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STEFANO BERTOCCI
FEDERICO CIOLI

Franciscan Landscapes

Conservation, Protection and Use of Religious Cultural Heritage in the Digital Era

vol. 1

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This volume collects the papers presented at the concluding conference of the European project 'F-ATLAS: Franciscan Landscapes: The Observance between Italy, Portugal and Spain' that took place in Assisi, May 11-13, 2023.
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SURVEY OF THE STATE OF CONSERVATION OF THE MONASTERY OF SANT MIQUEL D'ESCORNALBOU IN TARRAGONA (SPAIN) THROUGH DIGITAL, ANALYTICAL AND IR TECHNIQUES

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Abstract

The IRT survey is one of the most widely used techniques to monitor buildings, manufacts, masonry, and cultural heritage in general. In this contribution, this technique is applied to the Monastery of Sant Miquel d'Escornalbou (Tarragona, Spain). The monumental complex has undergone to architectural transformations over the centuries, and the functionality of this place is closely linked to the domination of the territory, Vatican schemes and industrial, political and military interests. Today, the state of the art of the monastery represents a challenge in the conservation field because of the natural decay of the original parts and the prolonged absence of maintenance works. The present work aims to investigate the historical-constructive events of the monastic complex through historical sources and digital surveys useful to understand the main architectural-structural problems necessary for a possible conservative intervention. At this first stage, recognition using Non-Destructive Techniques (NDTs) based on imaging systems such as a combination of IR thermography, photogrammetric surveys and visual inspection is preferable. According to these techniques, it is possible to discover not only degradation phenomena like: structural defects, biodegradation, air cavities, raising dampness phenomena, water infiltration, but also a stratigraphic documentation of the monastic complex. The synergy of the imaging techniques allows the reading of the construction phases of the monastery and guide subsequent analytical studies useful to identify the nature of the local stone used for the construction of the buiding.

Keywords: Infrared thermography, Photogrammetry SfM, stratigraphic documentation.

Fig. 1
Aerial panoramic image of the monastic complex of Sant Miquel d'Escornalbou and the valley (acquisition credit: Pietro Becherini).

1. Introduction

The castle-monastery of Sant Miquel d'Escornalbou is located near the town of Riudecanyes (Baix Camp, Tarragona), Spain (Fig. 1). Thanks to its privileged location on top of a mountain and the fortified walls that surrounded it, the complex originated as a military fortification, first Roman then Arab, then, in 1686, it became a convent for Franciscan missionary fathers, until 1907, when an important exponent of the Catalan Renaissance, Eduard Toda, began the castle's final renovation converting it into a private residence (Sanabra Ramos, 2021).

In this scenario the monastery has been chosen as an emblematic example of coexistence between architecture and territory, reflecting an essential part of European culture of the Franciscan Observance. This research is part of the European project F-ATLAS – Franciscan Landscapes the Observance between Italy, Portugal and Spain, which aim is to study the Franciscan Observance network and to find effective strategies for the conservation, protection and promotion of this important heritage. The work provides the development of a documentation protocol through operations of digital relevance, which represent the fundamental basis for the critical analysis of architecture and its link with the human and natural context (Bertocci et al., 2023; Soler Sala, 2022).

2. Materials and Methods

2.1 Integrated digital techniques (Laser scanner 3D and Photogrammetry SfM)

The survey campaign was approached by exploiting the integration of traditional and computer-based tools for surveying and data processing. These included the use of technology offered by 3D laser scanners and the acquisition of photographs for the reconstruction of photogrammetric models. For the Terrestrial Laser Scanning survey an Imager Z+F 5016 static laser scanner was used, which acquires up to 1,000,000 points per second at a maximum distance of 360 meters with horizontal rotation of 360° and vertical rotation of 320°. It offers precision even at long distances (2/3 mm accuracy) and is equipped with an HDR camera that returns well-balanced color data (Soler Sala et al., 2023). At the same time, a photographic campaign through digital cameras and drone was carried out to obtain a three-dimensional model and photoplanes of the monastic complex by the Structure from Motion (SfM) technique (Cottini, 2022). These elaborates are essential to integrate the variations in color and surface pattern, and especially to superimposed the thermographic data useful to complete and optimize the historical and conservative framework of the monastery (Martin et al., 2022; Morena et al., 2021).

