# Assessing weathering damage in Arenitic Rock using Non Destructive Testing: the case study of the stone coats of arms of Palazzo Ricasoli in Florence

Eugenio Segabinazzi[1] (eugenio.segabinazzi@unifi.it), Teresa Salvatici[1], Irene Centauro[1], Sara Calandra[1,2], Carlo Alberto Garzonio[1]

1 Department of Earth Sciences, University of Florence, 50121 Florence, Italy
2 Department of Chemistry "Ugo Schiff", University of Florence, 50019 Sesto Fiorentino, Italy

## 1. INTRODUCTION

The urban environment poses a threat to the preservation of cultural heritage due to the increasingly polluted aerosol conditions it presents. Degradation phenomena related to atmospheric interaction with stone artifacts can lead to the loss and destruction of entire works of art. The characteristics of case studies involving artistic works compels us to limit the invasiveness of diagnostic investigations as much as possible [1]. Therefore, to preserve historically significant stone artifacts, it is important to develop investigation methodologies based on non-destructive techniques (NDTs).
This study utilized a combination of NDTs such as Sonic-microseismic test and laser scanning to assess the degree of weathering of the two stone coat of arms on the façade of Palazzo Ricasoli in Florence. The results of in situ nondestructive techniques were compared with those obtained from micro-destructive tests in order to verify the possibility of using these types of tests to obtain reliable information without the need for invasive sampling.

Fig. 1 - Palazzo Ricasoli and its Coats of Arms representing the Ricasoli family (left) and Medici family (right)

Palazzo Ricasoli (Fig.1) is an exemplary Renaissance palace located in the heart of Florence's historic center. Built between 1472 and 1480, the palace boasts two coats of arms on its primary façade that are contemporary to the construction of the building . The large stone coats of arm are crafted from local sandstone, a widely-used material in Florentine architecture. Measuring approximately 2 meters in height and 1.5 meters in width, the coats of arms exhibit evident signs of alteration and degradation phenomena including fractures, erosion, and the accumulation of deposits. The visible deterioration is the result of a prolonged exposure to environmental conditions that can lead to structural damages.

## 2. METHODOLOGY

In this study, both destructive (via a microinvasive sampling of millimetric fragments) and non-destructive techniques were utilized to analyze the two coats of arms (Ricasoli and Medici). The Sonic-microseismic test (Fig. 2) was used to determine whether it was possible to characterize areas of differential degradation based on sonic velocity gradients.
The 3D laser scanner (Fig. 3) was used to calculate the length of the internal wave paths of the sonic analysis. The complex morphology of the coats of arms on Palazzo Ricasoli's façade made it impossible to accurately measure internal distances using traditional methods.

The NTDs workflow consisted of three main phases:

**Recording the Time of Flight (ToF) from T to R**

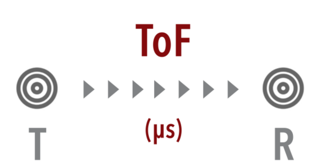
Each individual test consists of a punctual reading, localized where the receiving station is positioned. The parameter extracted from each of the recorded waveforms is the time of flight of the sonic wave between the probes.

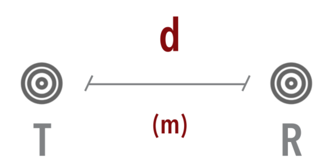
**Measuring the distance (d) between the receiving (R) and transmitting station (T)**

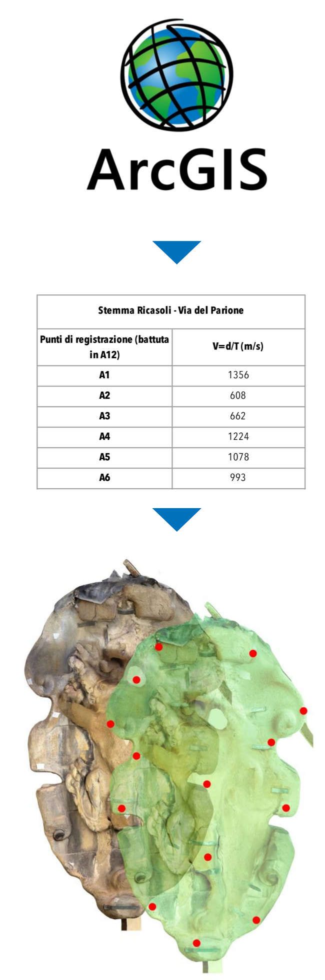
A 3D model of each coat of arms was obtained and the distance between the transmitter and the receiver for each recorded point was measured via software on the 3D models (Fig.3).

