# CONSERVAR PATRIMÓNIO

ARP · Associação Profissional
de Conservadores-Restauradores
de Portugal
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Lisboa, 15 de Julho de 2019

# CONSERVAR PATRIMÓNIO 36

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## **Notas** Notes

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# 2020: o património, a pandemia e a revista

# 2020: heritage, the pandemic and the journal

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2020 foi um ano atipicamente difícil. A pandemia global COVID-19 obrigou, a espaços, ao encerramento de vários sectores de atividade, incluindo universidades, laboratórios e empresas, levando a que, investigadores e técnicos, se vissem forçados a interromper temporariamente a sua investigação ou, na melhor das hipóteses, a desenvolvê-la de forma limitada. Menos reconhecido, mas igualmente significativo, foi o impacto direto da COVID-19 na preservação e proteção do património cultural. Encontra-se já relativamente bem estudado o impacto negativo que, ao longo das últimas duas décadas, o terrorismo, o tráfico de arte, as alterações climáticas, a falta de financiamento, e até a negligência, tiveram na preservação e proteção do património cultural [1]. É plausível assumir que a COVID-19 possa ter um impacto semelhante, mas num espaço de tempo inacreditavelmente curto. A Estupa de Topdara [2], no Afeganistão, ou a Tumba de Askia [3], no Mali, são apenas dois exemplos de património cultural de significado internacional cujos processos de conservação e/ou reabilitação foram abruptamente interrompidos pela pandemia. Não menos importante é o impacto da COVID-19 nas viagens e na indústria do turismo, dois sectores fundamentais para o setor do património cultural. Em alguns locais patrimoniais no sudeste asiático, por exemplo, estima-se que o número de visitantes tenha caído cerca de 99 % [4], estrangulando a capacidade de gerar receitas e, em consequência, de manter este património. No contexto Europeu e Norte Americano, várias associações e instituições têm procurado quantificar este impacto. O inquérito da Network of European Museum Organisations (NEMO) [5] dirigido a profissionais de museus no contexto Europeu, o inquérito Britânico e Norte Americano sobre recursos digitais para o acesso ao património [6] e, em Portugal, o inquérito levado a cabo pela Associação Profissional de Conservadores-Restauradores de Portugal (ARP) a profissionais conservadores-restauradores [7], são disso exemplo.

Ainda assim, e apesar do contexto global fortemente desfavorável, 2020 foi um ano muito positivo para a Conservar Património. Entre 1 de janeiro e 31 de dezembro de 2020, a Conservar Património teve um acréscimo de 72 % no número de submissões relativamente a 2019, submissões essas provenientes de 17 países. Foram publicados 32 artigos no total dos três números de 2020 – valor sensivelmente igual ao alcançado em 2019 (Figura 1). De entre os artigos publicados em 2020, importa notar que a maioria foi publicada na forma de "artigos" (59 %), com um menor número na forma de "notas" (16 %) e "intervenções" (13 %) (Figura 1). A estes acrescem quatro outros, dos quais dois "editoriais", um artigo de "apresentação" e um artigo de "opinião".

Embora não existam ainda valores definitivos em relação ao impacto dos artigos publicados pela Conservar Património em 2020, de acordo com a Scopus (a 10 de janeiro de 2021), a revista deverá manter-se entre as melhores nas categorias de Museologia (Q2) e Conservação (Q2), com um CiteScore, ainda provisório, de 0,6. Uma subida em relação a

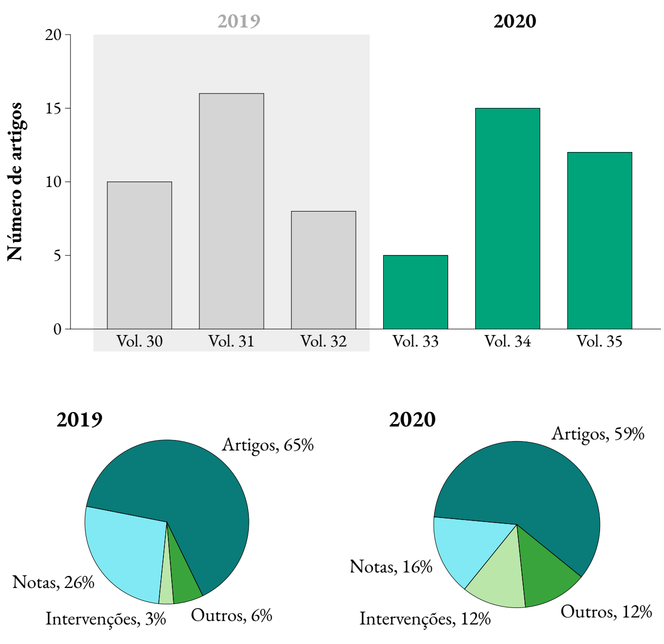


**Figura 1.** Distribuição do número de artigos publicados em 2019 e 2020, por volume e por tipo.

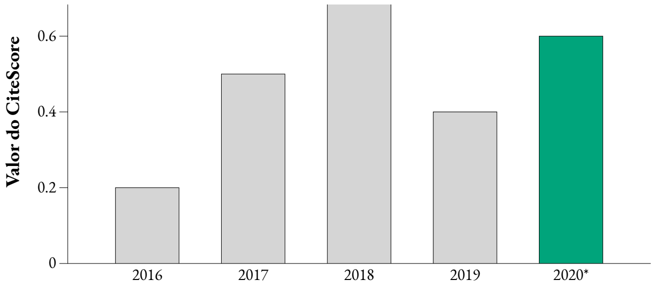


**Figura 2.** Evolução do CiteScore desde 2016. Fonte: Scopus (*valor de 2020 provisório).

2019 (Figura 2) que marcará, esperamos nós, uma tendência positiva de afirmação da revista entre as melhores da área no panorama nacional e internacional.

2021 adivinha-se tão ou mais desafiante que 2020. Para a Conservar Património, 2021 será um ano de crescimento e de consolidação dos resultados obtidos e das alterações implementadas em 2020 [8]. A nós, editores e diretores da Conservar Património, cabe-nos deixar o compromisso de trabalho e dedicação em prol da revista e agradecer a todos aqueles que contribuíram para este sucesso, nomeadamente aos autores, que gentilmente contribuíram com os seus valiosos trabalhos, aos membros da equipa editorial, aos revisores e, claro, aos leitores. Ainda uma palavra de agradecimento à Associação Profissional de Conservadores-Restauradores de Portugal (ARP), pelo apoio incansável e incondicional que tem dado à direção. A todos, o nosso obrigado.

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2020 was an untypically difficult year. The global COVID-19 pandemic has forced the closure of various sectors of activity, including universities, laboratories and businesses, impelling researchers and technicians to temporarily halt their research or, at their best, to develop it in a limited way. Less recognised but equally significant was the direct impact of COVID-19 on the preservation and protection of cultural heritage. The adverse effects that, over the last two decades, terrorism, art trafficking, climate change, lack of funding, and even negligence, have had on the preservation and protection of cultural heritage is already relatively well studied [1]. It is plausible to assume that COVID-19 may have a similar impact but in an unbelievably short space of time. The Stupa of Topdara [2], in Afghanistan, or the Tomb of Askia [3], in Mali, are just two examples of cultural heritage assets of international significance whose conservation and/or rehabilitation processes were abruptly interrupted by the pandemic. No less significant is COVID-19's impact on the travel and tourism industries, two key sectors for the cultural heritage field. In some heritage sites in Southeast Asia, for example, it is estimated that the number of visitors has fallen by about 99% [4], strangling the ability to generate revenue and, as a result, to maintain this heritage. In the European and North American context, several associations and institutions have sought to quantify this impact. The Network of European Museum Organisations (NEMO) survey [5] targeted to museum professionals in the European context, the British and North American survey on digital resources for heritage organisations [6] and, in Portugal, the survey carried out by the Professional Association of Conservators-Restorers of Portugal (ARP) targeted to conservation-restoration professionals [7], are examples of this kind of analysis.

Still, and despite the strongly unfavourable global context, 2020 was a very positive year for Conservar Património. Between 1 January and 31 December 2020, Conservar Património had a 72 % increase in the number of submissions in relation to 2019. The origin of these submissions is geographically varied, coming from 17 different countries around the globe. The three issues published in 2020 included 32 articles – a figure roughly equal to the one achieved in 2019 (Figure 1). Among the articles published in 2020, the majority was published in the form of "articles" (59 %), a significant number as "notes" (16 %) and "interventions" (13 %), with a smaller number (12 %) in the form of "editorials", "forward" or "opinions" (Figure 1).

Although there are still no definitive figures regarding the impact of the articles published by Conservar Património in 2020, according to Scopus (on January 10, 2021), the journal should remain among the best in the Museology (Q2) and Conservation (Q2) categories, with a CiteScore, still provisional, of 0.6. This represents an increase in relation to 2019 (Figure 2) that will mark, we hope, a positive trend of affirmation of the journal among the best journals both at the national and international panorama.

2021 will likely be as or more challenging than 2020. For Conservar Património, 2021 will be a year of growth, and a year to consolidate the results obtained and the changes

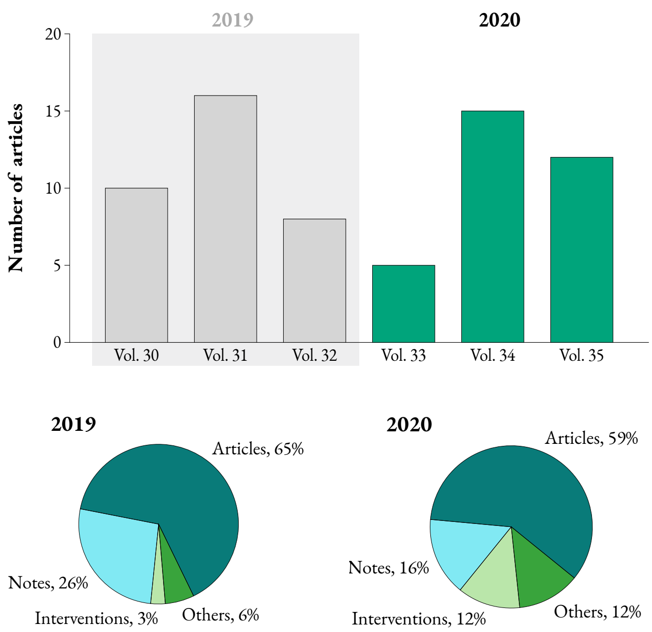


**Figure 1.** Distribution of the number of articles published in 2019 and 2020, by volume and type.

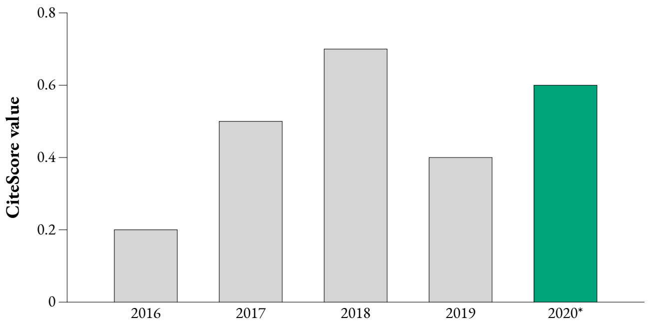


**Figure 2.** Evolution of CiteScore since 2016. Source: Scopus (*provisional value for 2020).

implemented in 2020 [8]. We, as editors and directors of Conservar Património, would like to take this opportunity to reaffirm our commitment to the journal, and to thank all those who have played a part in this success – the authors, who have kindly shared their valuable works, the members of the editorial team, the reviewers and, of course, the readers. A final word of thanks to the Professional Association of Conservators-Restorers of Portugal (ARP), for the tireless and unconditional support they have given to the editorial board of the journal. Thank you all.

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# Non-invasive wood identification on parts of King Horemheb's ritual couches (New Kingdom)

# Identificação não invasiva de espécies de madeira presentes em camas funerárias do túmulo do Rei Horemheb (Império Novo)

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**Abstract**

The inclusion of couches as basic artefacts of ritual use in ancient Egyptian royal tombs first emerged in the New Kingdom; these are very rare objects, and very little information is available concerning the timber used to make them. To address this knowledge gap the present paper deals with the identification of wood from parts of ancient Egyptian ritual couches from King Horemheb's tomb using reflected light microscopy as a non-invasive analytic technique. Although these couches are from a royal tomb, our results show that the four identified wood species (Cedar of Lebanon, Sycamore fig, Tamarisk and Christ's thorn) are among the most common timbers found in ancient Egypt. This confirms that the shortage of timber in ancient Egypt forced the use of the few available timbers for specific purposes, according to their properties, and led the Egyptian carpenters to use large logs from external sources, such as cedar of Lebanon, thus confirming the trading of wood in ancient Egypt.

**KEYWORDS**
King Horemheb
Ritual couches
Wood identification
Cedar of Lebanon
Christ's thorn

**Resumo**

A inclusão de camas funerárias como artefactos rituais em túmulos reais no Egipto antigo teve o seu início no Império Novo. Tratam-se de objetos de elevada raridade, havendo muito pouca informação relativamente à madeira utilizada para os fabricar. O presente artigo incide sobre a identificação de madeiras pertencentes a peças de camas funerárias egípcias provenientes do túmulo do Rei Horemheb, utilizando microscopia ótica com luz refletida como técnica analítica não-invasiva. Embora estes objetos pertençam a um túmulo real, os resultados obtidos demonstram que as quatro espécies de madeira identificadas (Cedro-do-Líbano, Sicómoro, Tamargueira e Espinho de Cristo) encontram-se entre as mais comuns do Egipto antigo. Estes dados confirmam que a escassez de madeira no Egipto antigo levou a que as poucas espécies de madeira existentes localmente fossem utilizadas para funções específicas, de acordo com as suas propriedades, enquanto para a obtenção de madeira de maior envergadura, os carpinteiros Egípcios tiveram de recorrer a fontes externas, tais como o Cedro-do-Líbano, confirmando a existência de rotas comerciais de madeira no Egipto antigo.

**PALAVRAS-CHAVE**
Rei Horemheb
Camas funerárias
Identificação de madeira
Cedro-do-Líbano
Espinho de Cristo

## Introduction

The inclusion of ritual couches as basic artefacts in ancient Egyptian royal tombs first appeared in the New Kingdom; they were supposed to symbolize the transference of the deceased King to celestial regions and the conferring of immortality and deification upon them exerted far-reaching and manifold effects as it was diffused abroad among other people [1]. This type of couches present three different shaped mythical animals (lioness, hippopotamus and cow). The basic construction of each couch is similar, consisting of four parts: the couch itself, which has a footboard and an imitation mesh mattress; two supporting animal-shaped side-sections attached to the couch through metal staples, hooks and angle pieces; and a rectangular base, where the feline legs and feet from the animal-shaped side-sections are slotted into [1-2]. They were made of wood, then gessoed and gilded or painted, and sometimes covered with black resin. The couches are very rare and very little information is available concerning the timber used to make them in ancient Egypt. Due to the low availability of wood for sampling and analysing, a large amount of Egyptian wooden artefacts are preserved in museums without scientific identification such as the collection of King Horemheb at the Egyptian Museum in Cairo. In recent papers, reflected light microscopy (RLM) was considered as an effective tool for non-invasive identification of historical wooden objects [3-4]. So, the purpose of this work is to non-invasively identify the botanical species of wood, through the use of reflected light microscopy, to improve our knowledge of wood species used for making ritual couches in King Horemheb period for the first time since the discovery of his tomb in 1908.

## Materials and methods

**The studied objects**

Parts of three animal-shaped wooden couches, which are summarized in Table 1, were discovered inside the tomb of Horemheb (KV57) in the Valley of the Kings by British Egyptologist Edward Ayrton, in 1908. Unfortunately, the complete construction of these funerary items was damaged due to the rubble that filled the tomb, and by floods caused by heavy rains for thousands of years. After the discovery of the tomb, these items were preserved in the Egyptian Museum without scientific identification. In 2018, these items were transported to the Wood Conservation Laboratory of the Grand Egyptian Museum – Conservation Center (GEM.CC) for investigation and conservation.

**Optical microscopy**

Visible wooden areas of these objects were observed with a Keyence VHX – 900F digital microscope (Japan) equipped with VH-ZST Dual-objective zoom lens, which allows observation at magnifications from 20 to 2000× with changing lenses and light from normal to polarized. All sections were observed rigorously using a VW-S 200 Free angle stand (which facilitates the observation of the objects with the camera and lens positioned at any angle), avoiding any kind of surface alteration (Figure 1). Each visible feature was recorded and documented through reflected light using a VHX – 5020 digital camera. Because of the reduced visibility of features entailed in the observation of non-prepared surfaces (i.e. neither oriented nor surfaced), the absence of specific features was not used for identification.

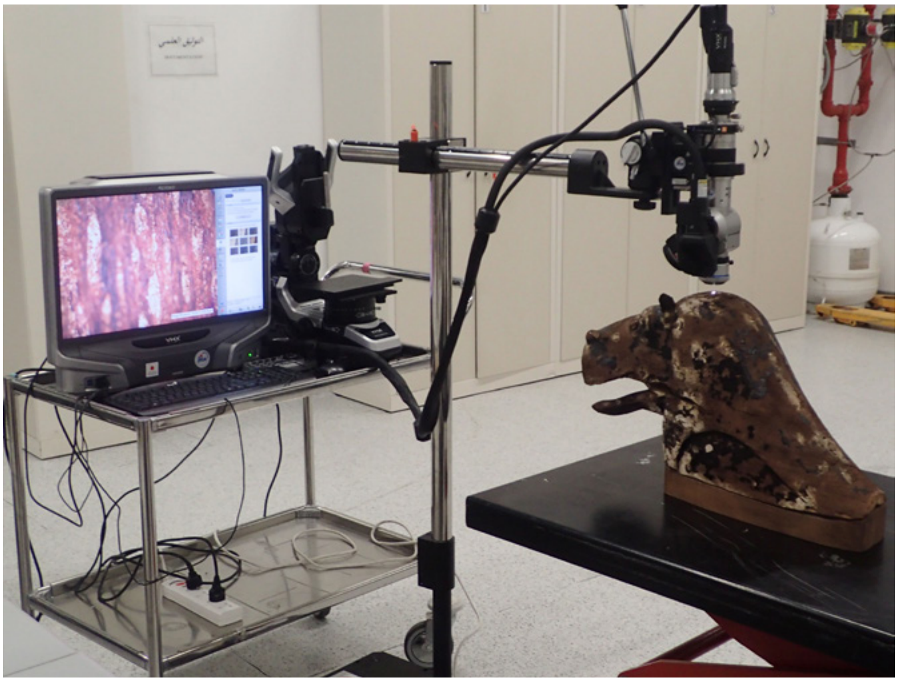

**Figure 1.** Set up for non-invasive wood identification of hippo headed couch using a Keyence VHX – 900F digital microscope equipped with VW-S 200 Free angle stand, which enables the observation of the objects with the camera and lens positioned at any angle, avoiding any kind of surface alteration through reflected light.

**Species identification**

Observation and description of anatomical features for the wood were based on wood anatomy atlases, textbooks and databases [5-10].