2.2 IR Thermographic survey

Among the non-Destructive Techniques, the Infrared Thermography (IRT) represents a valuable tool for the investigation of architectonic structures (Grinzato, et al., 2002; Balaras, et al., 2002). This technique exploits the property that each material spontaneously emits electromagnetic radiation in the infrared range in relation with its temperature. The electromagnetic radiation is carried out recording the infrared radiation emitted by a particular detector (infrared camera) (Burnay et al., 1998).
The IRT technique is used to investigate the structure and composition of walls by detecting the different inertial thermal behavior of materials. The surface temperature of the wall is influenced by the internal heat propagation, which in turn is influenced by environmental conditions and by the emissivity of each material. A variation of such conditions, either natural (passive mode) or artificially induced (active mode), causes a thermic disequilibrium that can be easily visualized through the infrared camera. (Paoletti et al., 2013). IRT has been adopted on wall of Sant Miquel d'Escornalbou as a preliminary screening procedure together with the photogrammetric investigations. In particular, the inspection was starting with the aim of detecting degraded areas and then move on to the recognition of defects in the masonry in order to estimate the state of conservation of the monastic complex and the structural remakes made during the centuries (Brizzi et al, 2022).

Fig. 2
Left) Aerial image of the monastic complex of Sant Miquel d'Escornalbou with the IRT investigated areas highlighted in blue. Right) thermografic long-range shot using thermal camera (credit: Sofia Brizzi).

opposite page
Fig. 3
Diffractograms of samples ME_01_rock and ME_04_mortar.

Fig. 4
a) Degradation of the stone in the cloister of the monastic complex b) Stereo-microscopy observation of the sample ME_04_mortar; c) Stereo-microscopy observation of the sample ME_01_rock.

The FLIR thermal camera, model T540, with a resolution of 464x348 pixels, thermal sensibility of (NETD) <30 Mk a 30 °C (optic lens of 42°) di 50mK, temperature range from -20 °C to +350 °C, and accuracy of ± 2%, was used to produce thermal maps. Values for ambient temperature, relative humidity, distance to target area, and relevant emissivity of target surfaces were used as controls (FLIR *Systems* AB). IR images were analysed using FLIR software (*Thermal Studio*). The IRT survey was done in the façades shown in Fig. 2, by performing close and long-range investigations, i.e. by detecting the temperature respectively near and far with respect to object.

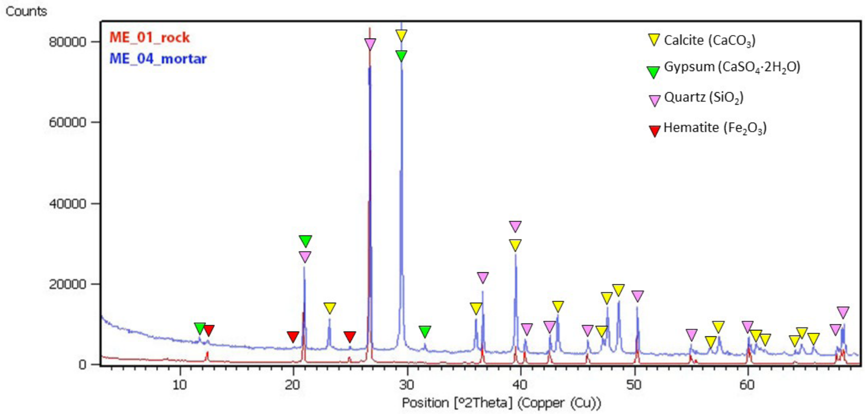
2.3. X-ray powder diffractometry (XRPD)