**Processing numerical point data into a readable map**

ArcGis software was utilized for the interpolation of the numerical data that were collected, transforming them into a heatmap. This enabled us to identify critical areas and collect representative samples .



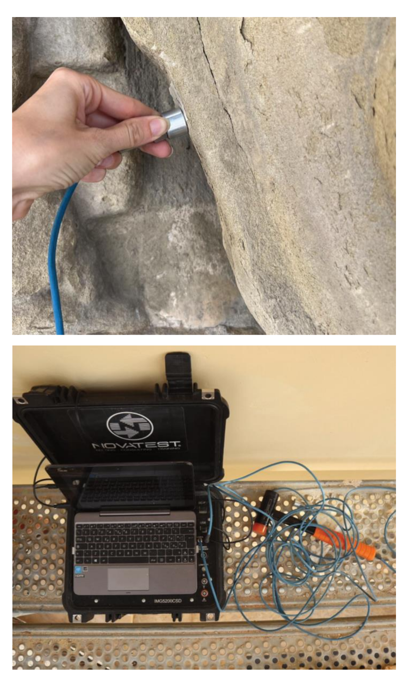



Fig. 2 - Sonic Test setup

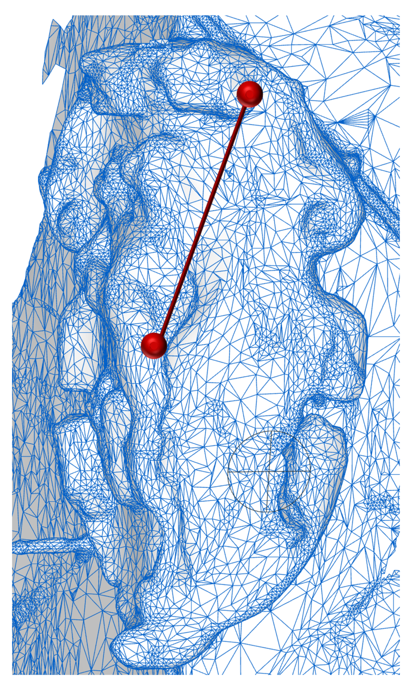


Fig. 3 - 3D mesh of the Ricasoli family Coat of Arms

To compare the results of the sonic velocities maps with the visible degradation phenomena, a careful visual investigation was also carried out. A detailed degradation map was created for each coat of arms. The degradation phenomena were mapped following the ICOMOS-ISCS : Illustrated glossary on stone deterioration patterns [2].

## 3. RESULTS AND DISCUSSIONS

Fig. 5 - Green markers: sonic Test grid point on the Ricasoli family coat of arms. Red markers: position of Fig.6. Blue marker: position of the sample AP2