## Results and discussion

The results of microscopic identification from wood objects are summarized in Table 1. The anatomical features observed through reflected light microscopy used to identify the four wood species are listed in Table 2. Four different species of wood (*Cedrus Libani* (Cedar of Lebanon), *Ficus Sycomorus* (Sycamore fig), *Tamarix sp.* (Tamarisk), *Ziziphus spina-christi* (Christ's thorn) were identified in different parts of the objects, as shown in Figures 2 and 3.

***Cedrus Libani* A. Rich (Cedar of Lebanon)**

The obtained microphotographs (Figure 4) show the wood used for the main parts, such as the two lionesses headed couch, animal body and legs, which was identified as *Cedrus Libani* (Cedar of Lebanon). In addition, small parts used for the lower jaw of the hippo mouth were also identified as Cedar of Lebanon. The features that were crucially diagnostic in the identification of Cedar of Lebanon – scalloped torus margins on bordered pits in tracheid radial walls (Table 2) – can clearly be seen in Figure 4*d*. The wood from Cedar of Lebanon had been imported into Egypt from

**Table 1.** Object number, piece name, and species identification.

| Object No | Piece name | Identification | |
|---|---|---|---|
| | | **English name** | **Botanical name** |
| GEM 13936 | Hippo-headed couch (Figure 2*a*) | Sycamore fig | *Ficus Sycomorus* L. |
| | | Cedar of Lebanon | *Cedrus libani* A. Rich |
| | | Tamarisk | *Tamarix* sp. |
| GEM 13887 | Hippo-headed couch (Figure 2*b*) | Sycamore fig | *Ficus Sycomorus* L. |
| | | Cedar of Lebanon | *Cedrus libani* A. Rich |
| | | Tamarisk | *Tamarix* sp. |
| GEM 13913 | Lioness-headed couch (Figure 2*c*) | Cedar of Lebanon | *Cedrus libani* A. Rich |
| | | Tamarisk | *Tamarix* sp. |
| Other 55339 | Lioness-headed couch (Figure 2*d*) | Cedar of Lebanon | *Cedrus libani* A. Rich |
| | | Tamarisk | *Tamarix* sp. |
| Other 3979 | Mouth of cow-headed couch | Sycamore fig | *Ficus Sycomorus* L. |
| GEM 80017 | Legs of cow couch (Figure 3*a*) | Cedar of Lebanon | *Cedrus libani* A. Rich |
| Other 4062 | Part of animal body couch (Figure 3*b*) | Cedar of Lebanon | *Cedrus libani* A. Rich |
| GEM 13878 | Bracket (Figure 3*c*) | Christ's thorn/ sidder | *Ziziphus spina-christ* (L.) Willd. |

**Table 2.** Anatomical characteristics used for wood identification.

| ***Taxa*** | **Transverse section (TS)** | **Tangential longitudinal section (TLS)** | **Radial longitudinal section (RLS)** |
|---|---|---|---|
| *Cedrus libani* (Cedar of Lebanon) | Growth rings distinct, transition from early to late wood gradual (Figure 4*a*). Although not present in this specimen, it should be noted that cedar of Lebanon wood, can sometimes have an arrow of tangentially orientated traumatic resin canals which show up in TS. | Rays exclusively uniseriate. Its height is high to very high (more than 30 cells) (Figure 4*b*). | Radial tracheids present. End walls of ray parenchyma cells distinctly pitted (white arrows) (Figure 4*c*). Figure 4*d* shows scalloped torus margins of bordered pits in the radial walls of tracheids, which are diagnostic of Cedar of Lebanon. Bordered pits with cross fields of taxodioid type were difficult to observe. |
| *Ficus Sycomorus* (Sycamore fig) | Growth rings indistinct, diffuse-porous, vessels solitary and in multiples (Figure 5*a*). Banded axial parenchyma with most bands greater than four seriate; scanty paratracheal or vasicentric axial parenchyma (Figure 5*b*). | Multiseriate rays of two distinct widths; some rays 4-10 seriate; some rays greater than 10 seriate (Figure 5*c*), some sheath cells and laticifers present (Figure 5*d*). | Simple perforation plates and alternate inter-vessel pits (Figures 5*e, f*). |
| *Tamarix* sp. (Tamarisk) | Wood diffuse to semi ring-porous. Vessels arranged in radial bands separated by large rays. Axial parenchyma paratracheal (Figures 6*a, b*). | Multiseriate rays (6-20 seriate) (Figures 6*c, d*). | Heterocellular rays (Figures 6*e*). Perforation plates simple (Figures 6*f*). |
| *Ziziphus spina-christ* (Christ's thorn) | Wood diffuse-porous. Vessels solitary and in radial multiples. Diffuse apotracheal axial parenchyma present and paratracheal axial parenchyma scanty or vasicentric (Figure 7*a*). | Rays exclusively uniseriate (Figure 7*b*). | Heterocellular rays with procumbent, square and upright cells mixed throughout the ray. Prismatic crystals in ray cells (Figure 7*c*). |


**Figure 2.** Images of the analyzed animal heads from King Horemheb's tomb, as numbered in Table 1, and rendering of the wood species present: *a)* hippo-headed couch GEM No. 13936; *b)* hippo-headed couch GEM No. 13887; *c)* lioness-headed couch GEM No. 13913; *d)* lioness-headed couch other No. 55339.

very early ages and had a very high reputation as a precious raw material due to its excellent technological characteristics (straight-grained, aromatic, very durable, and taking a good polish), and cedar was the tallest tree in the eastern part of Mediterranean Sea [11-12]. Such properties made cedar wood a favoured choice in ancient Egypt for making high-status coffins and funerary artefacts as well as ships and timber structures [12-17]. So, the presence of cedar in the main parts of the royal couches of King Horemheb is somewhat expected. However, why use such a precious

**Figure 3.** Images of the cow couch parts of King Horemheb as numbered in Table 1: *a)* leg parts GEM No. 80017; *b)* animal body part (Other No. 4062); *c)* bracket GEM No. 13878.

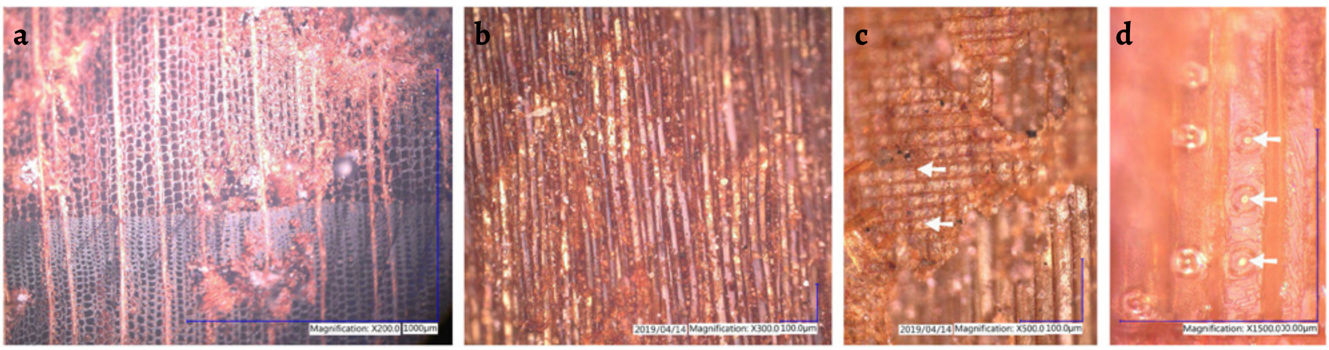

**Figure 4.** Microphotographs of wood sections under the microscope in reflected light showing the anatomical characteristics of *Cedrus libani*: *a)* TS; *b)* TLS; *c)* RLS; *d)* details of RLS showing scalloped torus margins of bordered pits (white arrows) in radial walls of tracheids, which are diagnostic of Cedar of Lebanon.

wood for small parts as lower jaw of hippo mouth? Giachi et al. [11], stated that the use of cedar wood for main parts produced wastes as small fragments that could be recycled for the production of small parts or objects such as the lower jaw of hippo mouth in this study.

***Ficus sycomorus* L. (Sycamore fig)**

The obtained microphotographs (Figure 5) show the wood used for the hippo and cow heads, which was identified as *Ficus sycomorus* (sycamore fig). The features that were crucially diagnostic in the identification of sycamore fig are banded axial parenchyma with most bands greater than four seriate (Figures 5*a*, *b*) and some sheath cells and laticifers present in rays (Figure 5*d*). Sycamore fig is native to Egypt and one of the relatively few local trees that grow tall enough to yield the long lengths of timber suitable for coffin construction and other artefacts. It also had considerable religious significance, since this tree, and its fruits, in particular, were associated with the goddess Nut. Although much used in ancient Egypt, sycamore fig wood is light, not of high quality and is prone to insect attack [18-21]. In this case, the use of the black resin that covered the wood surface of the couches may have reduced these drawbacks. So, the presence of sycamore fig in royal couches of King Horemheb is somewhat expected and agree with the published data on the black resin shrines from King Tutankhamun collection which showed the use of sycamore with cedar wood for the main parts [22].

***Tamarix* sp. (Tamarisk)**

Figure 6 shows that the wood used for the ears of the animals is *Tamarix* sp. (tamarisk). The species of tamarisk present in Egypt, the Sahara and adjacent regions are virtually impossible to separate reliably based on their wood anatomy. The properties of tamarisk woods include medium bending and compression strength, moderate hardness and a coarse and fibrous texture [23]. Moreover, *Tamarix* sp. woods are unlikely to have been available for use as large planks. However, they are ideal where short lengths of timber are required [18-22]. Such properties made tamarisk woods a favoured choice in ancient Egypt for making small parts, objects, dowels and tenons over a wide chronological period [12]. The obtained result agrees with the previous literature and the published data on the black resin shrines and gilded wooden bed from King Tutankhamun's collection, which showed the use of tamarisk for the small parts [22,24].

***Ziziphus spina-christi* (L.) Willd. (Christ's thorn/sidder)**

*Ziziphus spina-christi* (Christ's thorn) is also native to Egypt [25]. This tree is not large enough to provide the boards that formed the main parts of the large artefacts, but its wood is hard and durable and is highly suitable for tool handles, furniture components, tenons and pegs [12, 18, 22]. The obtained microphotographs showed that Christ's thorn (Figure 7) was used for making brackets, confirming the previous texts which showed that carpenters in ancient Egypt tended to make use of off-cuts of high-quality wood, such as cedar of Lebanon, and also often specifically chose

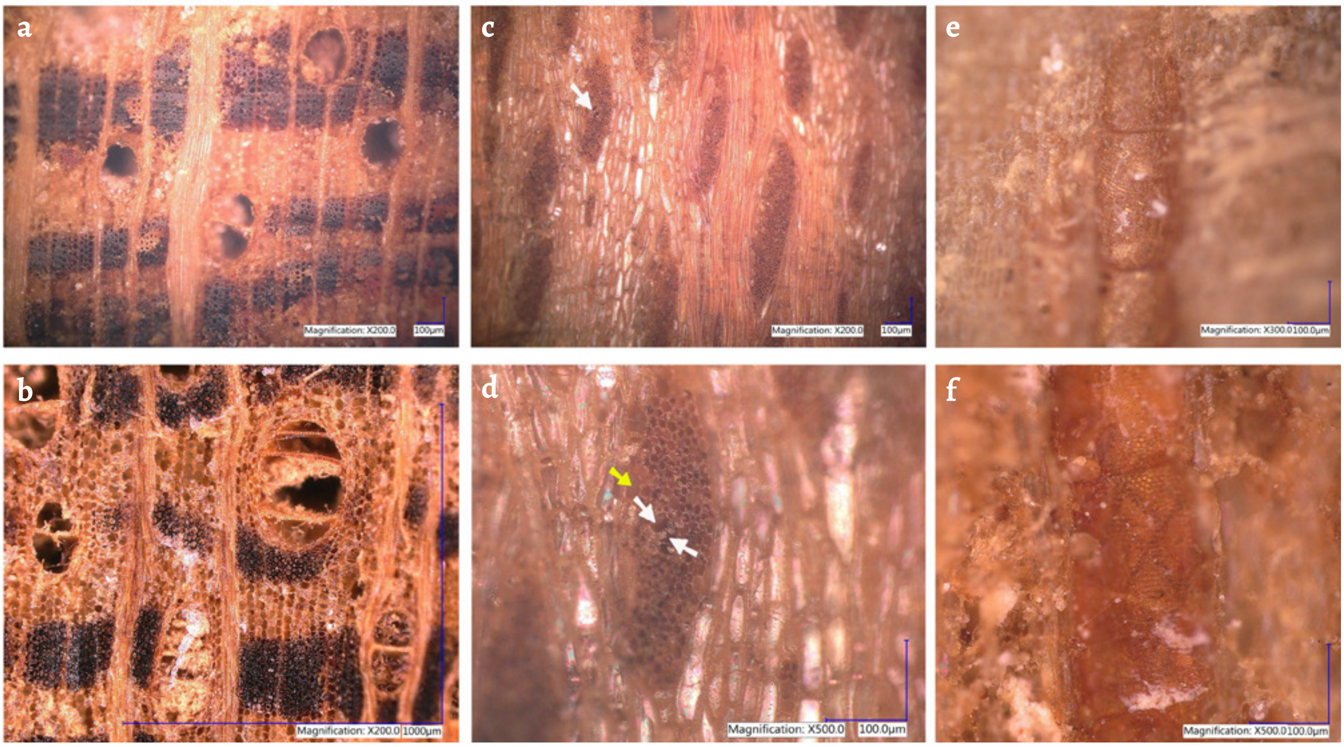


**Figure 5.** Microphotographs of wood sections under the microscope in reflected light showing the anatomical characteristics of *Ficus sycomorus*: *a, b)* TS showing its characteristic structure of wide-banded fibres; *c)* TLS; *d)* Details of TLS showing sheath cells (yellow arrows) and laticifers (white arrows); *e, f)* RLS.

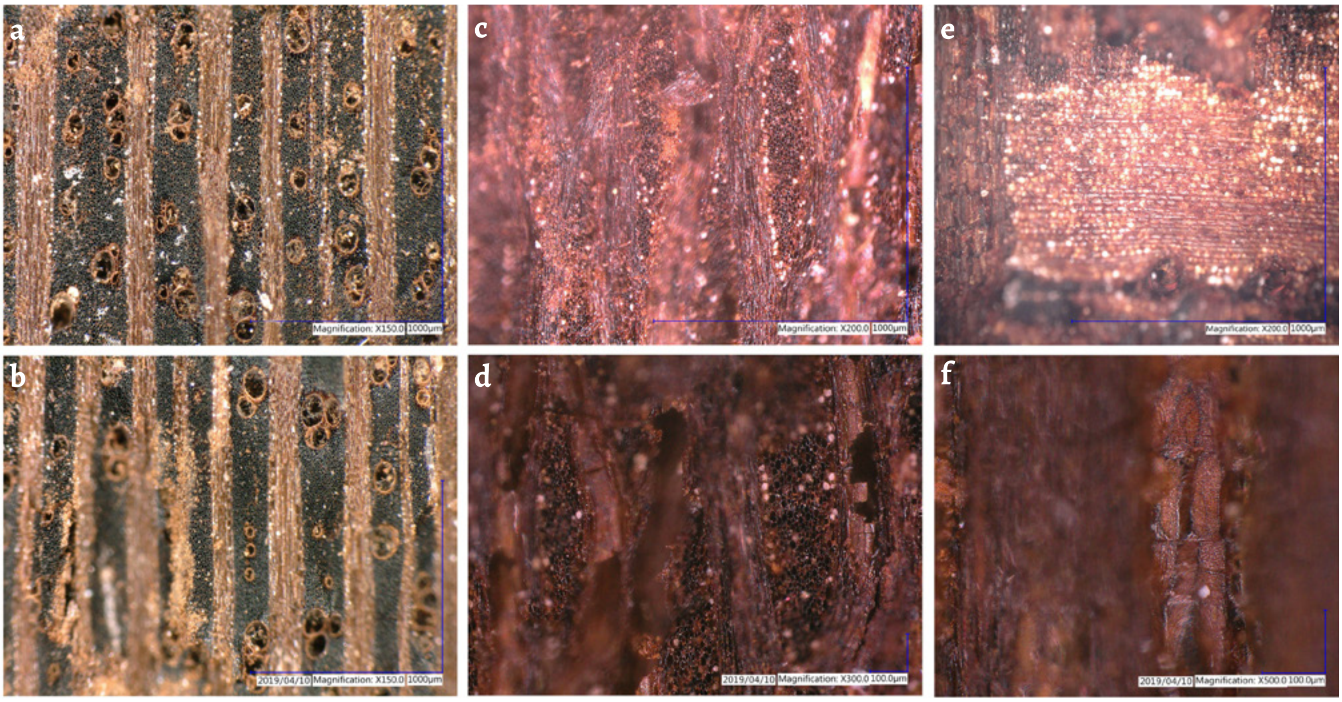

**Figure 6.** Microphotographs of wood sections under the microscope in reflected light showing the anatomical characteristics of Tamarix sp.: *a), b)* TS; *c), d)* TLS; *e), f)* RLS.

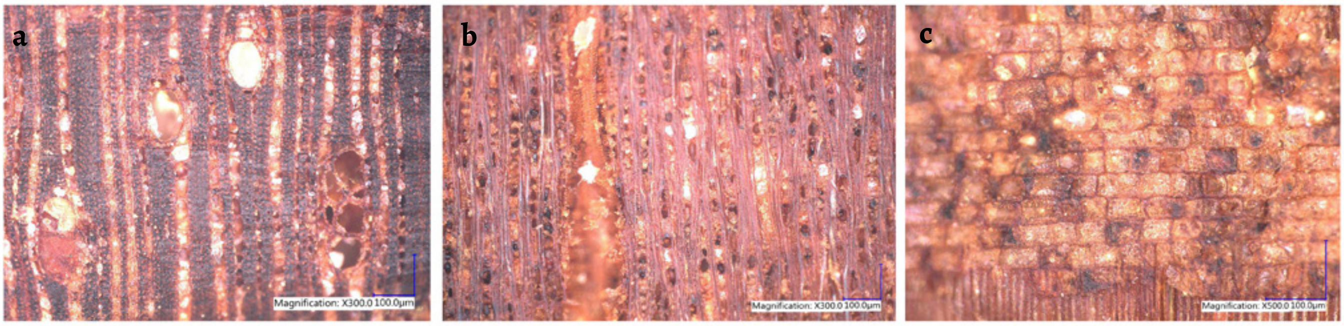

**Figure 7.** Microphotographs of wood sections under the microscope in reflected light showing the anatomical characteristics of *Ziziphus spina-christ* (L.) Willd.: *a)* TS; *b)* TLS; *c)* RLS.

woods that were not of the same species as that used for the main part of the artefact. This works well when the different properties of the various species selected respond in a way that creates a tight fit, locking the components together. It also enables hard dense woods such as *Acacia* spp. (acacia) and *Ziziphus spina-christi* (Christ's thorn), which are normally only available as short lengths of timber, to be used to their maximum effectiveness [17, 19].