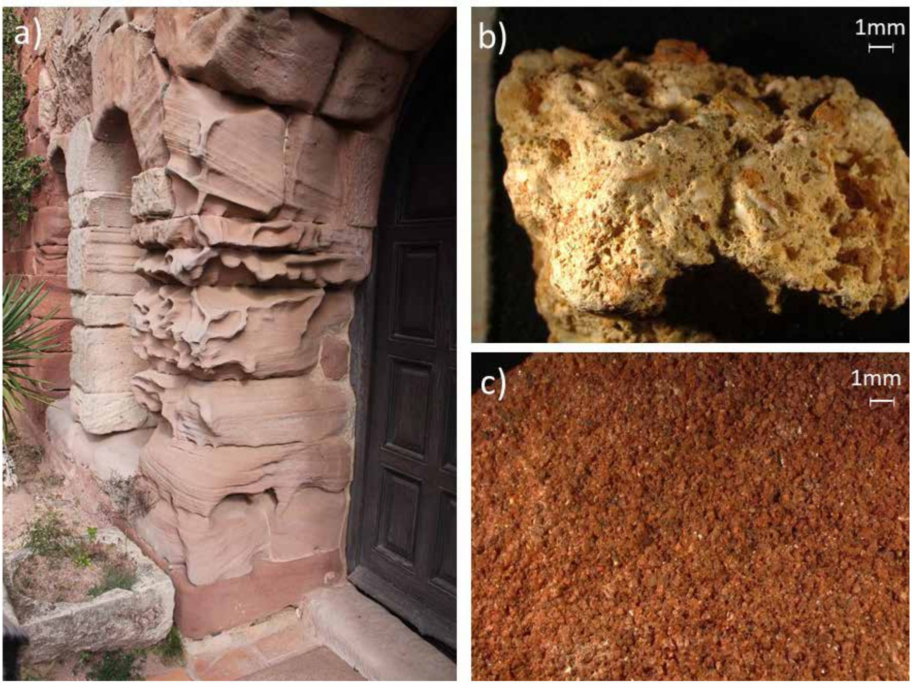
In order to investigate the mineralogical and petrographic characterization of mortars between the church ashlars and the stone used for the construction of the monastery, the XRPD analysis was carried out (Cobirzan, 2014; Vettori, 2016). The nature of the stone was also essential to determine the exact emissivity of the material for the correct reconstruction of the thermograms of the IR survey. X-ray Powder Diffractometry (XRPD) was employed on powders to determine the mineralogical composition using a powder X-ray diffractometer (Cu anticathode (k= 1.54 Å)), under the following conditions: current intensity of 30 mA, voltage 40 kV, angular range 3°<2θ<70°.

3. Results

3.1. X-ray powder diffractometry (XRPD)

Through diffractometric analysis, it was possible to observe that the local stone samples analyzed show the same composition, consisting of the prevailing quartz mineralogical association, which is followed by the presence of iron minerals (hematite), feldspars


Counts
80000
60000
40000
20000
0
ME_01_rock
ME_04_mortar
Calcite (CaCO3)
Gypsum (CaSO4·2H2O)
Quartz (SiO2)
Hematite (Fe2O3)
10
20
30
40
50
60
Position [°2Theta] (Copper (Cu))


a)
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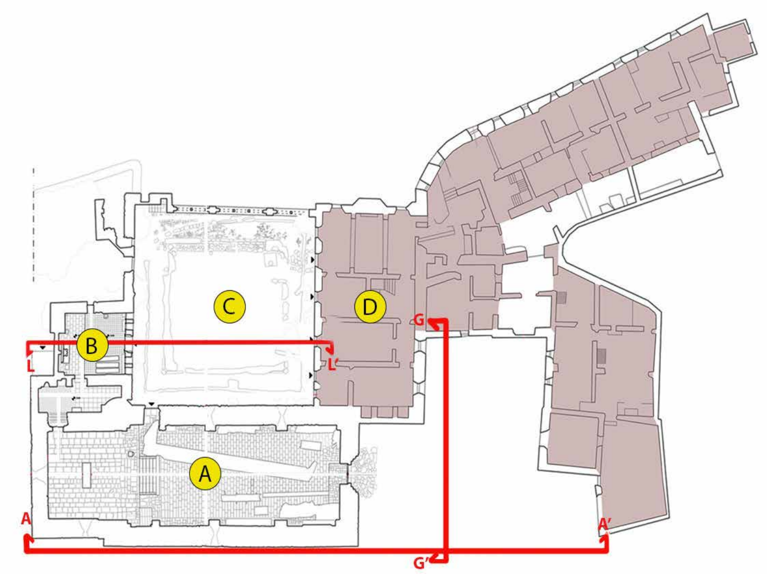


Fig. 5
General plan of the complex with the indication of the main rooms: A- church of Sant Miquel; B-Chapter room; C- Cloister; D- Manor house and the elevations object of this work (section A-A', G-G', L-L').