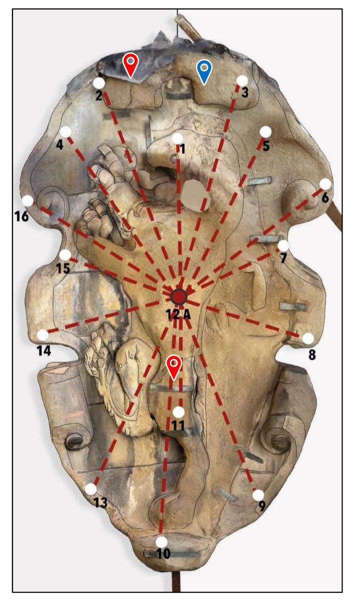


Fig. 6 - Low sonic velocity areas of the Ricasoli Family coat of arms

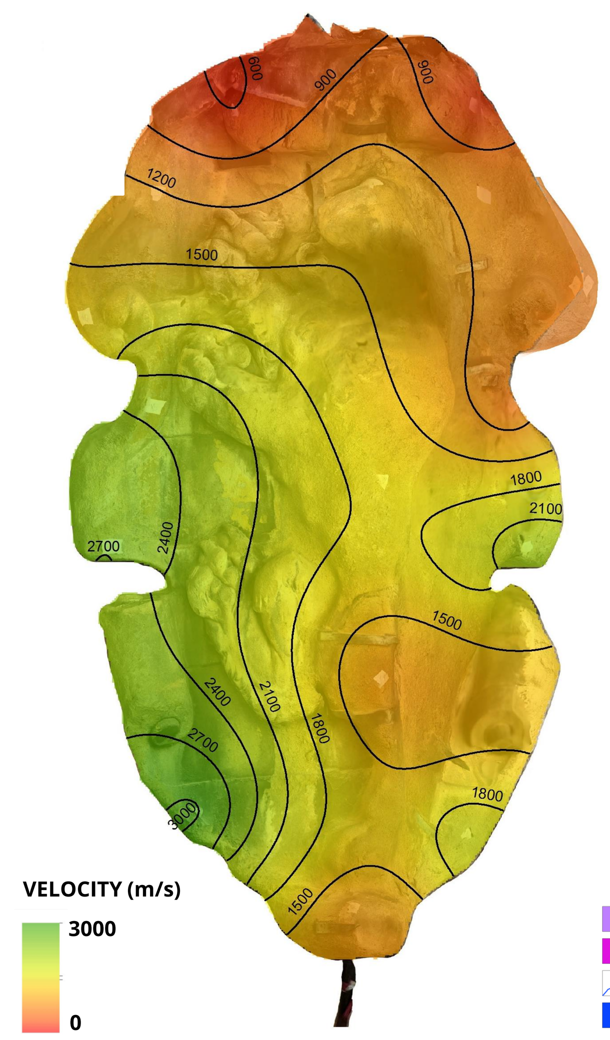



Fig. 7 - Sonic velocities heatmap of the Palazzo Ricasoli coat of arms

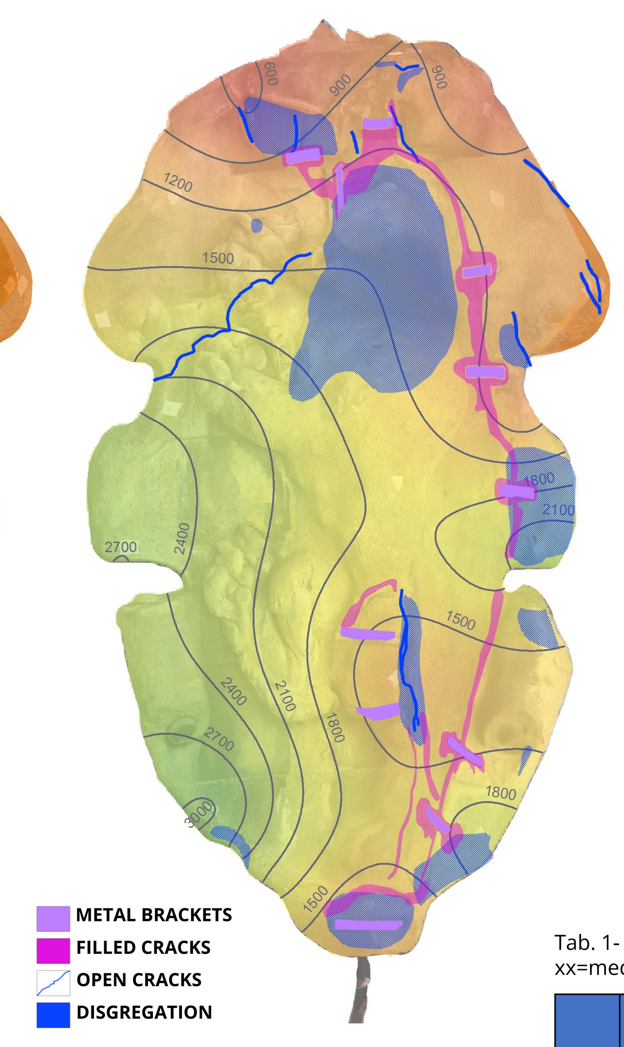



Fig. 8 - Degradation map of the Ricasoli family coat of arms

### RICASOLI FAMILY COAT OF ARMS

The sonic velocities heatmap (Fig.7) clearly highlights two main areas of degradation, located in the upper left and lower right portions of the element. These areas (Fig. 6) are affected by cracking and surface degradation. The left portion of the coat of arms is in better conservation status, as shown by both the degradation map and the sonic velocities heatmap. The results obtained from the mineralogical analysis indicates the level of weathering that has occurred in the area where the sonic velocity is slow (measuring at 600 m/s). The location of the micro sample is visible in Fig.4. The microscopic analysis confirm that the stone is sandstone with a clay