## Conclusion

In this study, the identification of wood species for an ancient Egyptian couches parts of King Horemheb using a non-invasive technique through the reflected light microscopy was successfully conducted. In several examined cases accurate wood identification was possible and the use of polarized light improved the visibility of characteristic features. Shape and orientation of surfaces influenced the visibility of microscopic characters in few cases; however, it can anyway provide important information, useful to help decide about supposed species, or to limit the invasiveness of possible further analyses by addressing them on specific features. The results showed that the wood used on the couches is not limited to one species, but instead, four kinds of wood (*Cedrus Libani* (Cedar of Lebanon), *Ficus Sycomorus* (Sycamore fig), *Tamarix* sp. (Tamarisk), *Ziziphus spina-christi* (Christ's thorn/ Sidder)) were identified on different parts of the couches. These results reveal that the Egyptian funerary carpenters not only used whatever wood was most readily available or common locally, irrespective of its particular properties, but also selected specific woods primarily because their properties matched carpentry and design requirements. The results of this research represent a first step in determining the wood species used to produce this particular kind of couches during King Horemheb's period.

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# Archaeological chert artifacts from Atapuerca sites (Burgos, Spain): characterization, causes of decay and selection of compatible consolidating products

# Artefatos arqueológicos de cherte de Atapuerca (Burgos, Espanha): caracterização, causas de deterioração e seleção de produtos de consolidação compatíveis

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**Abstract**

Chert tools from Galería and Gran Dolina Caves, located in the Sierra de Atapuerca site complex (Burgos, Spain), were characterized (macro-visual inspection, mineralogical phases, degree of crystallinity, soluble salts, surface morphology and optical surface roughness) and compared to chert samples collected from the surrounding Atapuerca mountain range. The chert tools were studied to determine their causes of decay and for selecting the most compatible consolidation treatments. It was found that samples solely containing quartz were not significantly altered and required little conservation treatment compared to those that contained quartz and moganite, which were more weathered and powdery, requiring consolidation. The efficacy of the consolidating products traditionally used by conservators (acrylic resin and ethyl silicate) to preserve these chert remains, together with novel nanoparticle-based products ($SiO_2$ and a mixture of $SiO_2$ and $Ca(OH)_2$ nanoparticles) were assessed in this study. Changes produced by these consolidating products in the physical (surface morphology and cohesion) and aesthetic properties of the chert tools were evaluated using non-destructive techniques (peeling test, spectrophotometry and optical surface roughness), followed by destructive techniques, such as SEM and XRD.

**KEYWORDS**

Archaeological chert artifacts
Consolidation
Nanosilica
Nanolime
Acrylic resin
Ethyl silicate

**Resumo**

Os utensílios de cherte das grutas Galería e Gran Dolina, localizadas no complexo da Sierra de Atapuerca (Burgos, Espanha), foram caracterizados (inspeção macro-visual, fases mineralógicas, grau de cristalinidade, sais solúveis, morfologia da superfície e rugosidade óptica da superfície) e comparadas com amostras de cherte recolhidas na cordilheira de Atapuerca. Os utensílios foram estudados para determinar as causas de deterioração e selecionar os tratamentos de consolidação mais compatíveis. Verificou-se que as amostras contendo exclusivamente quartzo não foram significativamente alteradas e exigiram pouco tratamento de conservação em comparação com as que continham quartzo e moganite, que estavam mais alteradas e pulverulentas, exigindo consolidação. Neste estudo foi avaliada a eficácia dos produtos de consolidação tradicionalmente usados pelos conservadores (resina acrílica e silicato de etila) para preservar os restos de cherte, juntamente com novos produtos baseados em nanopartículas ($SiO_2$ e uma mistura de nanopartículas de $SiO_2$ e $Ca(OH)_2$). As alterações produzidas por estes produtos consolidantes nas propriedades físicas (morfologia e coesão da superfície) e estéticas foram avaliadas por técnicas não destrutivas (teste de descamação, espectrofotometria e rugosidade da superfície óptica), e destrutivas, como SEM e DRX.

**PALAVRAS-CHAVE**

Artefatos arqueológicos de cherte
Consolidação
Nanossílica
Nanopartículas de $Ca(OH)_2$
Resina acrílica
Silicato de etilo

## Introduction

Chert is a sedimentary cryptocrystalline siliceous rock primarily composed of quartz ($SiO_2$) and other silicate minerals like moganite, opal, or clay or carbonates and organic material, which are considered impurities [1]. The intrinsic properties of chert, such as hardness and conchoidal fracture, had made it widely used as a raw material for knapping throughout the history of mankind. Although it is a durable material, chert artifacts are often found in poor conservation conditions in archaeological sites such as Sierra de Atapuerca, limiting their study and requiring consolidation treatments to enable examination and conservation. Sierra de Atapuerca (Burgos, Spain) is a limestone karst complex with many cavities in which archaeological fieldwork has been systematically carried out since 1978 [2]. The archaeological site has provided crucial data on human evolution in Eurasia from 1.2 Myr to the end of the Middle Pleistocene [4]. Therefore, it was included in the UNESCO's World Heritage list in 2000. Fieldwork extended throughout the cave system and around the range, including open-air and rock shelter sites, has increased the time period up to Holocene occupations [6].

The chert samples included in this study come from Gran Dolina and Galería (Figure 1*a*), two of the cave sites located in the Trinchera del Ferrocarril. The stone tools recorded at Galería and Gran Dolina Caves comprise various raw materials such as sandstone, quartzite, and other less well-represented materials, but the majority are chert artifacts, particularly Neogene chert that is usually highly altered. It is formed after silica precipitation in a hypersaline environment rich in gypsum and carbonates. It appears in the Neogene border of the Duero River and belongs to the late Miocene [10]. Almost all the Neogene chert artifacts from the Atapuerca sites have been whitened and lost their original luster. They also present visibly increased surface porosity, with an aspect that corresponds to the commonly described "white patina" [11]. The alteration, however, does not concentrate on the surface; in fact, it is more pronounced in the inner part, where usually the chert becomes powder [14]. In some cases, this issue impedes the recovery of intact artifacts from the site, as they often break during the excavation works and, on many occasions, require consolidation before being lifted or subsequently handled (Figure 1*b-d*).

Up to now, the chert artifacts of the Atapuerca sites have predominantly been consolidated with the acrylic resin Paraloid B72 and, occasionally, with ethyl silicate-based products [14].


**Figure 1.** Chert samples collected from Sierra de Atapuerca (Burgos, Spain) archaeological site: *a)* Upper part of Gran Dolina site; *b)* Prior consolidation with acrylic resin Paraloid B72 of an altered chert artifact found in the TD10.2 unit; *c)* Lifting of the treated artifact; *d)* Chert stone tool after conservation treatments.

The aim of this research is to characterize chert samples collected from the archaeological Atapuerca site to determine their composition, texture and conservation state, as well as the causes of their decay in order to select the most compatible consolidation treatments. In addition, we assessed the efficacy of the most widely-used consolidation treatments by comparing changes on the aesthetic and physical properties of the treated substrates with those produced by two novel consolidation products based on $SiO_2$ and $Ca(OH)_2$ nanoparticles. These products are still not widely used by conservators for conservation purposes and unreported for archaeological prehistoric stone tool preservation thus far.

## Materials and methods

### Chert samples

In the Atapuerca archaeological site, the chert is divided into two petrological groups based on its origin and geological period of formation, i.e., Cretaceous and Neogene [10, 16]. Neogene chert comes from Late Miocene formations and is found as large blocks outcropping in marls and marly limestone, and was formed due to silica precipitation in a hypersaline environment rich in gypsum and carbonates [10]. Previous studies have determined that this type of chert is composed of quartz and moganite; it also contains a certain amount of gypsum, calcite (filling some pores), and occasional impurities. Microscopically it appears highly heterogeneous and particularly porous in crystalline zones [17].

Six chert samples classified as having different degrees of decay based on visual inspection were selected to determine their composition, texture and state of conservation (Table 1). The causes of their decay were also studied with the purpose of being able to select and evaluate the necessary conservation treatments and the most suitable consolidating products for preserving the samples. Four samples of chert lithic remains came from the Middle Pleistocene units of the site. Two of them (samples SX3 and SX9) were collected from unit GIII of Galería site, dated at around 300 ky [18] and another two (samples SX1 and SX17) were collected from the TD10.2 unit in the upper part of Gran Dolina and dated at around 400 ky [10, 20]. Two further, fresh chert samples, were collected from the surrounding outcrops in the Sierra de Atapuerca (samples SX18 and SX19) with the aim of comparing these with the decayed samples collected from the archaeological sites (Figure 2). The soil remains that covered the samples from the dig were carefully removed from their surfaces with a brush, in order to carry out the compositional and textural analyses of the clean cherts.

**Table 1.** Studied chert samples from Atapuerca archaeological site.

| Nomenclature | | Nomenclature on site | | | |
|---|---|---|---|---|---|
| | | Year | Level | Square | Nº |
| Middle Pleistocene lithic remains | SX1 | 2008 | TD10 | M18 | 341 |
| | SX3 | 2004 | GIII | N03 | 71 |
| | SX9 | 2004 | GIII | N03 | 70 |
| | SX17 | 2011 | TD10 | L13 | 66 |
| Fresh chert samples collected from the surrounding outcrops | SX18 | | | | |
| | SX19 | | | | |

### Study of consolidation treatments

Sixteen chert samples from Middle Pleistocene units were

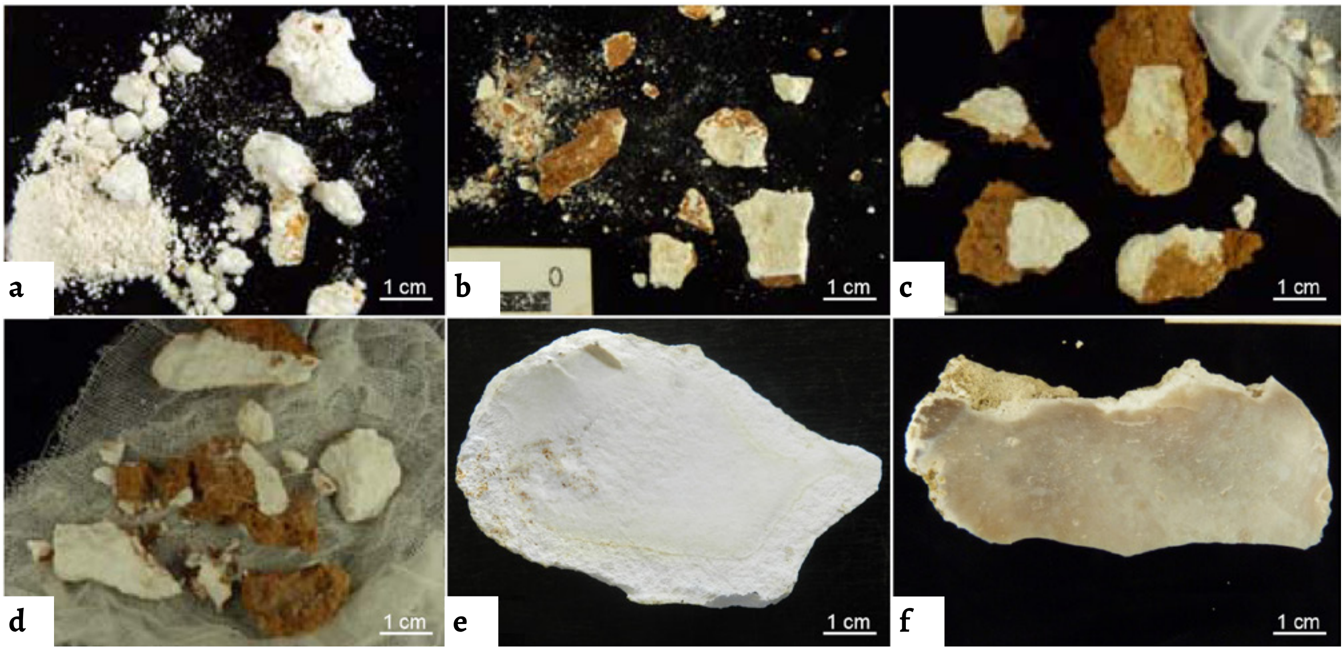


**Figure 2.** Studied chert samples: *a)* Sample SX17; *b)* Sample SX9; *c)* Sample SX3; *d)* Sample SX1, from the archaeological site of Atapuerca; *e)* Sample SX19, and *f)* Sample SX18 from the surrounding outcrops.

collected in two different sites to evaluate the different consolidating products after their treatment. Six samples were selected from the TD10.2 unit in the upper part of Gran Dolina and ten samples were collected from unit GIII at the Galería site. The samples were large enough to be analyzed using various analytical techniques and test methods (Table 2). The 16 selected samples (four control samples and 12 samples to be treated, three samples for each consolidating product) initially displayed a similar degradation state, i.e. milky white in color, loss of density and mass, superficial decohesion, large roughness, friable surface and loss of external areas (apart from samples SX2 and SX8 which preserved some parts of the most superficial area). As explained above, the soil covering the samples was brushed off to enable their characterization and further application of the consolidating products.

As it was described in a previous work by Zornoza-Indart et al. [21], four types of consolidating products were applied to consolidate chert artifacts (Table 2). The first one comprises the most widely-used conventional alkoxysilane consolidant (ethyl silicate: Tegovakon V100, Evonik Industries AG). This product was chosen because it is highly compatible with siliceous substrates and can form chemical bonds with substrates containing hydroxyl groups during the sol-gel process [22]. The second product was a colloidal dispersion of silica nanoparticles in water (Nano Estel, C.T.S.) with a particle size of 10-20 nm and a concentration of 150 g/L. This product was chosen because it is a novel product and is also expected to be chemically compatible with siliceous substrates due to the formation of a silica gel with silanol groups [23].

The third product was an acrylic resin, the most widely-used by conservators (Paraloid B72 by Dow Chemical), in a concentration of 5 % in xylene. The choice of solvent is based on its volatility. When Paraloid is used as a consolidant, a low volatile solvent is used to allow maximum penetration of the product (conservators use to apply acetone as a solvent when the product is used as an adhesive because the rapid evaporation rate of the acetone decreases the penetration of the product in the porous network remaining only on the surface). Although Paraloid is the most used consolidant, silicate-based products with a lesser penetration depth than ethyl has been reported [24].

Finally, a mixture of two inorganic products based on colloidal dispersions of nanoparticles was used (the aforementioned Nano Estel, and Nanorestore C.T.S., i.e. $Ca(OH)_2$ colloidal dispersion in isopropyl alcohol with a particle size of ≤ 100 nm and a concentration of 5 g/L), in a ratio of 1:1.

The products were applied to reproduce the application method used nowadays by most restorers, which usually follow the recommendations stated by the manufacturers. The application was performed through a capillary tube and deposited drop-by-drop (the most frequently used application method in conservation of archaeological artifacts) onto the surface of the samples. Then, the samples were exposed to a humid environment (19 ± 1 °C temperature (T) and 93 ± 3 % relative humidity (RH)) for one month, even though it should be noted that the time suggested by the manufacturer (2-4 weeks) might not be time enough to complete the polymerization process. This high RH was selected because the carbonation rate of $Ca(OH)_2$ nanoparticles is faster under higher RH [25]. In addition, new silica nanoparticles can be used in conditions where ethyl silicate or acrylic resin are not appropriate, such as in the presence of high levels of humidity, free water or wet

**Table 2.** Chert samples and applied consolidating products by dripping.

| Nomenclature | Nomenclature on site | | | | Applied consolidating product | | |
|---|---|---|---|---|---|---|---|
| | Year | Level | Square | Nº | Consolidating product | Commercial product | Applied amount of product (g) |
| MC SX1 | 2008 | TD10 | J19 | 85 | Control samples | | |
| MC SX2 | 2004 | GIII | N03 | 71 | | | |
| MC SX3 | 2004 | GIII | N03 | 71 | | | |
| MC SX4 | 2011 | TD10 | K14 | 151 | | | |
| SX1 | 2008 | TD10 | M18 | 341 | Nano $SiO_2$ | Nano Estel | 1.09 |
| SX2 | 2008 | TD10 | J19 | 85 | | | 2.29 |
| SX3 | 2004 | GIII | N03 | 71 | | | 1.2 |
| SX4 | 2004 | GIII | N03 | 71 | Ethyl silicate | Tegovakon V100 | 2.23 |
| SX6 | 2004 | GIII | N03 | 71 | | | 0.59 |
| SX7 | 2004 | GIII | N03 | 71 | | | 1.41 |
| SX8 | 1998 | TD10 | N14 | 34 | Acrylic resin | Paraloid B72 | 2.11 |
| SX9 | 2004 | GIII | N03 | 70 | | | 1.11 |
| SX13 | 1998 | TD10 | N14 | 34 | | | 1.53 |
| SX10 | 2004 | GIII | N03 | 70 | Nano $SiO_2$ + $Ca(OH)_2$ | Nano Estel + Nanorestore | 1.54 |
| SX11 | 2004 | GIII | N03 | 70 | | | 1.33 |
| SX12 | 2004 | GIII | N03 | 70 | | | 1.22 |

surfaces. Note that moisture is common in archaeological excavated objects, which can generate compatibility problems with conservation products. The temporary hydrophobicity of ethyl silicates, already investigated by other authors, can preclude future treatments, as the consolidation treatment is usually followed by cleaning of the samples. In this deeper cleaning procedure, hydric solvents are used, but, the cleaning is not possible if there is a hydrophobic layer. In addition, if a volumetric reintegration is made and the surface is hydrophobic, the adhesion of the reintegration stuccos is hinder. Also, the hydrophobicity of some consolidants preclude desalination treatments (very common in buried archaeological pieces). Although the concept of reversibility has been widely studied and discussed, the concept of retreatability is less studied. Research is usually focused on the application of these treatments, especially consolidation products to freshly excavated or deteriorated materials but not to samples that have been already treated with other products. Therefore and despite being one of the most important criteria in the selection of conservation products and treatments, retreatability is less considered in conservation studies.

The time of this hydrophobic behavior varies according to the authors and the research, as well as with commercial products applied and substrates treated. The hydrophobicity has been observed until 28 days of curing [26], five weeks [27], three weeks [28], one month [29], two months [30] and several months [22, 31].

Environmental data loggers, ibuttons model DS1923-F5, were introduced into the container and also placed in the laboratory to register T and RH during the test, using the software OneWireViewer version 3.04. Further details on the use of these consolidating products, application method and environmental conditions are described in Zornoza-Indart et al. [21].

## Analytical techniques and test methods

### *Chert characterization*

The decay and conservation state of the samples was studied following the protocol and terms established by Font et al. [15] based on macro-visual inspection with the naked eye. In addition, X-ray diffraction (XRD) was used to determine the main mineralogical phases and degree of crystallinity of the samples. A Phillips PW-1710 diffractometer was used with CuKα radiation to study the total powder fraction of samples. The measurements were conducted by step scanning 2θ from 2 ° and 68 °, scan step size 0.02 °, scanning rate 2 °/min, with a continuous mode and beam intensity of 40 kV and 40 mA. Three chert samples (SX3, SX17 and SX18) were analyzed with higher precision to distinguish the different silica polymorphs by means of a multi-purpose PANalytical X´Pert MPD with CuKα radiation. Analysis conditions were 2θ between 2 ° and 90 °, scan step size 0.02 °, count time of 3 seconds per step, with continuous mode and beam intensity of 45 kV and 40 mA. Furthermore, sample SX18 was preserved and analyzed, without grinding, using micro-diffraction analyses to obtain several diffractogram patterns on various spots of interest. The mineralogical phases were identified by comparing the sample with the Joint Committee on Powder Diffraction (JCPDS) database and Bruker AXS DiffracPlus EVA software.

