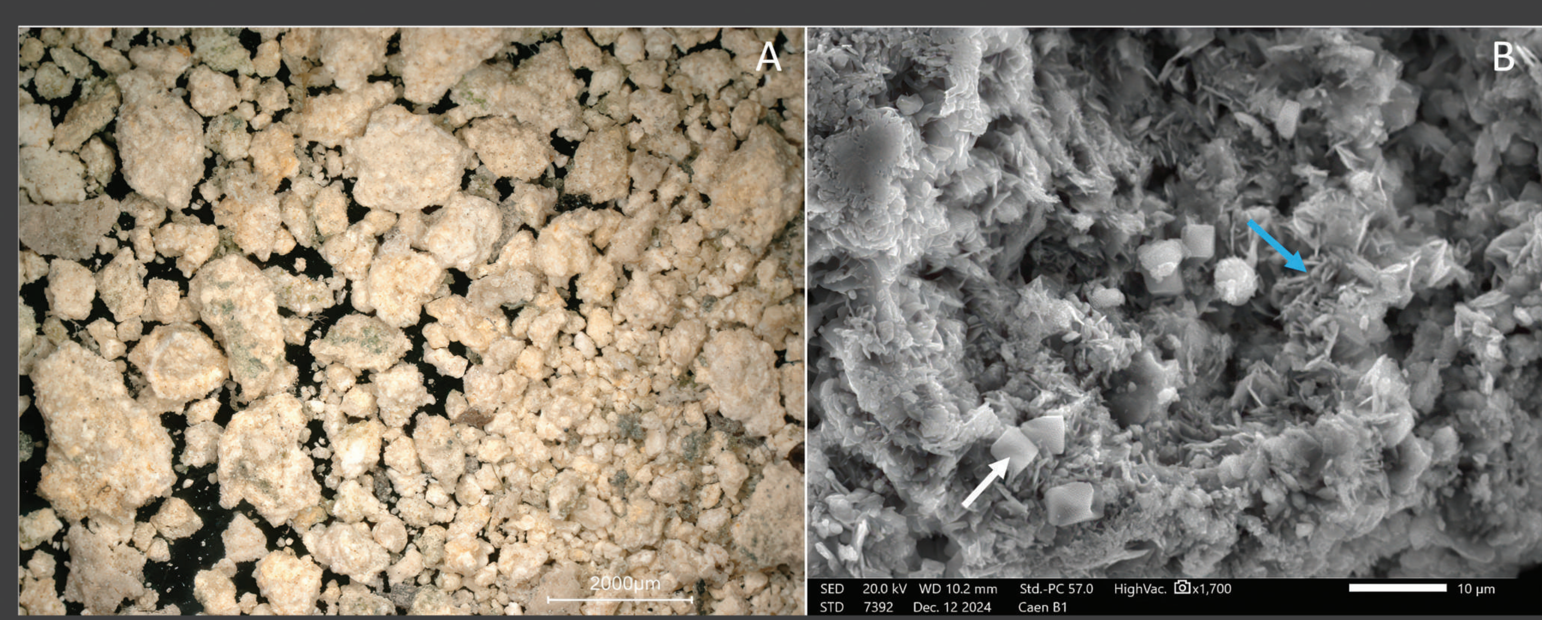

Figure 6: Loose grains of the Caen stone collected by the brush-off method (A); SEM-SE image of the surface of a grain containing needle-like gypsum (blue arrow) and isometric NaCl crystals (white arrow) (B)

Discussion and conclusions

Both objects are made of porous types of soft limestone with similar petrophysical characteristics and partly similar weathering patterns, but provoked by different mechanisms. The extensive amount of material loss (excluding the outlier from Caen - scale which flaked off in the process) on the objects´ surfaces proved by the brush-off method correlates well in both cases with the laboratory-confirmed salts and thus the salt-related deterioration mechanisms. However, the Maltese site is located in the vicinity of the sea (i.e., a few kilometers) explaining the origin of the sea salts in the masonry. For the Caen site, despite the more relevant distance to the

sea have already been made (Figueira et al. 1999, Cardell et al. 2003). Gypsum precipitation might have been promoted by the nearby smoke of steam trains as well as the emissions, for decades, of an important steel plant in the vicinity. The RTI showed variations in surface relief and reflectivity for both sites, indicating differential weathering patterns probably also influenced by the properties of the lithotypes, the design of the structures, and the local environmental conditions. In Malta, windborne salts contribute significantly to surface deterioration, particularly through alveolization. Additionally, biogenic colonization and microorganisms in some restricted parts of the stone's surface provoked biomineralization in the form of calcium-oxalate crusts. The mechanisms at the cemetery in Caen, on the other hand, are quite distinct: primary damage processes are mainly characterized by biological colonization and scaling, the latter also being increased or driven by salt-induced degradation processes. Although in the vicinity of the cemetery, many historic stone surfaces showed alveolar weathering, the cemetery itself is sheltered from the wind (positioned in an old stone quarry), and therefore no alveolization was detected. Instead, other damage patterns like bursting, peeling, and scaling can be connected to the presence of salts. Finally, extensive biogenic colonization plays a significant role in the deterioration processes, such as the retention of moisture or the damaging effect of root pressure.

The findings on limestone weathering from Caen and Rabat, along with results from other sites contribute to the ongoing development of a limestone-specific damage pattern glossary within the STECCI project.