matrix, with rare calcitic cement. The clastic granules consist of quartz fragments (in both mono- and polycrystalline individuals), feldspars (plagioclase and k-feldspars), calcite (in crystals and rare cement), muscovite and biotite and fragments of metamorphic and magmatic rocks. The porosity of this sample is high and a widespread intergranular disintegration and cracking is observed. The diffractometric results (Tab.1) are typical of this type of sandstone and does not show the presence of degradation markers like gypsum.

Tab. 1- Qualitative XRD Analisys: xxx=high content; xx=medium content; x=low content; tr=traces

| | Qz | Cal | Pl | Kfs | Ms+Bt+ Clay Minerals | Gp |
|---|---|---|---|---|---|---|
| AP2 | xxx | x | xx | x | x | - |

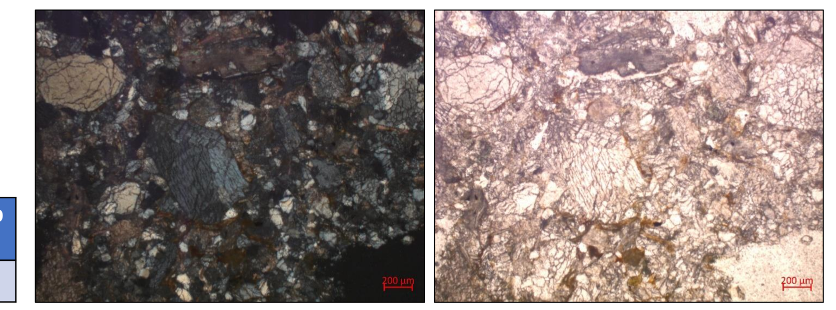


Fig. 9 - AP2 sample, thin section images (sx 5X n//, dx 5X nx)

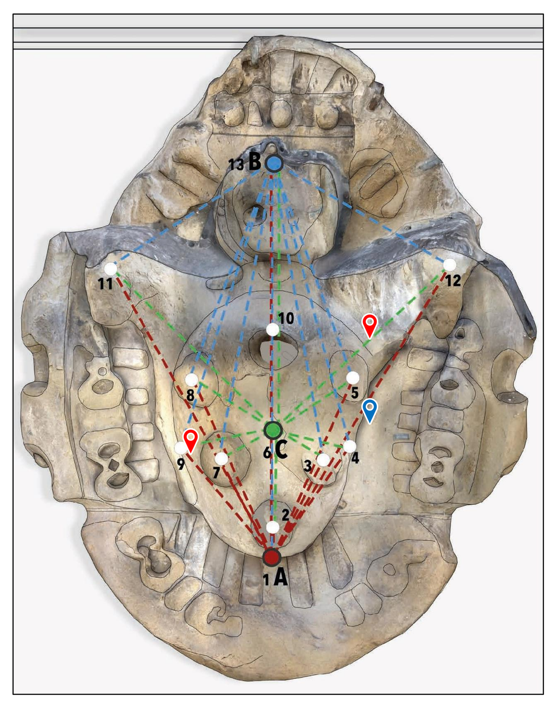


Fig. 10 - Sonic Test grid point on the Medici family coat of arms. Red markers: position of Fig. 11. Blue marker: position of the sample AC1