Ion chromatography (IC) analyses were performed to identify soluble salts in all the samples, i.e. type and quantity of some anions ($Cl^-$, $NO_3^-$ and $SO_4^{2-}$). Soil samples collected from the same dig areas as the chert samples were also analyzed to ascertain whether or not the presence of salts. Approximately 0.1 g of sample was dissolved in 10 ml of Milli-Q ultrapure water and placed for 45 min in an ultrasonic bath at room temperature. Afterward it was centrifuged for 5 min at 3500 rpm and 3400 rfc centrifugal force. The soluble salts in the extracted sample were quantified using a Metrohm 761 Compact IC ion chromatograph.

The surface morphology and texture of the specimens were examined by means of environmental electron scanning microscopy (ESEM) using an Inspect FEI microscope coupled with energy dispersive X-ray spectroscopy (EDS) (model 7509 Oxford Instrument Analytical, UK).

Optical surface roughness (OSR) analyses were also performed on the surface of samples SX18 and SX19 (the other samples were too small to take these measurements on). This was carried out to evaluate changes in the surface roughness caused by decay processes. The equipment used was a contact-free surface profilometer (white light), TRACEiT, Innowep GmbH. The OSR analyses included the generation of 3D-topography maps (25 $mm^2$) using Gyddion 2.44 software displaying the average roughness parameters according to ISO 4287 (1998) standards [33], i.e., Ra (arithmetic mean of the absolute values of profile deviations from the mean line) and Rz (sum of the vertical distances between the five highest peaks and the five deepest valleys within the sampling length). The cutoff (λc) used for the calculations was 0.80 mm.

### *Consolidation*

The sixteen specimens were also analyzed using various non-destructive techniques and test methods both before application of the consolidating products and one month later.

The surface morphology, texture of the specimens, and the distribution and morphology of consolidating products was examined by ESEM-EDS.

A peeling test was carried out on the surface of the samples to assess the detachment degree of the material using transparent double-sided adhesion tape (Tesa), with 1.5 cm wide × 5 cm long, on 1 zone per sample (ten sequences) and 90 seconds per each sequence. This method is commonly used for evaluating the consolidation effect of the products on stone surfaces by determining the detached material after applying and removing pressure sensitive tape over the surface [34].

Spectrophotometry was performed to determine the color parameters, with a spectrophotometer MINOLTA CM-700d using the CieLab color space; the measuring area was 1-3 mm. Three measurements were conducted for each sample, the standard illuminant was D65 and the observer angle, 10 °. The measured parameters were L*, which accounts for luminosity, a* and b* coordinates (a* being the red-green parameter and b* the blue-yellow), total chrome difference $\Delta C^*$ (from the formula $\Delta C^* = (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$), and total color difference $\Delta E^*$ (from the formula $\Delta E^* = ((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)^{1/2}$). The white (WI) and yellow (YI) indices were measured according to ASTM E313-73 [35] and brightness was measured according to ISO 2470-2 [36].

## Results and discussion

### Characterization of chert samples

#### *Macroscopic examination*

The main results from the macroscopic examination are shown in Table 3. All the weathered samples from the archeological sites displayed a milky-white color and lost the characteristic densely packed cohesion of chert. No fissures or fractures were observed with the naked eye in any of the samples. However, all of them showed a coarse surface with different degrees of decohesion (Figure 2*a-d*). Sample SX17 (Figure 2*a*) was the most damaged chert. Part of this sample was broken down into a white powder and the rest was very dusty, friable and disaggregated on the surface. Sample SX9 (Figure 2*b*) displayed a certain degree of compacted structure, slightly higher than the previous sample. It also had a dusty, friable and disaggregated surface that powdered to the touch. In spite of some lost material, samples SX3 and SX1 (Figure 2*c-d*) seemed to be better preserved compared to the other samples. These were more compacted and did not present the same degree of disaggregation as the previous samples, even though they also had coarse, grainy and quite dusty surfaces. Among the chert samples from the outcrops surrounding the archaeological sites, sample SX19 (Figure 2*a*) was muddy-white in color with a coarse but compacted surface, similar to samples SX1 and SX3. Two different zones could be distinguished on the surface of this sample, a more crystalline, compacted and smoother core zone, and another whiter, coarser and dustier external zone that appeared more weathered. Sample SX18, also from the surrounding outcrops, was grayish-brown in color with some faceted core areas that were fine grained and crystalline (Figure 2*f*). Only this latter zone of this particular sample displayed the characteristic cutting edge morphology caused by the distinctive conchoidal fracture of the chert. This core zone was surrounded by a 1 mm-thick crust, grayish-white in color and earthy but with a compacted appearance. This was circled by another 5 mm-thick, white external crust that in spite of its compacted structure displayed a similar aspect to the more weathered samples previously described (milky-white in color, rough, dusty and with a disaggregated surface).

**Table 3.** Macroscopic examination of archaeological chert samples.

| Nomenclature | | Macroscopic examination |
|---|---|---|
| Middle Pleistocene lithic remains | SX1 | Better preserved. More compacted, without disaggregation but with coarse, grainy and quite dusty surfaces. |
| | SX3 | |
| | SX9 | Certain degree of compacted structure but, dusty, friable and disaggregated surface that powdered to the touch. |
| | SX17 | Most damaged. Broken down into a white powder, very dusty, friable and disaggregated on the surface. |
| Fresh chert samples | SX18 | Grayish-brown in color with some faceted core areas that were fine grained and crystalline. |
| | SX19 | Muddy-white in color with a coarse but compacted surface. Two different zones: a more crystalline, compacted and smoother core zone, and another whiter, coarser and dustier external zone that appeared more weathered. |

#### *X-ray diffraction (XRD)*

All the XRD results obtained from the total powder samples showed the presence of quartz ($SiO_2$) and moganite ($SiO_2$ polymorph), with the exception of SX9 and SX17 which were solely composed of quartz and calcite ($CaCO_3$); SX17 had a large amount of calcite. These results are in agreement with those obtained by other authors for similar materials [17, 37]. Sample SX19 had more moganite in the whiter external zone compared to the more crystalline core zone. The amount of moganite was even higher in sample SX3, which also displayed some calcite, followed by sample SX18 (Figure 3*a*). The four diffractogram patterns obtained in different spots on this unground sample indicate certain mineralogical differences (Figure 3*b*). The external zone (surrounding crust; crust 1) was mainly composed of quartz and calcite with a lower proportion of dolomite, and had poorly-defined broad peaks indicating less crystallinity. The most external white crust (crust 2) showed only quartz and very well-defined moganite peaks. The quartz peak at 41 ° 2θ only appeared well-defined in the crystalline core zones of the sample (Chert 1; Figure 3*b*). As inside the same nodule or quartz level textures and impurities can change, that's the main difference between the faceted and colored areas in the crystalline core zone of the sample [38]. This is also the main difference between the faceted and colored areas in the crystalline core zone of this sample, since changes in texture and impurities can occur inside the same nodule or quartz level [38].

The chert samples from the archaeological site and the most weathered samples from the surrounding outcrops (with a totally disaggregated surface), i.e., samples SX17, SX9 and the most external crust of sample SX18, displayed quartz and calcite minerals. The less-weathered samples,

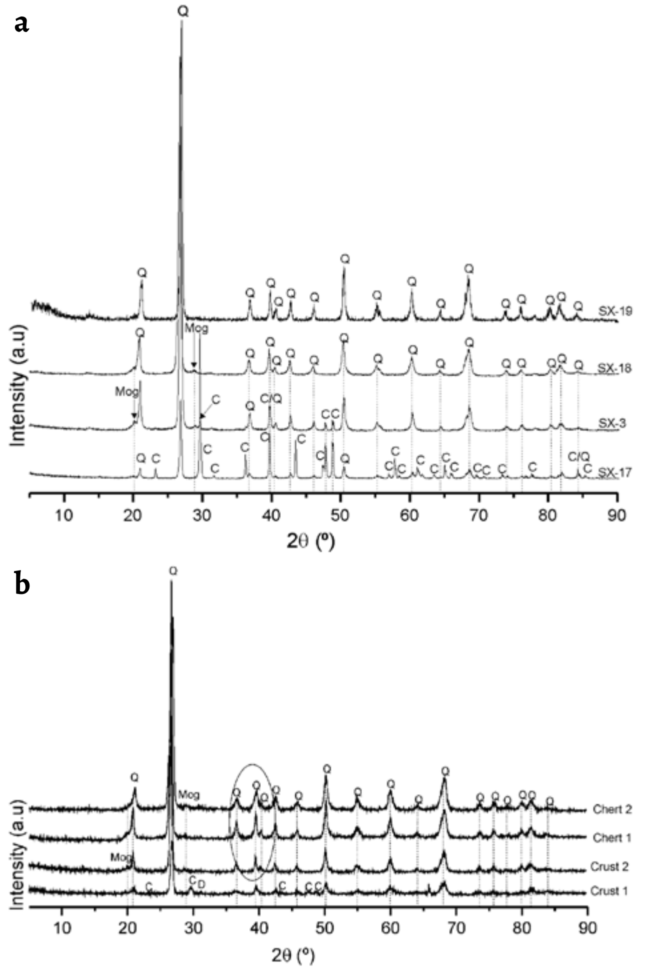


**Figure 3.** X-ray diffraction (XRD) patterns of the archaeological chert samples: *a)* XRD obtained from the total powder samples; *b)* Diffractograms from micro XRD analysis (no powdered samples) obtained in SX18 sample, in the external (crust) and in the core zones (chert). Q: quartz; Mog: moganite; C: calcite; D: dolomite.

with coarse, grainy but more compacted surfaces (samples SX1, SX3, SX19 and middle crust of sample SX18), contained quartz, moganite and small amounts of calcite. Finally, the best preserved crystalline cores of samples SX18 and SX19 had only quartz.

High alkalinity, sulfates and ferric ion activity play a certain role in the precipitation of moganite [38]. In the research work on Mogan rocks from Gran Canaria, Spain, carried out by García-Guinea et al. [39], it was found that their core area and edges (more porous, whiter and with additional ions) resulted in a different cathodoluminescence spectrum. This was interpreted as late hydrothermal weathering mechanisms with alkaline ions, metals and volatiles to form moganite. In silica weathering, moganite represents an intermediate position between opaline phases and quartz [38]. It is considered a metastable phase which can be transformed into quartz if there is enough time or there are changes in the surrounding environmental conditions [40]. The abundance of moganite in arid environments has been partially explained by the lack of water for mediating the dissolution of this mineral and the simultaneous precipitation of quartz, as between 10 % and 80 % of the silica present in different varieties of fine-grained quartz is in fact moganite [41]. In this case, the quantity of moganite is a key indicator in the decay of chert samples. The crystalline core zone of sample SX18 from the outcrops, which only has quartz, is in a good state of preservation. The chert samples from the archeological site and the outer crust of sample SX18 (with mixtures of quartz-moganite) are weathered, with coarse, porous and disaggregated surfaces. In quartz-moganite mixtures, fast weathering may occur, as moganite is more soluble than quartz. This means that those parts of the chert containing moganite could be more weathered and more porous, favoring fluid penetration leading to disaggregation processes. In the research conducted by Navazo et al. [17], poorly-preserved Neogene chert, and massive, well-preserved Cretaceous chert samples with low porosity, both from outcrops close to the Atapuerca mountain range, were compared. They also found that moganite played a significant role in chert decay and preservation state, since the quantity of this mineral was the main difference between the two types of chert. Increased amounts of calcite and decreased moganite in the samples, relating to a greater degree of decay and weathering, may be due to the fact that the areas originally comprising moganite could have been weathered or dissolved. This favors fluid penetration and pore filling by external compounds [39], in this case by calcite since these cherts were within limestones rock settlements.

The absence of moganite in the most weathered chert samples could be in line with the data provided by Heaney & Post [41] and Rodgers & Cressey [40], who report that moganite does not appear in weathered or eroded cherts, since it completely disappears due to dissolution processes.

***Ion chromatography (IC)***

Ion chromatography data indicate negligible amounts of soluble salts (chlorides, nitrates and sulfates), with total weight percentages of salts below 0.08 % in all samples as it was described in Zornoza-Indart et al. [21]. The soil samples collected from the same dig areas where the chert samples were buried also contain insignificant amounts of salts. Therefore, the decay of the chert samples by salt crystallization processes is discounted.

***Optical surface roughness (OSR)***

The surface roughness analysis results are shown in Table 4.

**Table 4.** Optical surface roughness (OSR) parameters (Ra and Rz) of fresh chert samples SX18 and SX19, measured on the external crust, weathered surfaces and smooth areas.

| Sample | Area | Ra (μm) | Rz (μm) |
|---|---|---|---|
| SX18 | Smooth | 2.57 ± 0.40 | 9.35 ± 1.37 |
| | Crust | 7.43 ± 0.34 | 40.82 ± 1.84 |
| SX19 | Smooth | 3.67 ± 0.29 | 17.52 ± 1.12 |
| | Weathered | 10.30 ± 0.42 | 41.62 ± 1.94 |

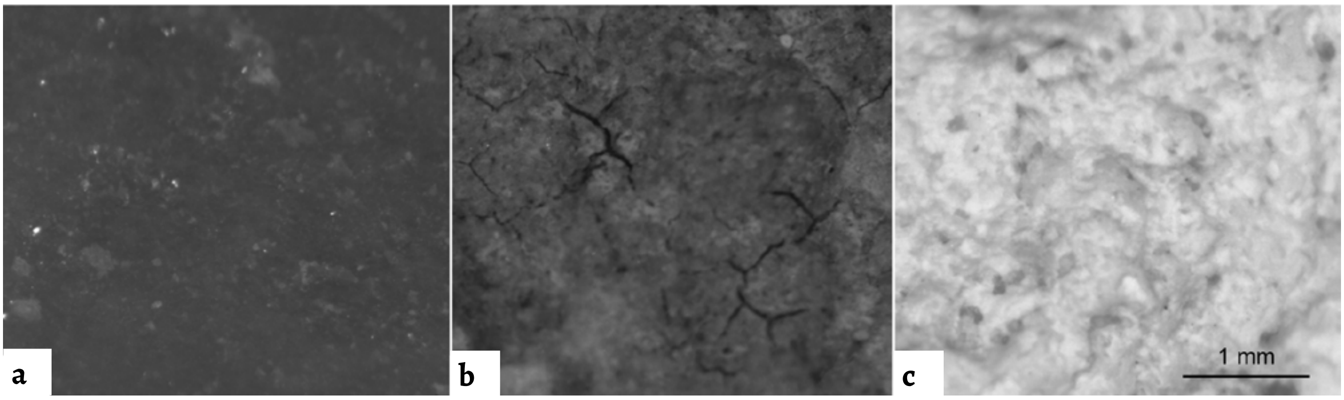


**Figure 4.** Micro-detailed images obtained by optical surface roughness (OSR) measurements: *a)* Even area of sample SX18; *b)* External crust of the sample SX18; *c)* Coarse surface texture of sample SX19.

The micro-detailed surface images can be seen in Figure 4, and 3D OSR maps are presented in Figure 5.

By comparing the results obtained on the smooth, crystalline core zones and less weathered parts (that are more similar to fresh chert) of the two studied samples (SX18 and SX19), it can be seen that the Ra roughness values for sample SX19 are 43 % higher than for sample SX18 (3.67 ± 0.29 µm vs. 2.57 ± 0.40 µm, respectively). The same occurs with the Rz values that are 87 % higher in sample SX19 (17.52 ± 1.12 µm vs. 9.35 ± 1. 37 µm). These results show that sample SX19 is much coarser than sample SX18 due to surface degradation processes, as was also observed in the macroscopic study. The average surface roughness values are greater in both the smoother and better-preserved areas and across the entire surface of sample SX19, which is denoted by the longer distances between the highest and deepest parts of the measurement areas indicated by the Rz parameter. In the coarse and decayed areas, the rough and dusty external zone of sample SX19 and the external crust of SX18 (crust 1, which according to XRD comprises quartz and calcite), roughness values are similar in the two samples, although slightly higher in sample SX19 (7.43 ± 0.34 µm vs. 10.30 ± 0.42 µm in the Ra parameter and 40.82 ± 1.84 µm vs. 41.62 ± 1.94 µm in the Rz parameter respectively).

The micro-detailed images obtained with the profilometer (Figure 4) and the surface roughness 3D height maps

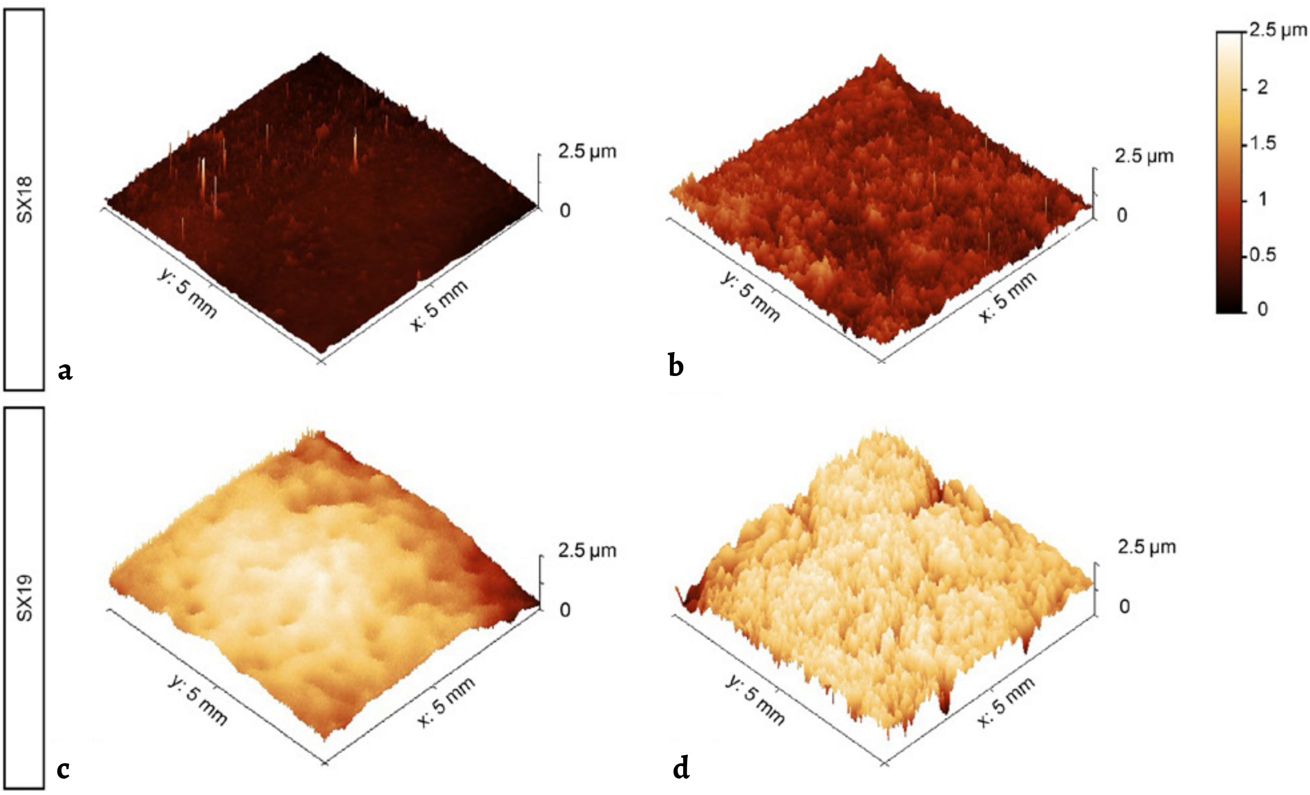


**Figure 5.** Surface roughness 3D height maps obtained under optical surface roughness (OSR) on the different surface areas of chert SX18 and SX19 samples: *a)* Even area of sample SX18; *b)* External crust of the sample SX18; *c)* Even area of sample SX19; *d)* Coarse surface of sample SX19.