(albite and microcline), micas (muscovite), and clay minerals (kaolinite), (Fig. 3). These results, based on macroscopic and microscopic examination together with, the degradation forms of the stone (alveolisation, chemical-physical erosion and exfoliation, (Fig. 4) and mineral-petrographic investigations, show that the local stone, which characterises the entire monastery complex and valley, is a sandstone with siliceous cement. Iron ores (hematite) are responsible for the reddish color that characterizes the entire valley. It should be noted that, in order to differentiate the sandstones in question more precisely, analyses of the clay fraction < 4 μm, which could have provided indications of the ancient quarries of provenance, and petrographic thin section analyses capable of determining grain size and texture, would have been appropriate to deepen the study. As for the mortar, it shows the presence of calcite, quartz and gypsum, with smaller amounts of hematite as well, demonstrating the use of local stone as an inert in the mortar mix of the ashlar bedding (Fig. 3).

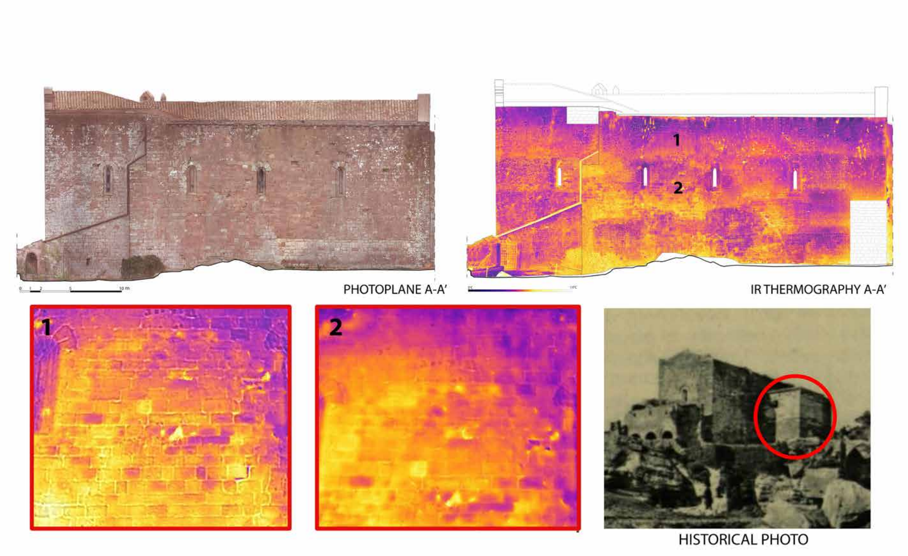
opposite page
Fig. 6
North-West side of the church of Sant Miquel d'Escornalbou. Above: VIS and IR photoplans. Below: two close-range thermograms and the historical photo. (Sanabra Ramos, 2021) (acquisition credits: Sofia Brizzi, elaboration credits: Simone Alinari).

3.2. Integrated digital techniques (3D laser scanner, photogrammetry SfM and IR thermography)

In order to support the data merging operations between geometric and radiometric data, a complete 3D metric survey was necessary to obtain the geometric base, which represents the starting point for the subsequent data fusion operations (Lerna et al., 2012). The VIS photoplanes in Fig. 5 are obtained through the laser scanner and photogrammetric survey, and they are used to construct, in scale, the IR photoplanes of the building façades. The results, combined to historical photos, allow a stratigraphic reading of the monastic complex and all the reconstruction works carried over the centuries.

The emissivity of the local stone, which, according to the XRD results, has been classify as a sandstone rock with silicate cement, is 0.67 at 40 °C. The façades investigated in this work are shown in the map of Fig. 5, while the numbers 1 and 2 shown in drawings of Figg. 6-9, represent the location of the most relevant thermal discontinuities seen in long and close range modality. Some elements were identified in relation with the structural remakes made during the centuries:

• In Figure 6, the presence of a side chapel in the North-West side, demolished in 1907 by Eduard Todà (Sanabra Ramos, 2021), appears. The comparison of this image with the thermographic survey shows the presence of an arch between the second and third windows of the church, probably dating back to the opening of the old chapel. The presence of abundant biological patina and rising capillary moisture from the ground is also evident.