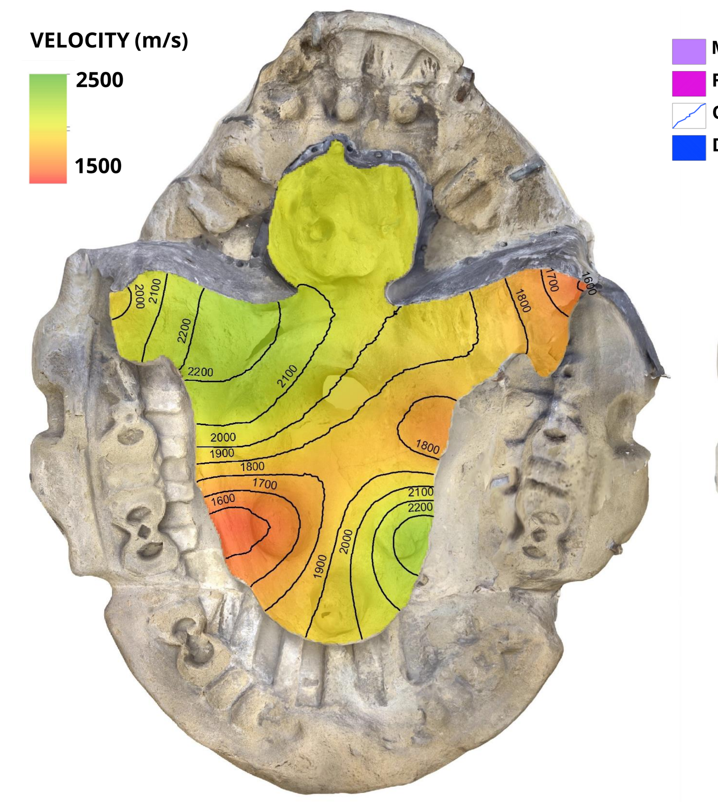



Fig. 12 - Sonic Test grid point on the Palazzo Ricasoli coat of arms

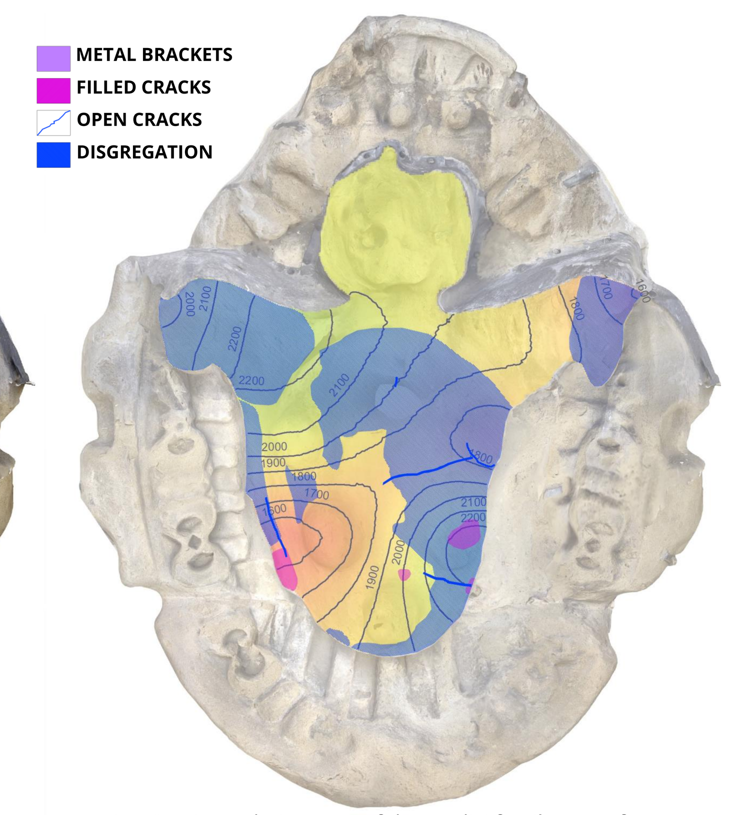



Fig. 13 - Degradation map of the Medici family coat of arms

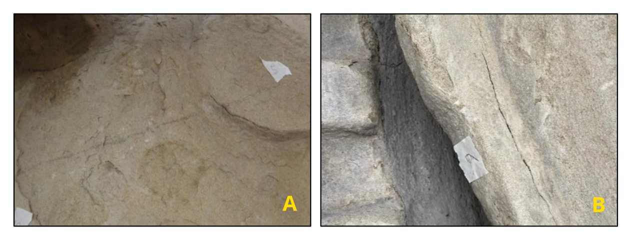


Fig. 11 - Low sonic velocity areas of the Medici Family coat of arms

Tab. 2- Qualitative XRD Analisys: xxx=high content; xx=medium content; x=low content; tr=traces

| | Qz | Cal | Pl | Kfs | Ms+Bt+ Clay minerals | Gp |
|---|---|---|---|---|---|---|
| AC1 | xxx | tr | x | tr | x | x |