(Figure 5) show the surface differences on the texture morphology, and hence the surface roughness contrast among several zones of both samples. The image of an even area of sample SX18 shows a smooth, compacted and homogeneous surface (Figure *4a* and Figure *5a*), whereas the image of sample SX19 reveals a whiter color and dustier, poorly-compacted surface, where mineral grains are clearly observed, as well as discontinuous areas with pores (Figure *4c* and Figure 5*c-d*). In the most decayed areas, some further differences can be seen (Figure 5*b-d*). The transition from the smooth area towards the external rough zone of sample SX19 can be observed as a progressive loss of homogeneity and compaction of the surface, showing up as a more white and porous, disaggregated grainy zone where loss of material is observed. In sample SX18, the image shows the previous step in the total decay process observed in sample SX19. The color is still darker than the surface coloring of sample SX19, although white areas not detected in the smooth zone can be observed. The surface of SX18 sample maintains its continuity and homogeneity, but cracks and fissures appear and, eventually, if decay processes continue, there could be loss of material and disaggregation of the surface, in a similar way to that observed in sample SX19.

***Environmental SEM-EDS***

Sample SX3 from the archaeological site exhibits silica with radial-fibrous textures in some areas and nodular textures in others (Figure 6). Even though sample SX17 is more homogenous, the fibrous texture is less rigidly oriented (Figure 6*d*).

The external part of sample SX18, from the outcrop, shows signs of dissolution, retraction cracks and has a higher calcium content (Figure 7*a*). A different zone (corresponding to the whitish crust) displays a similar texture to the crystalline core zone. However, in this case it is weathered due to dissolution-recrystallization processes (Figure 7*b*). In the crystalline core zone, a crypto-crystalline, fairly fibrous texture can be seen (Figure 7*c*), together with some areas containing pores and fissures from 50 to 100 µm in size, almost completely cemented by micro-crystalline quartz crystals (Figure 7*d*). These pore and fissured areas might correspond to moganite, leading to a certain degree of micro-porosity.

These results are in line with those obtained by XRD, where differences between the two crusts were distinguished (the outer crust had a higher degree of alteration and comprised quartz and calcite, while the other crust was composed of calcite and moganite). Variability in moganite content has been linked to macroscopic color and texture variations within a sample, indicating that variable moganite content may be linked to changing environmental or depositional conditions [42]. The outer zone of sample SX19 presents crystals with radial-fibrous morphologies (which could be moganite) together with nodules of agglomerated

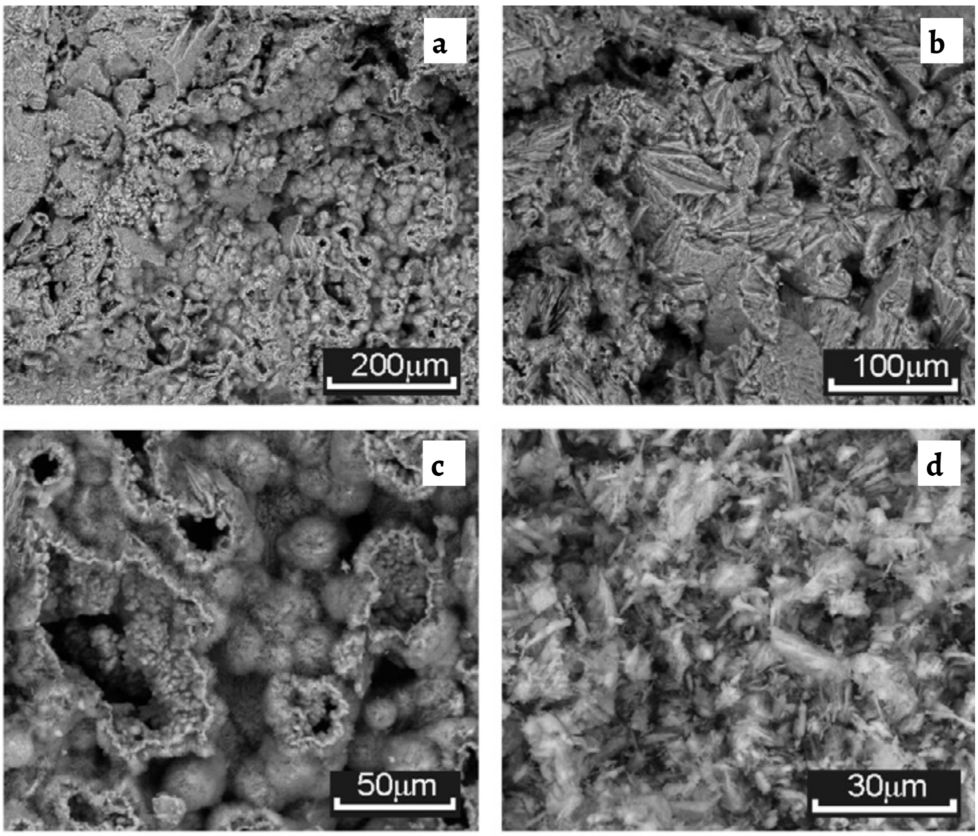


**Figure 6**. Environmental SEM (ESEM) images from the archaeological site chert samples: *a)* Sample SX3; *b)* Detail of radial-fibrous texture area in former sample; *c)* Detail of nodular textures in the same sample; *d)* Detail of disoriented fibrous texture in sample SX17.

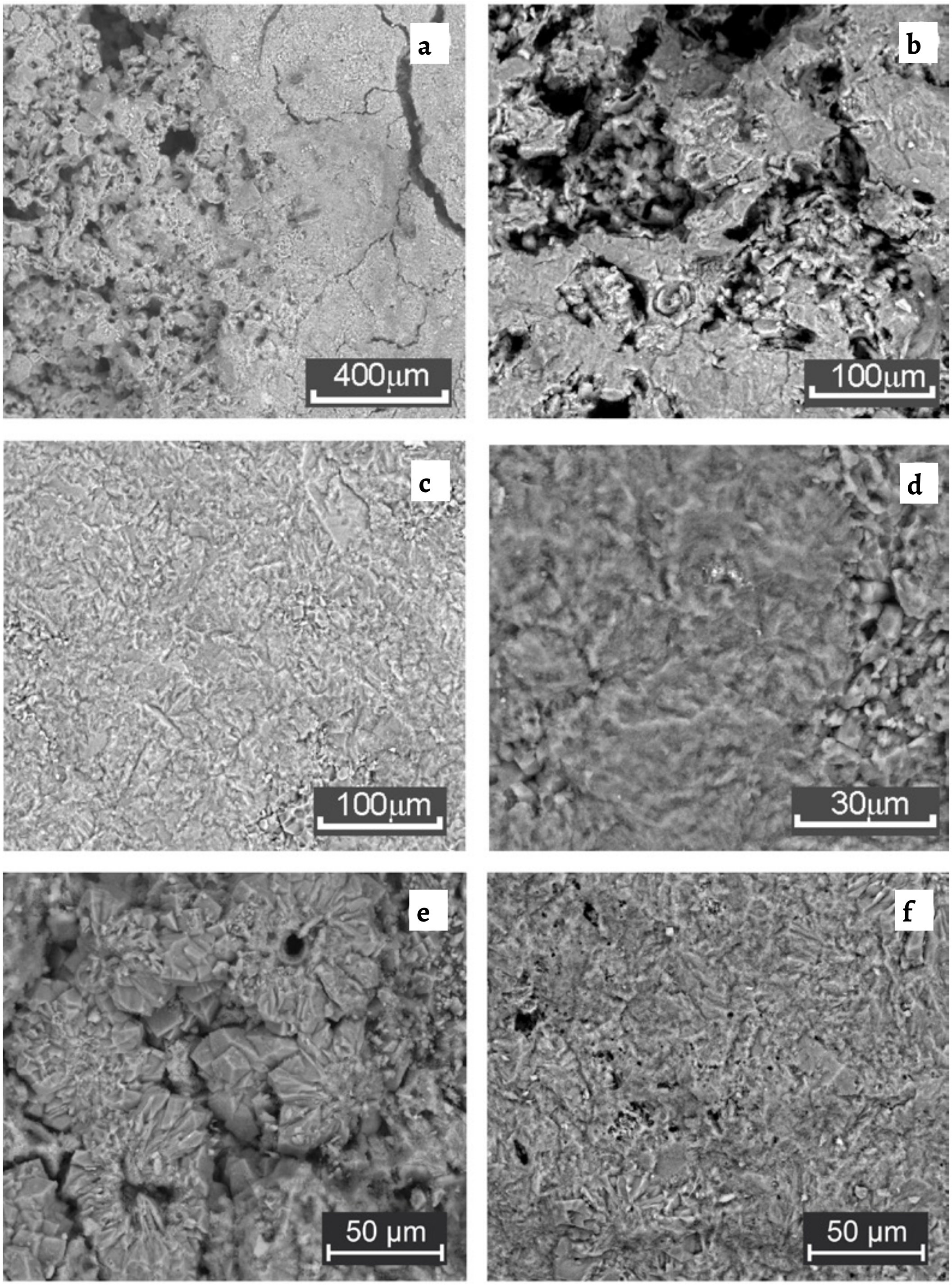


**Figure 7**. ESEM images from chert outcrop samples: *a)* external porous zone of sample SX18 with signs of dissolution processes and retraction cracks; *b)* crystalline core zone of sample SX18 weathered due to dissolution-recrystallization processes; *c)* crystalline core zone of sample SX18 with a crypto-crystalline quite fibrous texture; *d)* pores and fissures completely cemented by micro-crystalline quartz crystals in sample SX18; *e)* crystals with radial-fibrous morphologies in external zones of sample SX19; *f)* inner zone of sample SX19 with less abundant radial-fibrous crystals.

dodecahedral crystals with inter-crystalline porosity (Figure 7*e*). The inner zone of this sample displays less abundant radial-fibrous crystals. However, there are signs of corrosion pits which give rise to porosity in the crypto-crystalline quartz matrix (Figure 7*f*). These corrosion signs might be the cause of the higher roughness values obtained in the inner zone of this sample compared to the values measured on the crystalline core zone of sample SX18.

**Study of consolidation treatments**

***Environmental SEM-EDS***

Figure 8 shows some representative ESEM images of the samples before and one month after the application of the consolidating products. The surface morphology is altered in all cases due to the application of the products. In the samples treated with $SiO_2$ nanoparticles (e.g., sample SX3), the product is heterogeneously distributed (Figure 8*c-d*)

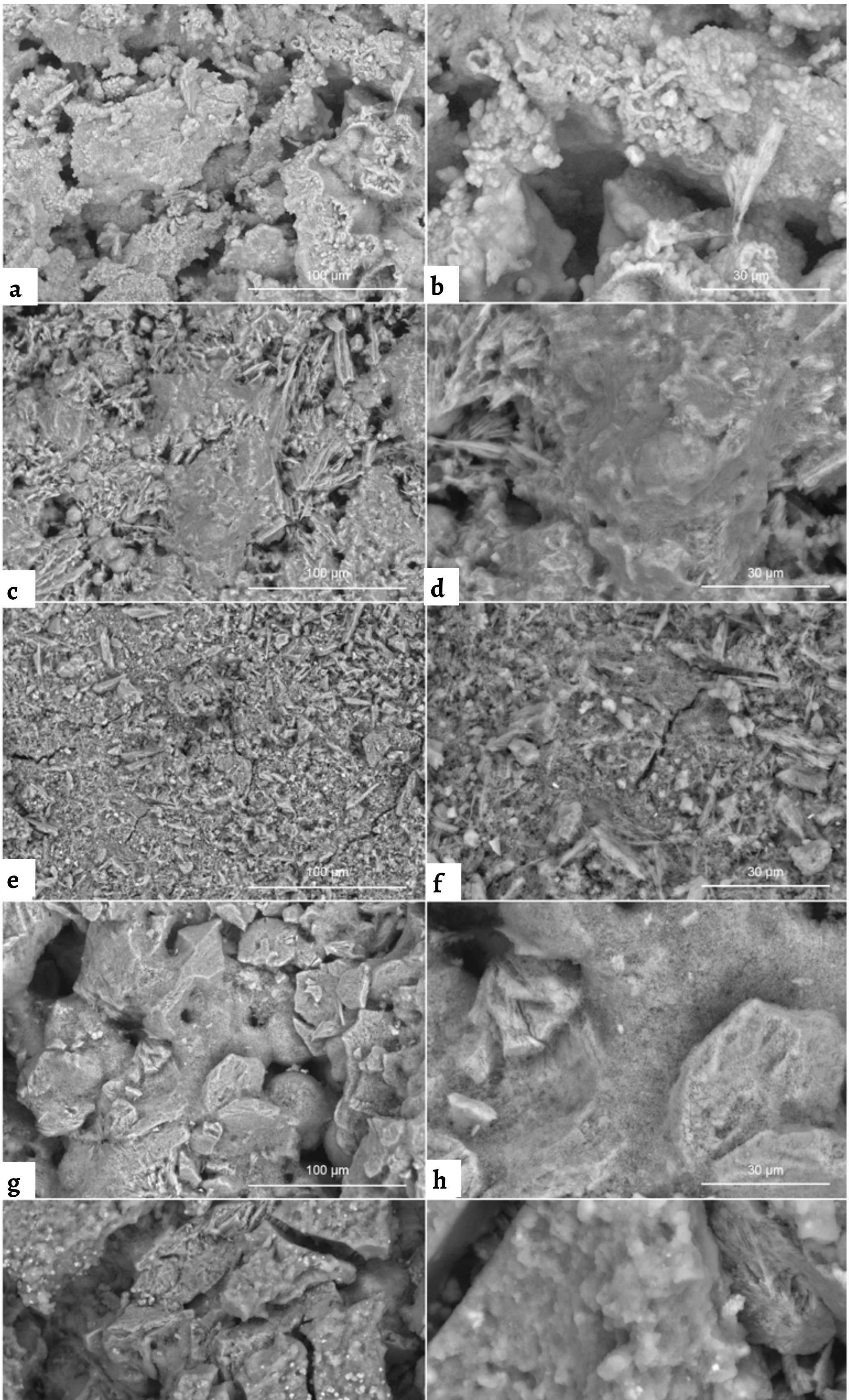


**Figure 8**. ESEM images with 800x and 3000x magnifications of control sample and the samples one month after the application of the consolidating products: *a,b)* Control sample SX3; *c,d)* Sample SX1 treated with $SiO_2$ nanoparticles; *e,f)* Sample SX6 treated with ethyl silicate; *g,h)* Sample SX9 treated with acrylic resin; *i,j)* Sample SX11 treated with the nanoparticle $SiO_2$ and $Ca(OH)_2$ mixture.

giving rise to agglomerations in the less porous and more crystalline areas of the sample. In addition, a dense gel layer with a texture apparently smooth can be observed surrounding and covering the quartz crystals. This morphology is similar to that observed in previous research works where the same product was applied to sandstone samples [23]. However, in this case, cracks are not observed in the consolidating product due to the formation of fewer surface agglomerations. In the samples consolidated with ethyl silicate (e.g., sample SX6) a fractured coating can be seen across the entire surface (Figure 8*e-f*). Despite both products produce silica gel, the morphology of this gel is very different. The samples consolidated with acrylic resin (e.g., SX9) show a surface covered by a smooth, dense coating that also covers the small pores (Figure 8*g-h*). The product is also accumulated in the inter-granular areas. By comparison of this coating with that produced by $SiO_2$ nanoparticles, in this case the outer layer is smooth and continuous whereas the nanoparticles generate micro-roughness surfaces.

Figure 8*i* and 8*j* show the surface of sample SX11 after the application of the mixture of $SiO_2$ and $Ca(OH)_2$ nanoparticles. A totally fractured, dense, thick coating has been generated on the surface. In the detailed image (Figure 8*j*) it can be seen that this dense coating is formed by $Ca(OH)_2$ nanoparticles embedded in the silica gel. The morphology of these nanoparticles is similar to those observed in previous research works [25], but in this case the agglomeration is produced inside the amorphous silica gel, giving rise to an increased roughness surface.

***Peeling test***

The results of this type of adhesion test performed one month after the application of the products are compiled in Table 5. In all the samples a reduction of released material was produced after the application of the products due to the consolidating effect that increases the surface cohesion. The greatest reduction was produced in the samples treated with ethyl silicate, where the released material was 95 % less (54 mg of released material in the control samples decreased to 3 mg in the consolidated samples). The $SiO_2$ nanoparticle product was the next most effective product, since the released material was reduced by 89 % (6 mg of material being released). The acrylic resin product and the mixture of nanoparticles resulted in a much lower reduction (54 % and 41 %, respectively). By mixing both types of nanoparticles, the consolidation effectiveness of the $SiO_2$ nanoparticles seems to be limited since alone its reduction of released material is much higher (89 %) than when it is mixed. In all cases, the material released in the tenth sequence was less than the amount released in the control samples (3.5 mg), i.e. with ethyl silicate it was 0.2 mg, and with $SiO_2$ nanoparticles it was 0.13 mg, since a greater reduction is produced by the higher surface cohesion.

**Table 5.** Average of released material (mg) obtained by peeling test on control and treated chert samples after one month of the consolidating product application and decrease of release material (%) regarding the control sample.

| | | **Released material (mg)** | | | | |
|---|---|---|---|---|---|---|
| | | Control sample | Nano $SiO_2$ | Ethyl silicate | Acrylic resin | Nano Mixture |
| Test sequence | 1 | 11.40 | 0.73 | 0.50 | 6.00 | 5.20 |
| | 2 | 9.10 | 0.70 | 0.30 | 4.13 | 4.87 |
| | 3 | 6.70 | 0.23 | 0.30 | 3.37 | 4.77 |
| | 4 | 6.15 | 1.27 | 0.40 | 2.03 | 3.13 |
| | 5 | 4.85 | 1.27 | 0.17 | 1.70 | 3.03 |
| | 6 | 4.20 | 0.27 | 0.23 | 1.80 | 2.30 |
| | 7 | 2.80 | 0.33 | 0.23 | 1.53 | 2.17 |
| | 8 | 3.60 | 0.37 | 0.07 | 1.17 | 1.63 |
| | 9 | 2.15 | 0.90 | 0.13 | 1.70 | 2.07 |
| | 10 | 3.50 | 0.13 | 0.20 | 1.43 | 2.93 |
| Released material (mg) | | 54 | 6 | 3 | 25 | 32 |
| Decrease of released material (%) | | n/a | 89 | 95 | 54 | 41 |

***Spectrophotometry***

The average values of chromatic changes on the surface of the samples one month after applying the consolidating products are compiled in Table 6. These changes can be divided into two groups: *i)* those generated by the nanoparticles, which produced similar results although there were greater variations in the case of the nanoparticle mixture, and *ii)* changes produced by the ethyl silicate and the acrylic resin (being greater in this latter product). The milky-white color of the samples made some changes easily visible to the naked eye, more than on any other color.