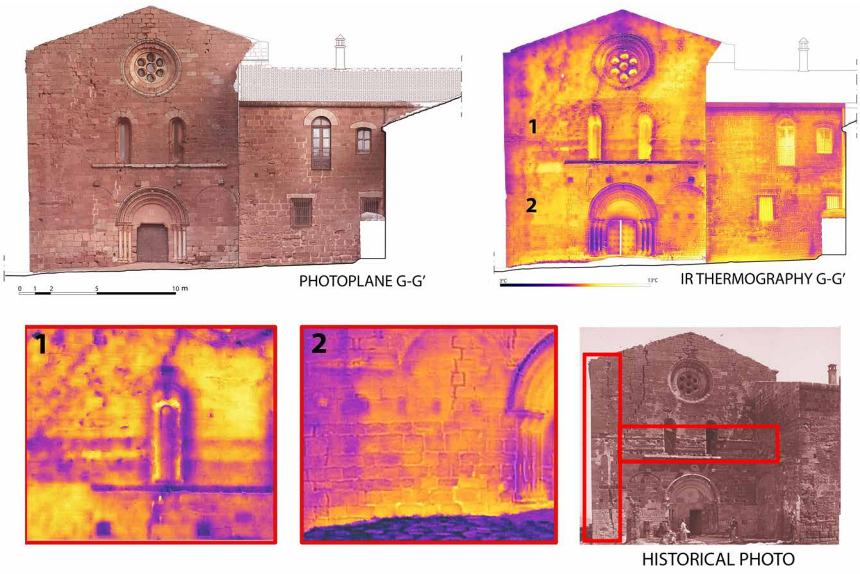


Fig. 7
Frontal façade of the church of Sant Miquel d'Escornalbou. Above: VIS and IR photoplane. Below: two close-range thermograms and the historical photo (Sanabra Ramos, 2021). (acquisition credits: Sofia Brizzi, elaboration credits: Simone Alinari).

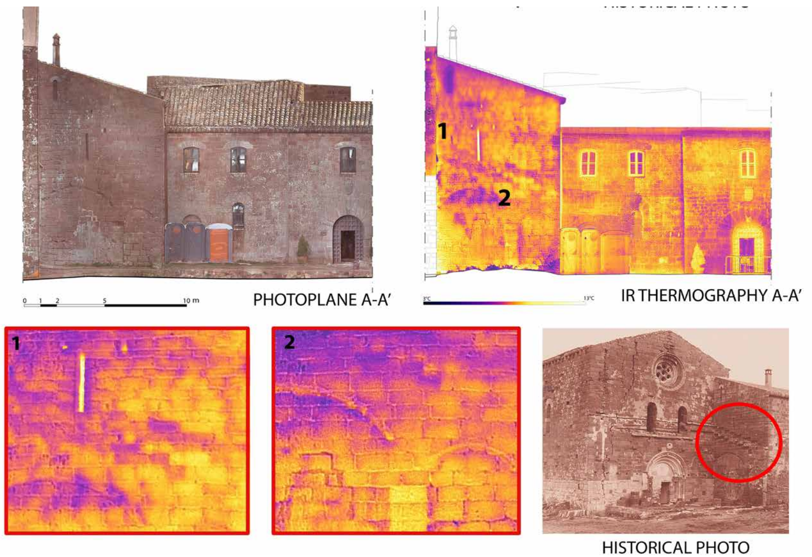


Fig. 8
North-West façade of the church of Sant Miquel d'Escornalbou. Above: VIS and IR photoplane. Below: two close-range thermograms and the historical photo (Sanabra Ramos, 2021). (acquisition credits: Sofia Brizzi, elaboration credits: Simone Alinari).