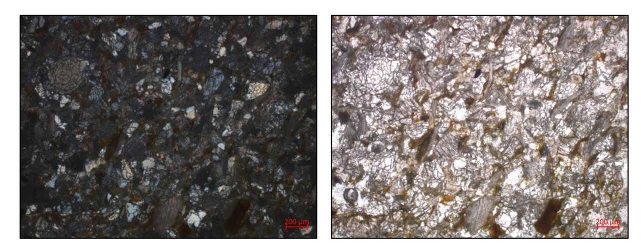


Fig. 14 - AC1 sample, thin section images (sx 5X n//, dx 5X nx)

### MEDICI FAMILY COAT OF ARMS

The heatmap of sonic velocities (Fig. 10) clearly indicates two primary areas of degradation located in the lower left and middle right sections of the element. These areas (Fig. 11) correspond to where two major open cracks are located. The degradation map shows areas where surface degradation is not associated with a decrease in sonic velocity, such as the upper left wing.
Mineralogical analyses show the partial weathering state achieved by the material in the area that has a medium sonic velocity (1800 m/s). The location of the micro sample is visible in Fig.10. The microscopic analysis confirm that the stone is sandstone with rare calcitic cement. The clastic grains consist of fragments of quartz (both mono and polycrystalline individuals), feldspars (plagioclase and K-feldspars), calcite (in crystals and rare cement), muscovite and biotite, with shapes ranging from sub-angular to sub-rounded, and fragments of metamorphic and magmatic rocks. The porosity is high, due to the loss of the clay matrix and the rare presence of calcitic cement, which is likely caused by carbonate dissolution.
The diffractometric analysis (Tab.2) detects the presence of Gypsum, a marker of the processes of sulfation, caused by the interaction of calcitic material with SO2 polluted air.

## 4. CONCLUSIONS

The non-destructive diagnostic techniques employed in this study have proven to be an useful tool for investigating the effects of weathering on stone-built cultural heritage.
By combining various NDTs, we were able to to obtain critical information on the effectiveness of this methodology for the in-situ characterization of these materials.
Sonic analysis has shown results capable of differentiating significant velocity gradients. The integration of these results with micro-invasive techniques has allowed us to obtain information on how physical modifications of the material can affect the internal sonic velocity parameter.
By comparing the sonic velocities heatmaps to the degradation maps, we were able to assess that the sonic analysis effectively highlighted areas with mechanical problems such as disgregation and cracking, enabling us to identify areas that are critical for the integrity of the artifact.
In addition, we discovered that areas with surface degradation were not necessarily problematic internally, as observed in the Medici family coat of arms.
Mineralogical analyses revealed that the portions with low sonic velocities had a damaged microstructure characterized by high porosity and internal cracking. This type of damage to the binding phase of arenitic rocks is typically attributed to weathering phenomena, which emphasizes the importance of non-destructive testing methods in identifying and understanding such degradation.
Our study emphasizes the importance of collecting data and insights on the degree of weathering of stone-built cultural heritage in polluted urban environments. This information can be crucial in developing appropriate and detailed conservation strategies that ensure the long-term stability and preservation of these artifacts. Non-destructive testing methods can be especially useful in this regard, as they allow for the collection of valuable data without damaging the unique cultural and aesthetic values of these artifacts.

Sharing is encouraged

**REFERENCES:**

1. Salvatici T, Calandra S, Centauro I, Pecchioni E, Intrieri E, Garzonio CA. Monitoring and evaluation of sandstone decay adopting non-destructive techniques: On-site application on building stones. Heritage. 2020;3(4):1287-1301.
2. ICOMOS International Scientific Committee for Stone ICOMOS-ISCS: Illustrated glossary on stone deterioration patterns. 2008