**Table 6.** Average variations (Δ) promoted on chromatic parameters (L*, lightness; a* position between red and green; b* position between yellow and blue; C*, Chroma; E*, total color; YI, yellow index; WI, white index and brightness) on the chert samples after one month of the consolidating products application.

| **Consolidating product** | **ΔL*** | **Δa*** | **Δb*** | **ΔC*** | **ΔE*** | **YI (E313-73)** | **WI (E313-73)** | **Brightness (ISO)** |
|---|---|---|---|---|---|---|---|---|
| Nano $SiO_2$ | -5.74±2.99 | -0.74±0.49 | -2.73±1.12 | -2.88±1.19 | 6.15±3.30 | -3.59±1.51 | -4.24±1.09 | -9.04±4.25 |
| Ethyl silicate | -6.16±2.16 | 1.15±0.76 | 3.67±2 | 3.86±1.3 | 7.43±3.73 | 2.98±0.39 | -17.30±10 | -13±11 |
| Acrylic resin | -11.60±1.5 | 2.61±0.04 | 5.95±2.99 | 6.51±2.7 | 13.75±2.9 | 11.95±4.6 | -16.1±3.45 | -17.63±1 |
| Nano Mixture | -14.22±2.1 | 0.04±0.19 | -1.21±0.77 | -1.17±0.79 | 14.28±2.16 | -1.21±0.14 | -14.02±3 | -24.20±4.1 |

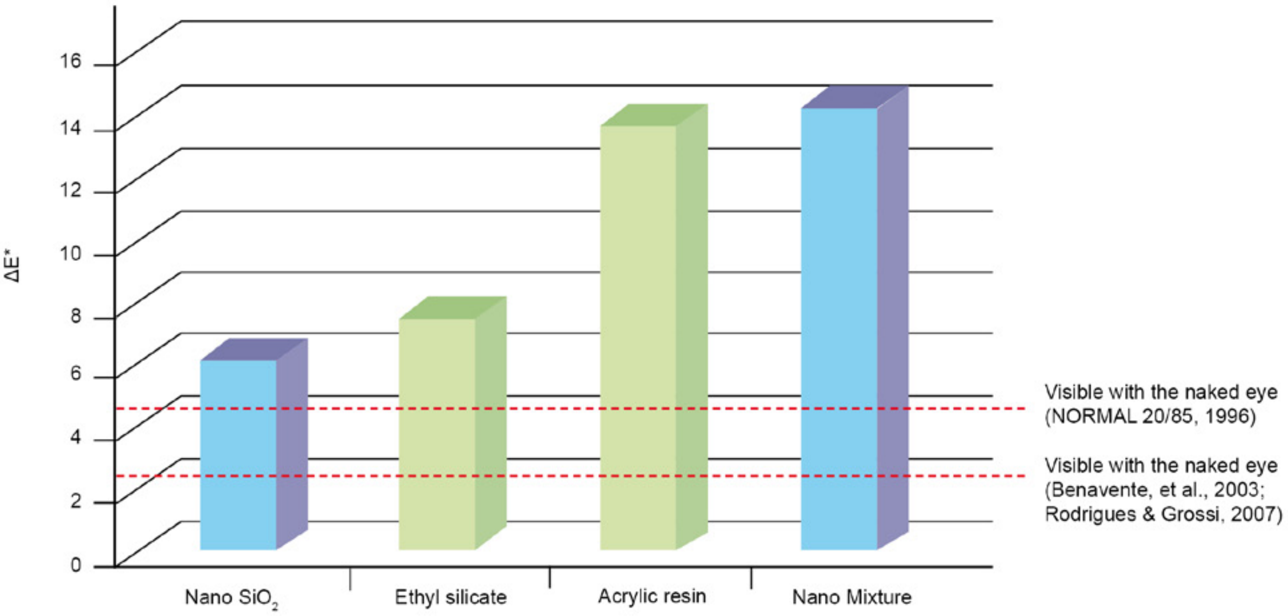


**Figure 9**. Total color difference (ΔE*) values of chert samples before and after one month of the application of consolidating products.

The product that generates the least chromatic changes is that based on $SiO_2$ nanoparticles. However, the total color difference (ΔE*) caused by this product before and after its application is very high (6.15 ± 3.30). This means that the changes produced by this product are visible with the naked eye, since ΔE* is higher than 5 [43] or above 3 according to other authors [44] (Figure 9). Changes in other chromatic parameters included a reduction in the lightness values (-5.74 ± 2.99). The b* parameter decrease (-2.73 ± 1.12) means that the sample develops a bluish tone. In previous work on $SiO_2$ characterization [23] a certain bluish coloring of the silica gel was also observed, even though this product was originally transparent. This bluish tonality is also the cause of the reduction in the Chroma parameter (C*) (-2.88 ± 1.19), making the original color of the sample (white) look less pure and more mixed, as well as the reduction in the yellow index (YI) (-3.59 ± 1.51) due to the tone change towards blue. Additionally, there is also a reduction in the white index (WI) values (-4.24 ± 1.09) losing the white tonality and decreasing the brightness value (-9.04 ± 4.25).

The nanoparticle mixture produces similar changes but becomes a little more pink. ΔE* is much higher (14.28 ± 2.16) and there is a greater decrease in the lightness and brightness parameters (-14.22 ± 2.1 and -24.20 ± 4.1, respectively). This yields the highest changes of all the products tested and makes this consolidating product inappropriate for being used (Figure 9). The changes produced by the ethyl silicate and acrylic resin are different regarding the tonality acquired by the surface of the samples after application. In both cases ΔE* is too high, this change is detectable with the naked eye (7.43 ± 3.73 for the ethyl silicate and 13.75 ± 2.9 for the acrylic resin). The lightness value also decreases to a greater extent than in the case of $SiO_2$ nanoparticles (-6.16 ± 2.16 for ethyl silicate and -11.60 ± 1.5 for acrylic resin). In both cases, and contrary to what happens with nanoparticles, the Chroma (C*) values increase due to the color change produced on the surface (3.86 ± 1.3 for ethyl silicate and 6.51 ± 2.7 for acrylic resin). The b* parameter also increases, with a surface tone change to yellow (typical of this type of consolidating product), giving rise to values of 9.13 ± 1 in the case of ethyl silicate and 5.95 ± 2.99 in the acrylic resin. Similar changes to the YI values are also seen; in this case the values increase due to the yellow coloring (3.67 ± 2 for ethyl silicate and 5.95 ± 2.99 for acrylic resin). The WI values decrease due to the loss of white tonality (the original color of the surface) to a greater extent compared to the $SiO_2$ nanoparticles (-17.30 ± 3 for ethyl silicate and -14.02 ± 3 for acrylic resin). Therefore, is important to note that although both products ($SiO_2$ nanoparticles and ethyl silicate) generate a silica gel in the treated samples, chromatically they behave very differently. The behavior of the $SiO_2$ nanoparticles is closer to that observed for the $Ca(OH)_2$ nanoparticles, whereas the result obtained with the ethyl silicate is closer to that of the acrylic resin.

## Conclusions

The state of conservation of the chert samples does not depend on the environment or burial conditions related to salt crystallization processes, since the natural decay of fresh chert samples is produced regardless of the archeological site where the chert remains were found. In the sites, the soils where the samples were buried did not contain soluble salts. Besides, similar degradation is seen in fresh chert samples from the surrounding outcrops. However, moisture and water percolation through the site where the samples were collected could have accelerated degradation processes causing further decay. The key point in chert decay seems to be moganite mineral content. Samples that contain only quartz are not significantly altered (and therefore need less preservation treatment); samples with moganite (more soluble and microporous) and quartz are more weathered and powdery (requiring consolidation treatments, particularly on their surfaces), whereas samples with quartz and calcite are the most detached and worst preserved (requiring both internal and surface consolidation treatments). The original moganite content of this latter group of samples could have been much higher, giving rise to the increased porosity and favoring the penetration of carbonate-rich water allowing calcite to precipitate within the pores. However, part of the calcite identified in the archaeological remains might come from the limestone outcrops where the chert was originally extracted.

The four consolidating products tested had positive and negative aspects that are reflected in the modifications caused in the physical (surface morphology and cohesion) and aesthetic properties of the samples. One product may be more adequate than another depending on the characteristics of the treated sample and the modifications that the product produces in the sample, including: *i)* composition of the substrate (which in this case is likely to determine conservation state); *ii)* chemical or physical compatibility between applied product and substrate; *iii)* superficial or internal damage, which determines conservation needs; *iv)* environmental conditions; *v)* need for later treatments, especially water-based; *vi)* future of the treated object (exhibition, storage, conservation on site) among others.

The mixture of $SiO_2$ and $Ca(OH)_2$ nanoparticles shows positive results with regard to surface cohesion, thicker morphology and resulting in a denser final product. However, the significant chromatic changes and shrinkage of the generated outer layer on drying make it unsuitable for being use as a consolidating product for archaeological samples. However, it could be a promising product for the volumetric reintegration of lost areas or for filling cracks and fissures in siliceous and calcareous substrates.

Acrylic resin Paraloid B72 (one of the most frequently-used consolidating products applied in the field of archaeological conservation) has a very low consolidating effect and very significant chromatic changes compared to the other products. This resin is not water soluble and when it is mixed with common solvents such as acetone a white thin film is developed on the surface. For this reason, even though it is the fastest-working product it is not suitable to be used under moisture conditions. The consolidation speed is a very important issue to consider as the manipulation of the samples (extraction, storage…) accelerate the deterioration process. The application of these treatments demands space and time that is not usually available. In addition, when such a treatment is applied, it is because the object is in very bad conditions. Thus, it is necessary to apply subsequent treatments that also require time.

The ethyl silicate product Tegovakon V100 shows a very effective consolidating action. However, it produces significant chromatic changes and develops a superficial film, occluding porosity and remaining temporally hydrophobic. Hence, this product will influence the performance of subsequent water-based treatments. Furthermore, the coating generated on the surface displays cracks and fractures partially due to the high humid consolidation environment that can commonly occur in archaeological sites.

Finally, the $SiO_2$ nanoparticle product shows an effective short-term consolidating action, with a gel generation of 3-4 days, being produced faster than in the case of ethyl silicate. The chromatic changes (although visually perceptible) are less significant. It could be applied to substrates containing water, allowing the subsequent application of water-based treatments including cleaning and volumetric reintegration. However, durability tests carried out on these materials using these products shows the longer-term effects and the importance of performing accelerating ageing tests before applying consolidating treatments to archaeological artifacts [17].

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# Digital three-dimensional architectural survey of traditional Bulgarian houses – architectural BIM from point cloud survey data

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# Levantamento arquitectónico digital tridimensional de casas tradicionais búlgaras – BIM arquitectónico a partir de dados de levantamentos em nuvem de pontos

**Abstract**

Nowadays the technology is often ahead of its implementation in the practice. Two novel technologies have affected the field of conservation and documentation of cultural and historic heritage and await their proper mutual integration. They are the 3D photogrammetric surveying and the Building Information Modelling (BIM). This research proposes a methodology for producing a complete and precise 3D Building Information Model from a point cloud, obtained via a 3D photogrammetric survey. An existing traditional house in Bulgaria is used as a case study. The aims were to optimise the process and to minimise the large number of software, used in the conventional workflow. They were achieved using only one application – ArchiCAD version 22. The complete BIM was later used for producing 3D artistic visualisations and for an interactive 3D web presentation. This paper describes the methodology and the software needed, discussing the techniques and the results.

**KEYWORDS**
BIM
ArchiCAD
Cultural Heritage
Traditional Houses
Reconstruction
Virtual Presentation

**Resumo**

Actualmente, a tecnologia está frequentemente à frente da sua implementação prática. Duas novas tecnologias afectaram o campo da conservação e documentação do património cultural e histórico e aguardam a sua adequada integração mútua: o levantamento fotogramétrico em 3D e a modelação da informação na construção (BIM). Esta pesquisa propõe uma metodologia para a produção de um Modelo de Informação de Construção 3D completo e preciso a partir de uma nuvem de pontos, obtida por meio de um levantamento fotogramétrico em 3D. Uma casa tradicional existente na Bulgária é usada como estudo de caso. Os objectivos eram optimizar o processo e minimizar o grande número de *softwares* utilizados no fluxo de trabalho convencional. Eles foram alcançados usando apenas um aplicativo – ArchiCAD versão 22. O BIM completo foi posteriormente utilizado para produzir visualizações artísticas em 3D e para uma apresentação 3D interactiva na *web*. Este artigo descreve a metodologia e o *software* necessários, discutindo as técnicas e os resultados.

**PALAVRAS-CHAVE**
BIM
ArchiCAD
Património Cultural
Casas tradicionais
Reconstrução
Apresentação virtual

## Introduction

In recent years, Building Information Modelling (BIM) has been the indisputable leader among the platforms for integrated architectural design. It has established as an invaluable tool in the field of documentation and preservation of cultural heritage too [1]. Moreover, a concept to integrate the model with survey data and extra information about the lifecycle of the building has been proposed and put into practice as "Historical BIM (HBIM)" [2].

Many historically valuable traditional houses in Bulgaria are in poor condition and there is a pending "real danger that many of these monuments will be destroyed irretrievably and lost for the future generations" [3]. A major step in preserving this national treasure is to make a thorough survey of as many as possible of these buildings before their actual destruction or loss and create a comprehensive digital archive. It will provide a basis for restoration and adaptation of these buildings to the modern conditions in the future.

Nowadays there are tools and capabilities to obtain various forms of data about a historical building and store massive amounts of it. This is gaining importance with the invention of the 3D laser scanning and photogrammetric survey technologies. This data is valuable for documentation and preservation purposes. But, when it comes to the actual implementation of it in architectural design for restoration, reconstruction, and adaptation of the historic buildings, the architects are baffled with the problem how to access and use it in practice. In reality there is "a total lack of accessibility to the entire corpus of information that should be shared by the specialists" and it is broken into "discontinuous isolated parts" [4]. The problem is that this data comes in the form of "unstructured datasets [...] that need to be converted to structured 3D models for useful further applications" [5]. The fluent transformation of the survey data into a building information model, suitable for architectural design, is still a process that creates serious obstacles and is in need of improvement.

Contemporary 3D modelling and Computer Aided Architectural Design (CAAD) software is able to open and use as a reference extra-large point clouds, generated from 3D survey data. The point cloud data can be generated from laser scanning or photogrammetric survey. But opening of large triangulated surface meshes in 3D CAAD applications is still impossible [6].

The aim of this research is to propose a practical and tested workflow for producing a precise and usable BIM from 3D point cloud survey data. The BIM is intended to facilitate both architectural design and cultural heritage restoration and reconstruction. For the purpose of this article, it may be called "Architectural BIM" in order to differentiate it from the BIM in general. The goal is to produce a refined working building information model within the shortest possible time frame and with the use of minimal number of software applications.

The proposed workflow benefits from the author's almost twenty-year experience as a practising architect and a university lecturer in computer-aided architectural design and 3D modelling.

### The house

A prominent historic house in the city of Shumen in Bulgaria had been chosen for the case study (Figure 1). It is known as the Srebrov House (in Bulgarian: *Среброва къща*) and is a designated *cultural property*, part of the *national cultural heritage*. It is an example of traditional Bulgarian architecture from the end of the nineteenth century.

**Figure 1.** Srebrov House, photo with the main entrance, Georgi Georgiev.

The house has been selected because of its geometry, which is characteristic of many traditional houses. It consists of simple volumes and elements plus several complex forms. The simple ones are: planes for the walls, boxes and cylinders for the stairs and others, various intersected pyramidal forms for the roofs, extruded complex shapes for the cornices, windows and doors, and railings. The complex ones are: the cantilevered part on the second storey, formed by two intersecting space shapes, and the complex profile of the cornice, following a space curve.

In its capacity as a cultural property, the house had been a subject of previous surveys via traditional methods. Detailed architectural drawings of it had been published in the seminal book on the architecture of the city *Shumen Revival Houses* (translation by the author, in Bulgarian: *Шуменски възрожденски къщи*) by Rashel Angelova [7]. A more recent 2D digital architectural survey, based on geodetic data, was also obtained, with the cooperation of the local municipality. These surveys provide valuable extra information for comparison with the photogrammetric survey and the BIM model.

The team of surveyors supplied a point cloud, obtained via a 3D photogrammetric survey, which was used as a basis for the BIM.

**The point cloud**

The photogrammetric survey consists of two separate stages – a photographic survey and a geodesy survey. The photographic survey is made with a digital single-lens reflex camera (DSLR) in three sessions – from the ground, mounted on a drone for aerial photos, and mounted on a drone for photos parallel to the elevation planes. The camera is Canon EOS 77D. The drones are DJI Mavic Pro and DJI Phantom 4 Pro. The data is verified with a geodesy survey, made with a Global Navigation Satellite System (GNSS) Leica ATX 1200 and a Leica TCRA1100+ total station. Three point-clouds are generated from the sessions and are merged into a single one, geodetically linked to a coordinate system [8]. An orthophoto and a triangulated 3D Digital Surface Model (DSM) have also been generated, but the later was not used because of its extremely large polycount [6].

**The software**

The selected BIM software is Graphisoft ArchiCAD, developed by the Nemetschek group. The latest available version is used with an educational licence – 22 EDU. The reason for its choice is that an intuitive and reliable application, which could secure a stable workflow, was needed. ArchiCAD complies with these requirements. It is one of the first real BIM applications [9]. The concept of HBIM also relies on ArchiCAD with the development of specialized libraries [5]. An elaborate comparison between "the two leading parametric modelling software", ArchiCAD and Autodesk Revit, had been carried out for "producing a detailed BIM of built heritage with complex shapes" [10] and ArchiCAD outmatched its competition by several criteria.

## Modelling

**Trimming the point cloud in ArchiCAD**

The point cloud can be opened in ArchiCAD as a *Library Part*, kept in an external library folder. In this way, it does not increase the file size and makes working with the file easier – "The fact that the point cloud was not kept inside the .pln file allowed for a very fast and trouble-free work within the application" [6]. The point cloud, obtained from the 3D photogrammetric survey, covers the area of the house with the courtyard, the street, and the nearby trees (Figure 2*a*). A large part of this information is not needed for the modelling of the house and is better to be removed for easier handling of the point cloud. This poses a problem because most CAAD and 3D modelling applications cannot manipulate point clouds and thus an additional application is required. An important advantage of ArchiCAD is its ability to trim the point cloud without the need of third-party software. This is done with the *3D Cutaway* function using custom *3D Cutting Planes* (Figure 2*b*). The trimmed parts are not deleted but are excluded from the 3D calculation and visualisation. They can always be brought back with a single shortcut.