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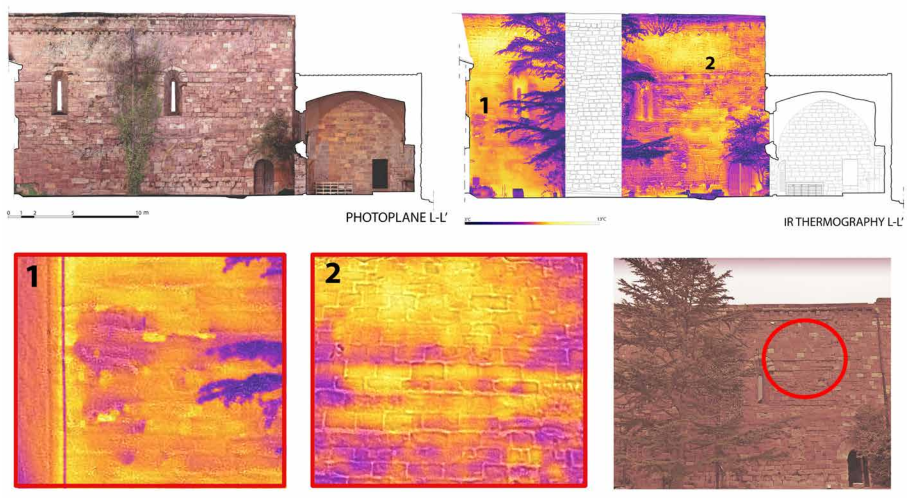
Fig. 9
South façade of the church of Sant Miquel d'Escornalbou. Above: VIS and IR photoplane. Below: two close-range thermograms and Vis close range photo (acquisition credits: Sofia Brizzi, elaboration credits: Simone Alinari).



• On the frontal façade in Fig. 7, two horizontal bands are visible at window height: they are the trace of an inclined pitch of the roof of an ancient narthex, as confirmed in the Noth-West façade (Fig. 8), where the two thermograms show the trace of the inclined pitch of the narthex and its arches.

• In the South elevation of the church, the two horizontal bands detected on the frontal façade are still visible: they run along the entire masonry and represent the beginning of the roof pitch of the ancient loggia inside the cloister (Fig. 9). Highlighted by the number 1, a presumed ancient access door to the church from the loggia cloister to the church is also visible.

4. Discussion and Conclusions

The IRT survey, linked to the integrated digital survey, provides a useful approach to obtain a stratigraphic reading of the monastic complex and to focus sampling for laboratory investigations useful to better characterize building materials and their degradation. The multidisciplinary research enabled the reading of some ancient architectural elements, such as: traces of an entrance narthex on the front of the church, an ancient chapel in the North- West façade and a two-level covered loggia inside the cloister. In Fig. 10, a 3D model reconstruction (made using Rhinoceros software) provides a view of the current state of the monastic complex and, highlighted in pink, all the elements detected in this work.

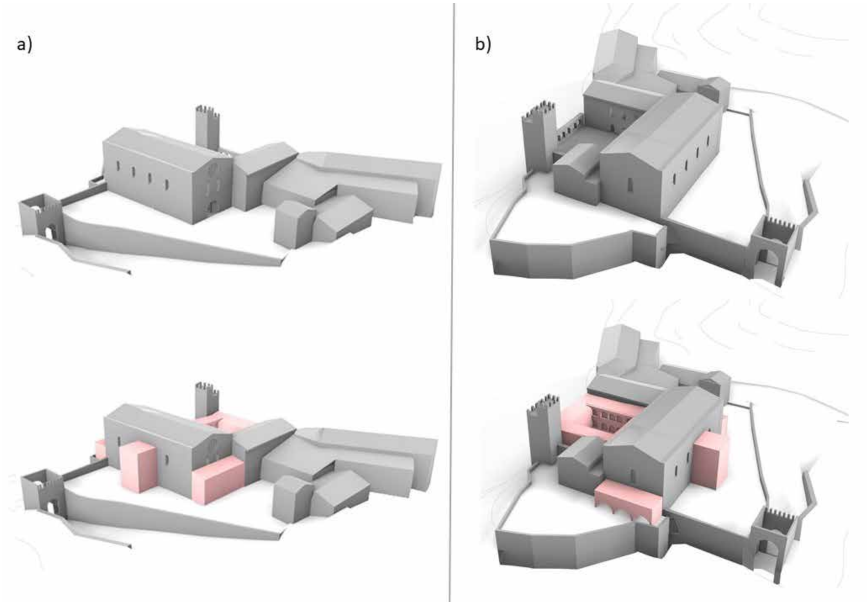


Fig. 10
a) North-West 3D model view b) East 3D model view of Sant Miquel d'Escornalbou. Above: current state of the art. Below: reconstructive hypothesis before the 1907 restoration. (elaboration credits: Simone Alinari).

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Integrating historical research with technological progress opens exciting possibilities to create comprehensive digital archives, virtual reconstructions, and immersive experiences that can bridge the gap between the past and the present.

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