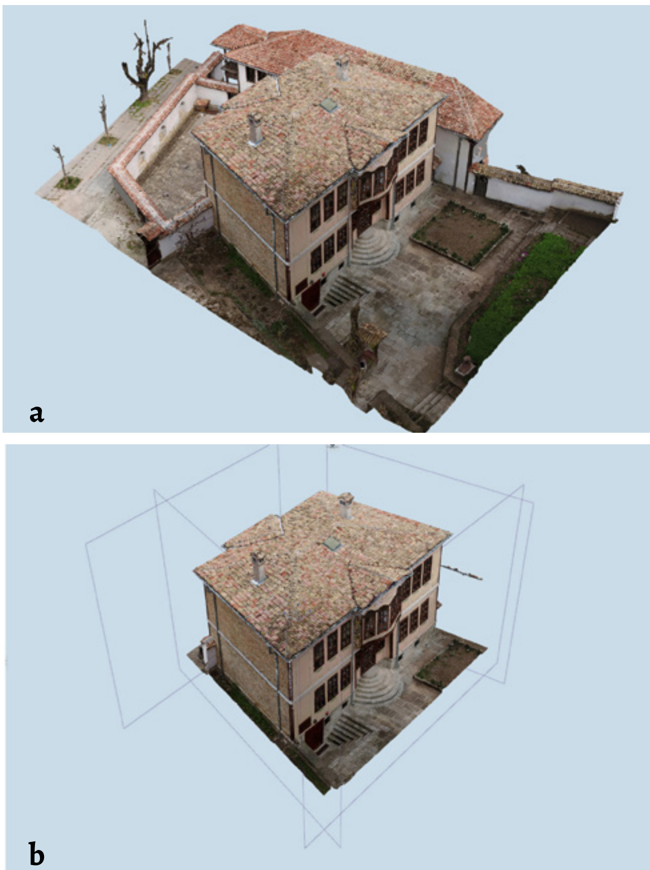


**Figure 2.** The point cloud in ArchiCAD: *a)* in full; *b)* trimmed.

**Modelling of the main volumes – Section generation modelling method**

The popular method for modelling from 3D laser scanned or photogrammetric data is by extracting contours via horizontal and vertical sections from a triangulated mesh. For this purpose the initial point cloud has to be triangulated beforehand, to produce a surface that could be cut. Usually, cutting is done in third-party 3D modelling software like Rhino or 3dsMax. In the past (2009), the resulting rough contour had to be brought to a CAAD application for cleaning and redrawing, and only after that used for modelling in the 3D application [11]. Nowadays the contour cleaning and the modelling can be done in the BIM application itself [10, 12-13].

ArchiCAD provides the opportunity to cut the point cloud directly and obtain a traceable contour. The contour can be redrawn (as a group of lines and curves, a polyline, or a fill) and used for modelling of the BIM. All of these operations can be done in ArchiCAD without the need of additional software. The horizontal sections are made with the *Storeys* function directly in the floor plan (Figure 3*a*). The vertical position of the sections is controlled by adjusting the *Floor Plan Cut Plane* and each position can be saved separately. The vertical sections are made with the *Section Tool*, characteristic for the application since its creation. By adjusting the *Horizontal Range* of the section, a very thin contour can be obtained (Figure 3*b*).

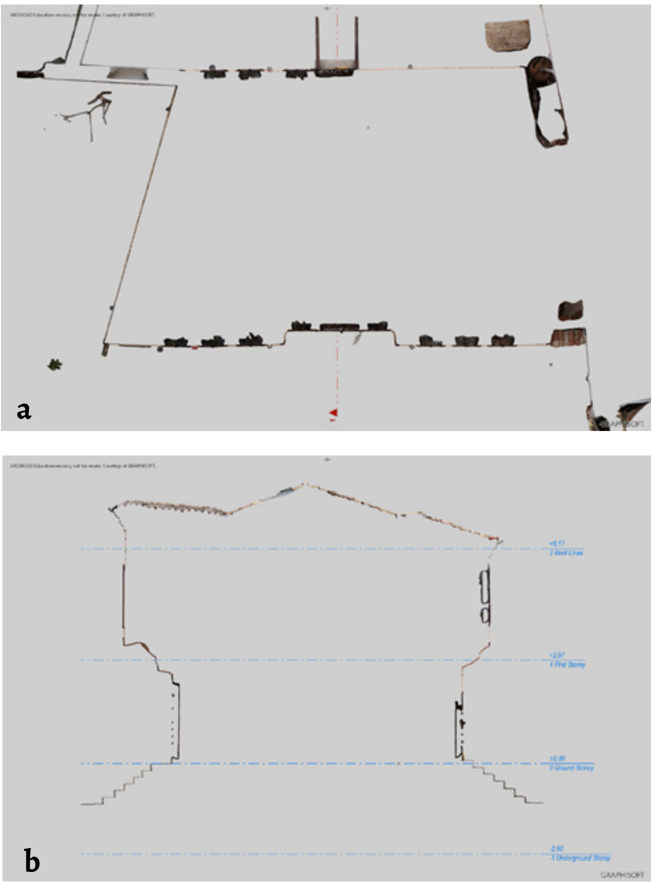

**Figure 3.** Sections through the point cloud in ArchiCAD: *a)* horizontal at height 1,20 m; *b)* vertical 1-1, depth 10 cm.

**Modelling of the main volumes – 3D volumes modelling method**

In this case study, a different method for 3D modelling is implemented, thanks to the enhanced capabilities of ArchiCAD. It can be called the "3D volumes modelling method". The volumes are modelled directly with three-dimensional elements that are superimposed over the point cloud. The process is carried out simultaneously in the *Floor Plan*, the *Sections* and the *3D* windows, depending on which view is more convent (Figure 4*a*). The modelling is done with native ArchiCAD 3D elements, both for planar and curved surfaces. These elements are called *Tools* and they include *Walls, Columns, Slabs, Roofs, Shells, Morphs* and *Meshes*. They are manipulated until the best overlapping with the point cloud is achieved by moving, rotating, tilting, stretching, pushing, etc. Painting the new elements with a contrasting colour enhances the visibility and hence the control over the process. In cases when the use of *Objects* (*GDL Library Parts*) is required, still native library parts from the standard library are preferred, instead of creating scripted or modelled customised ones (Figure 4*b*). The native elements in ArchiCAD have built-in *Classification and Properties* options – *Elements IDs, IFC IDs, Layers*, etc. They allow a very high level of identification and documentation to be achieved.

**Figure 4.** 3D volumes superimposed over the point cloud: *a)* white colour; *b)* contrasting solid colour.

A similar approach was chosen by other researchers, who used 3D elements that "were positioned so that the deviation standard between x, y, z coordinates of the point cloud and the surface of the elements was minimum" [14], but they overlapped the point cloud with *Library Objects* instead of the native 3D elements. This approach is based on the earlier Historic BIM (HBIM) concept, which relies on the development of customised parametric libraries with ArchiCAD's native scripting language *GDL (Geometric Description Language)* [2, 5].

The 3D volumes modelling method increases the accuracy of the new geometry and greatly reduces the time needed for creating the model. It proves to be more precise than the previous one. It does not rely only on "the number of section planes" [13] to define the form, but superimposes the form upon the point cloud. Thus, the interaction between the point cloud and the 3D volume is directly visualized. The method also avoids the need for scripting, which is time-consuming and can be done only by highly skilled professionals. Besides, the architects are more natural in modelling than coding. It is also significantly more fluent as the conversions and transfers between several separate applications are avoided.

**Modelling of specific elements**

Linear elements consist of a profile, extruded along a path. They include cornices, mouldings, pilasters, railings, etc. The contour of the profile is obtained via a partial section through the point cloud and is redrawn (Figure 5*a*). With the *Custom Profile* function, it is extruded along a path (straight or curved) using the *Wall*, *Beam* or *Column Tools*, generating a native ArchiCAD 3D element. In this case, the *Beam Tool* is preferred because it can automatically interact with the *Wall* element and subtract its volume from it. The new volume is superimposed upon the point cloud and its form can be checked against the existing geometry. The function is fully parametric and, when the initial contour is changed, the transformations are immediately reflected in the 3D geometry (Figure 5*b*).

Curved surfaces are modelled via a combination of techniques. The cantilevered volume above the main entrance follows a triple-arc curve, characteristic for the traditional Bulgarian architecture, called *kobillitza* (in Bulgarian: *кобилица*). It is modelled with a *Wall*, following the curve in plan, and is cut by an extruded surface, following a similar curve in elevation. As a result, a *space curve* is extracted and is used as a path for extrusion of the profile of the cornice on top (Figure 6*a*).

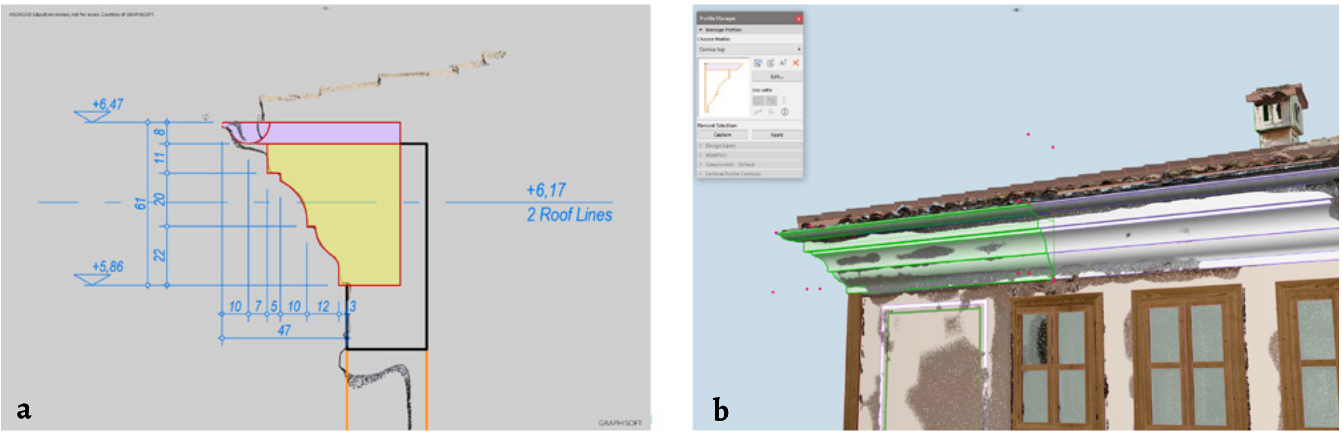


**Figure 5.** Section through the roof cornice with the redrawn contour *(a)*. 3D view of the Custom Profile *(b)*.

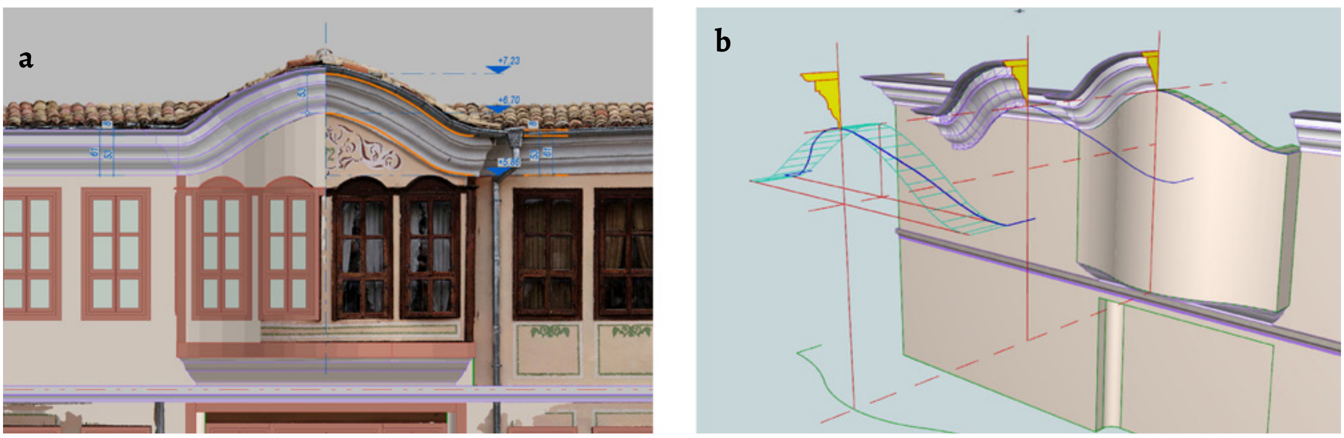


**Figure 6.** The triple-arc curve in elevation view, traced with a spline *(a)*. Modelling the cornice, based on a space curve *(b)*.

The restriction of the above mentioned *Custom Profile* function is that the path has to lie in a single plane, i.e., it has to be a *flat curve*. The extrusion along the space curve is done manually, using the *Morph Tool*. It results in a complex segmented form that is not fully parametric. Selective smoothing of the segments is needed to keep the vertical edges sharp and the horizontal ones smooth. This operation has to be done manually too (Figure 6*b*). The windows and doors of the house are historic building elements that are very different from today's ones. They are modelled entirely with the native ArchiCAD *Window Tool* and *Doors Tool* and are fully parametric. These tools offer an extensive set of parameters for modelling even the most demanding custom elements (Figure 7*a*).

All the painted decoration is three-dimensionally modelled. It is modelled with surfaces, parallel to the main volumes, intersected with *Custom Profiles*, which define the pattern. In this way, the patterns can be considered as parametric, because once put in place, they all can be changed by changing the contour of the *Custom Profile*. If needed, the geometry can be further refined or complicated (Figure 7*b*). Usually, such decoration is applied as bitmaps during the rendering stage. Modelling it provides more control over the geometry of the pattern and keeps the consistency of the BIM.

**Visualisation**

The visualisations are made using the original model from ArchiCAD without any further modifications (Figure 8*a* and Figure 8*b*). The platform is Autodesk 3dsMax. New materials from the modelling application are applied. The rendering is done with Chaos Group V-Ray Edu 3.60.04 engine (Figure 9*a* and Figure 10). Post-production and photomontages are done in Adobe Photoshop CS6.

An interactive 3D model is produced and published online (Figure 9*b*). It provides an avant-garde way of showcasing and accessibility. It can be viewed, zoomed and rotated directly in the web browsers without the need for other specialized software. The interactive 3D model is generated with the Sketchfab 3dsMax Exporter plug-in. It is published on the web site of the New Bulgarian University.

## Discussion

**Obstacle**

The major obstacle in the modelling was that the decimated mesh could not be imported into the CAAD applications because of its size of more than 1 million polygons. As it has been shown in the author's previous research, meshes with extra-large polycount still cannot be opened and processed

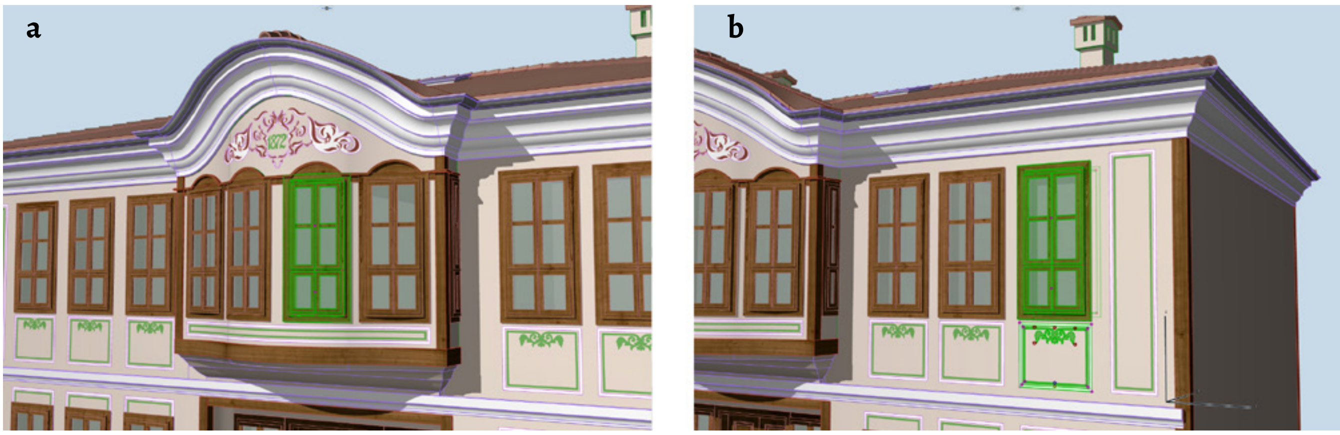


**Figure 7.** Windows detail *(a)*. Decoration pattern detail and decoration only in 3D *(b)*.

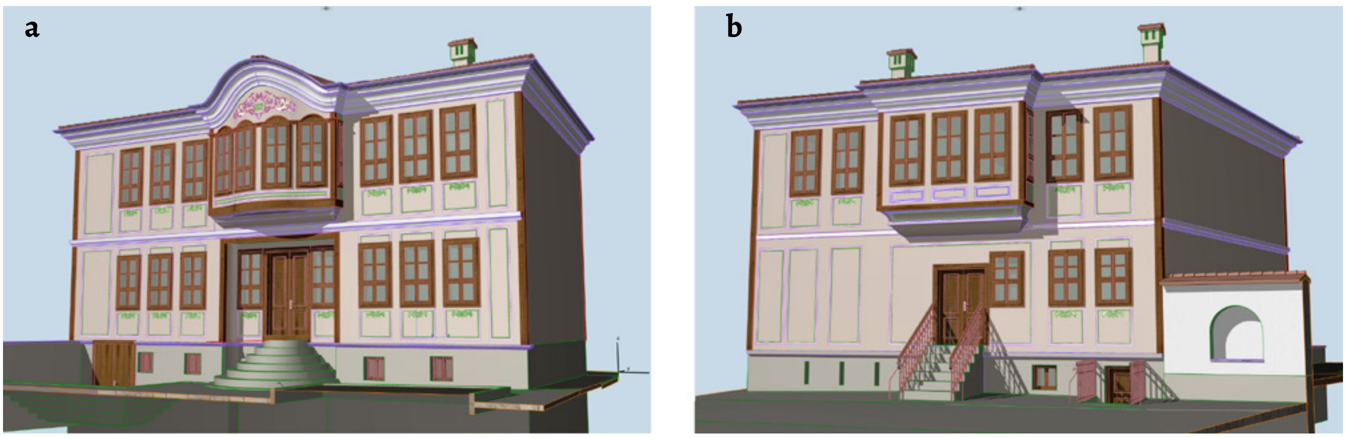


**Figure 8.** The finished Architectural BIM in ArchiCAD: *a)* front; *b)* back.

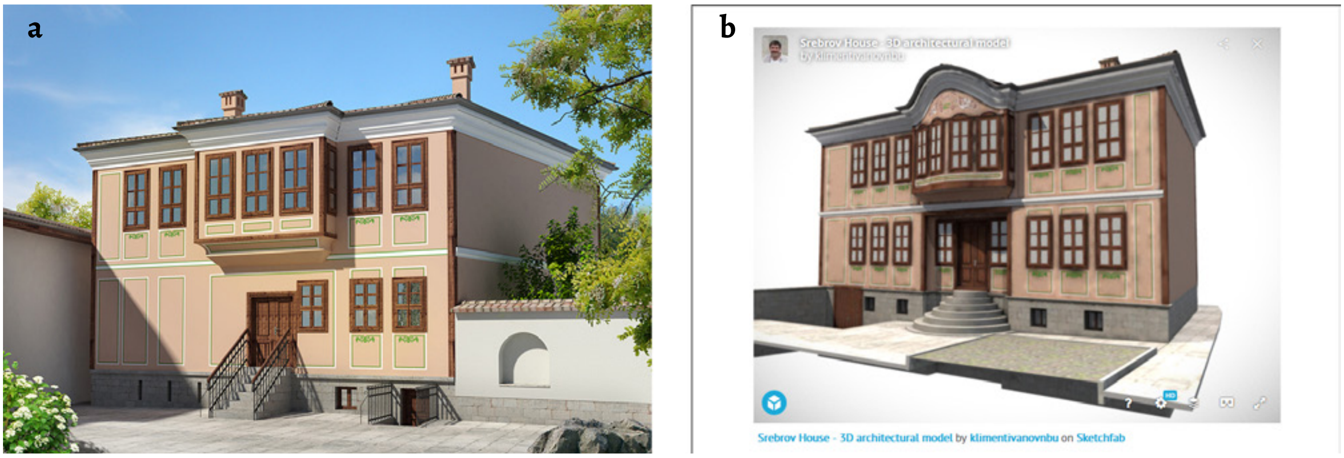


**Figure 9.** Architectural visualisation (V-Ray) – view to the back *(a)*. Interactive 3D model (Sketchfab) on the NBU website *(b)*.

**Figure 10.** Architectural visualisation (V-Ray) with photomontage – view to the front.

by 3D CAAD applications [6]. So the triangulated surface mesh, also supplied by the surveyors, was abandoned. Using another 3D modelling application was not a feasible option, because it would complicate the workflow and thus make it slower and more expensive. This is the reason the point cloud was chosen as the most suitable option. The problem with the point cloud is that when zoomed in too close, it falls apart and the geometry cannot be read precisely. But the precision is enough for the level of detail needed for the project, which is to model a whole house, not just a small decorative element.

**Comparison**

The finished BIM, and also the point cloud, are compared with the published drawings in the book *Shumen Revival Houses* [7] and with the architectural 2D survey from the municipality (Figure 11*b*). Two major inconsistencies between the drawings in the book and the BIM can be found. The first is that in the published floor plans in the book, the interior walls are parallel to each other, while in the 2D survey and in the BIM they are not, and some of the angles of the exterior walls are not correct (Figure 11*a*). The second is that in the elevation drawings in the book, the

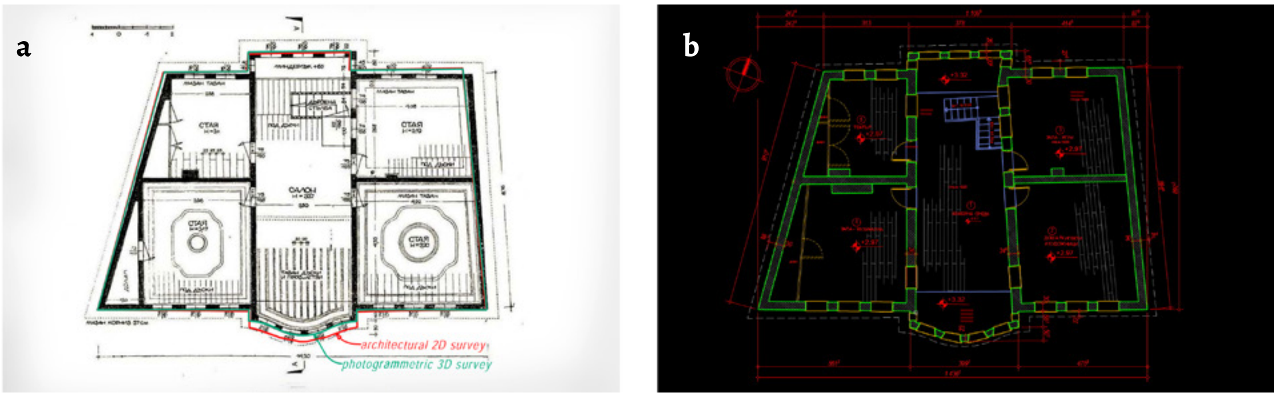


**Figure 11.** Second storey floor plan drawings: *a)* handmade drawing from the book Shumen Revival Houses with overlaid contours from the other surveys for comparison: red – architectural 2D survey, green – photogrammetric 3D survey; *b)* 2D CAD drawing from the architectural 2D survey in AutoCAD.

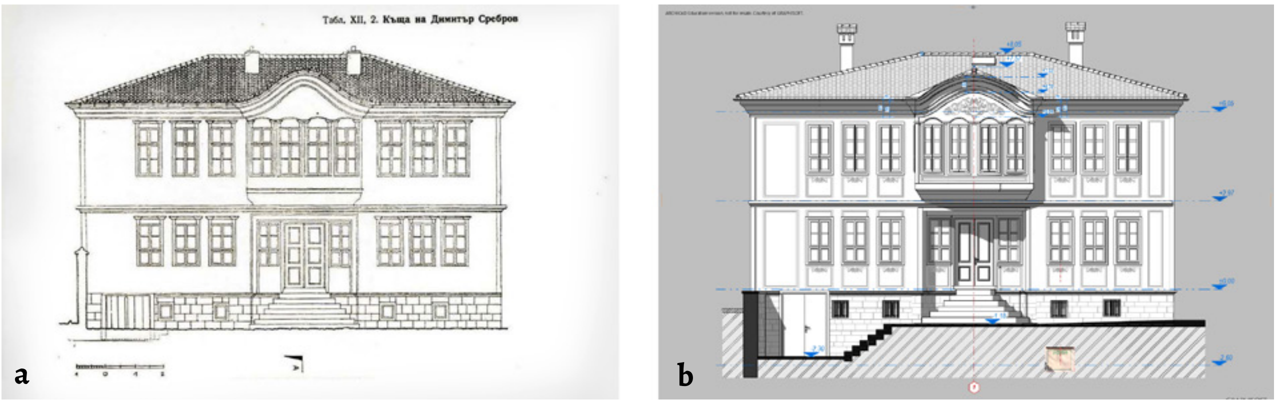


**Figure 12.** Front elevation drawings: *a)* handmade drawing from the book Shumen Revival Houses; *b)* generated drawing form the Architectural BIM in ArchiCAD.

decoration above the windows is completely different from the original and is probably copied mechanically among all the elevations (Figure 12).

The deviations between the 2D survey and the BIM vary for the planar forms and for the curved ones (Figure 13*b*). For the planar forms they are very small and completely within the acceptable limits. The reason for this is that in the 2D survey, both architectural hand measurements and measurements with geodetic tools have been used, which contributed to the accuracy improvement. These deviations are mostly due to the natural changes in the form of the building with time. For the curved forms, the deviations are significant, even worse than the ones from the published floor plans in the book. These are due to the extremely difficult task of taking measurements by hand from a curved volume, situated high above the ground and difficult to reach.

**Level of detail**

The architectural design relies on approximation for proper representation of the architectural idea via architectural

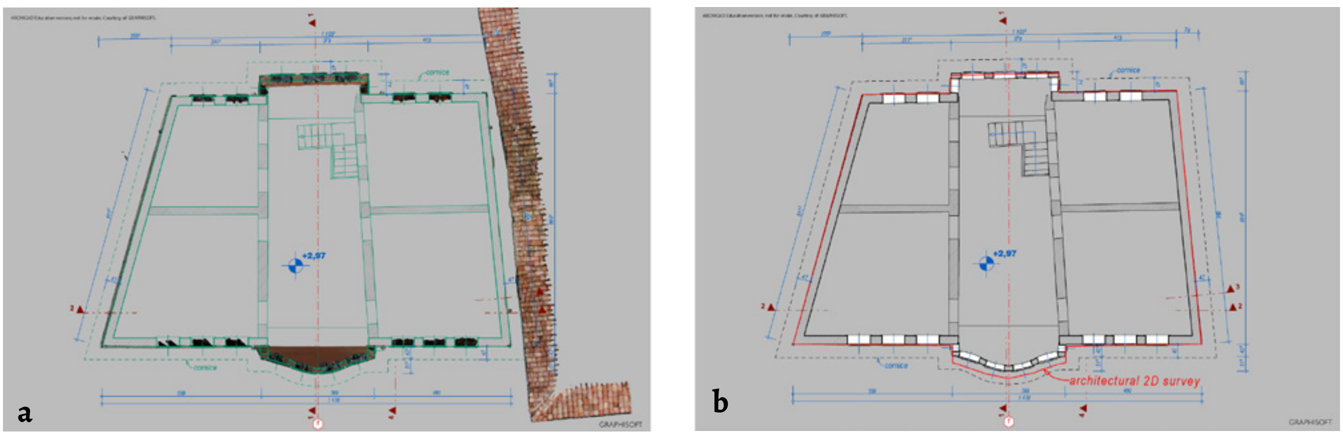


**Figure 13.** Second storey floor plan drawings – generated from the 3D Architectural BIM in ArchiCAD: *a)* with deliberately coloured contours, superimposed over the cut point cloud from the photogrammetric 3D survey; *b)* standard workflow view with an overlaid contour of the architectural 2D survey.

drawings or models. The level of detail is defined by the scale, in which the drawings are presented. For example, the main construction drawings are made in scale 1:100 or 1:50, while the detailed drawings are in larger scale like 1:20, 1:10, or even 1:1, and the stucco and rendering are not shown in scale up to 1:50. The stucco can reach a thickness of up to 6 cm, which affects the accuracy of the drawings and, respectively, the model.

Historic buildings pose a different problem – surveying works with the gross dimensions of the walls, respectively the building, which include the combined thicknesses of the wall structure, the stucco, and the cladding. All these components can vary significantly due to the construction techniques of the epoch and the skill of the execution. Besides that, the passing of time affects the building and causes deformation in its form and size. This addresses the issue of the precision of the survey and the accuracy of the model. Paul Richens also raises the question: "when should slight deviations from planarity or symmetry, or irregular spacing [...] be regularised?" [11].

The level of detail of the BIM has to be in conformity with the scale in which the architectural design will be presented, in order to ensure its best apprehension and readability. It doesn't mean that the model is imprecise, but that it has enough detail for execution. The architect defines the necessary level of detail through his knowledge and experience. The "reconstruction inevitably involves choices between different detailed interpretive possibilities, some quite difficult to call" [11]. Printing of the drawings on paper and making physical models is recommended in order to get a proper estimation of the necessary level of detail of the virtual model.

## Conclusions

The traditional method for architectural survey requires the architect to perform interpretations and approximations during the process of making the drawings. The resulting drawings reflect his skills and expertise. Hence, they can be considered as relatively inaccurate. On the other hand, the point clouds, both from photogrammetry or laser scans, are an accurate and objective record of the building "as is". Thus, the point clouds provide a permanent and reliable datum for reference.

The BIM can be regarded as a container of information that represents the process of documentation at a particular moment in time. But it can be complemented and expanded with new data whenever it is required in the future. The availability of the point cloud inside it serves as a permanent reference for additional modelling and design of particular elements. The new data can be about a different level of detail (small-scale decorative elements), new findings (historical layers), or future transformations (reinforcement, adaptive reuse). The BIM, in combination with the photogrammetric point cloud, provides the professionals with an accurate, reliable, and cheap platform for storing and updating the documentation about the cultural heritage (Figure 13*a*).

The methods for computer-aided design for documentation and preservation of cultural heritage need to be continuously updated. Many of the techniques, published as cutting-edge five or ten years ago, are outdated nowadays [15]. Likewise, many of the tools we used to dream of then have become mainstream practices today. In these terms, this work is providing both the researchers and practitioners with a reliable and proven workflow for 3D modelling, which will enable them to share the cutting-edge development in the field of architectural design and cultural heritage conservation.

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# Portuguese archives and libraries: a century of preservation and conservation practices for the control of biodeterioration

# Arquivos e bibliotecas em Portugal: práticas de conservação e preservação para o controlo da biodeterioração ao longo de um século

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**Abstract**

Biodeterioration has been a central subject for libraries and archives. Throughout the ages, different preventive and curative conservation measures were adopted to manage biodeterioration in Portuguese institutions, but the problem persists. A historic review of different methodologies used to prevent biodeterioration in the Portuguese context is presented and compared to international trends. It focuses on theories and practices of paper conservation on par with their evolution and a comparison between the art collectors' world and libraries and archives is also made. Biodeterioration management has always been a major concern, namely amid librarians and archivists, among the first ones to endorse the implementation of preservation policies. Although preservation awareness has a relatively long history, it is vital to encourage a better understanding of it at the decision-making level. In fact, the implementation of preventive conservation strategies continues to be unsatisfactory, despite the current sustainability issues and the dangers of handling contaminated documentation.

**KEYWORDS**
Biodeterioration
Preventive conservation
Archives
Libraries
Contamination
Sustainability

**Resumo**

A biodeterioração tem sido um assunto central para Bibliotecas e Arquivos. Ao longo do tempo, diferentes medidas de conservação preventiva e curativa foram adotadas para combater a biodeterioração nas instituições Portuguesas, mas o problema persiste. São revistas as diferentes metodologias usadas para prevenir a biodeterioração no cenário português e comparadas com as tendências internacionais. Focam-se as teorias e práticas da conservação de documentos gráficos, tendo em conta a sua evolução e é, ainda, estabelecido um paralelismo entre o mundo dos coleccionadores e a esfera dos arquivos ou bibliotecas. A gestão da biodeterioração tem-se mantido como preocupação central, nomeadamente entre bibliotecários e arquivistas, dos primeiros a implementar políticas de preservação. Apesar da reconhecida importância da preservação, é vital fomentar a sua compreensão ao nível da tomada de decisão. A implementação de estratégias de conservação preventiva continua a ser insatisfatória apesar dos actuais problemas de sustentabilidade e dos perigos no manuseamento de documentação contaminada.

**PALAVRAS-CHAVE**
Biodeterioração
Conservação preventiva
Arquivos
Bibliotecas
Contaminação
Sustentabilidade

## Introduction

Biodeterioration, and measures to halt it, have been central issues for libraries and archives for a long time. These settings comprise mostly paper-based objects exposed to a wide range of biological agents. The main components of paper are organic materials, such as cellulose fibres and sizing materials. Other frequent materials in libraries and archives are skin-based substances (i.e. parchment and leather), natural textile fibres (i.e. linen and cotton), and natural adhesives (i.e. animal glues, vegetable gums and starch), mainly found in bookbindings but also on paper sheets. All these materials are a basic source of nutrition for living organisms such as insects and micro-organisms [1]. These materials are biodegradable, that is, they degrade as a result of the action of micro-organisms or enzymes [2] and they are bioreceptive, being easily colonized by biodeteriogens [3]. Therefore, they are susceptible to biodeterioration, which is defined as the alteration in a material caused by the vital activity of biodeteriogens [4]. The intensity of deterioration depends mainly on the material composition of the object, environment conditions and the organisms' behaviour. Their action can affect not only the aesthetic appearance of objects, but also their chemical composition and physical and mechanical properties, resulting in inestimable material loss [6]. Insects can despoil, damage and even destroy objects, leaving detritus and dirt, and causing missing areas and loss of information. According to some authors, insects are the most numerous, resilient and persistent of all the agents of deterioration [7]. They have been recognised as one of the chief causes of deterioration in objects, libraries and archive structures and the damage they induce can often be found in entire collections or buildings [1]. Furthermore, the presence of micro-organisms and insects can result in debris and food for other highly destructive pests, such as rodents.

Micro-organisms, namely fungus, easily affect paper due to its hygroscopic capacity and composition [4]. Fungi grow easily when temperature and water availability is high (around 25-30 °C and 70-75 % RH or higher) and the bioreceptivity of the substrate and its physical-chemical properties are compatible with the needs of the colonizer [8]. Their metabolic activity on cellulose and even non-cellulosic materials present in paper is very high [8]. The enzymes produced and the organic acids excreted during the digestion process cause paper disintegration, mostly by the cellulose macromolecule hydrolysis, and results in the loss of its mechanical strength and the general loss of information [4]. Besides the weakness and decomposition of paper, fungus action usually results in very unpleasant staining caused by the production of coloured metabolites, which have a strong aesthetic impact on objects. Foxing spots, a descriptive term for scattered roundish stains of reddish or yellowish-brown colour found in paper or other fibre-based materials [12], are a common example. Usually an age-related process of deterioration, foxing is still under discussion and many causes for its formation have been suggested, including several abiotic processes [12] or growth of micro-organisms [13].

This fact raises an aesthetic concern, shared not only by libraries and archives but also by graphic art collectors and bibliophiles, as demonstrated in restoration manuals [14] and other technical literature [16]. As will be explained further (Early curative conservation praxis versus preventive conservation strategies section), this also uncovers important theories and practices of paper conservation and the evolution of concepts applied to paper heritage conservation [18]. Another important aspect is the health question, since many species of micro-organisms are pathogenic and toxic and recognized as allergenic triggers able to provoke respiratory diseases [8]. Thus, from the late nineteenth century to the end of the twentieth century different preventive conservation strategies and curative conservation praxis were implemented for the control of biodeterioration in paper objects and collections.

In Portuguese institutions, although preventive conservation appears to have been on the agenda for a long time, a prevalence of curative measures through chemical control is evident, resulting in serious damage to objects and causing public health problems in renowned institutions. In fact, the chemical substances traditionally used to prevent biodeterioration processes and to control pests are very toxic, affecting the environment and people's health, and often contributing to material alteration and deterioration of cultural heritage [6]. Nevertheless, it seems that cultural heritage Portuguese managers are not aware of the seriousness of this safety issue. On the other hand, the biodeterioration problem remains unsolved, although currently, several research centres are addressing these questions. In the last decade, studies were carried out in the field of cultural heritage and materials degradation by research units from various Portuguese universities. A few examples are the Transdisciplinary Research Centre "Culture, Space and Memory" – CITCEM, from University of Porto; the research unit Glass and Ceramics for the Arts – VICARTE and the Research Centre of Excellence in Green Chemistry – LAQV Requimte from Universidade NOVA de Lisboa; the Centre for Functional Ecology from Coimbra University; the HERCULES Centre of University of Évora and the Research Centre in Science and Technology of the Arts – CITAR plus the Centre of Biotechnology – CBQF, from Universidade Católica Portuguesa. Fields such as preventive conservation, risk assessment, pest control, archives biodeterioration, identification of different micro-organisms, microbial diversity, molecular biology, biotechnology, use of safe biocides, fungus stain cleaning and removal have been targeted by these research centres but the application of the new findings in cultural heritage institutional environments has been insubstantial.

This may result from insufficient knowledge transfer between research units and institutional environments, as well as inappropriate choices and policies on the part of managers. It is known that in times of economic downturn, maintenance is often the first area to be affected; storage areas are neglected or given less priority than readers' areas or high-profile projects with greater visibility [1]. Instead of creating infrastructures for preventive conservation such as continuous programmes for cleaning and hygiene, often viewed as menial tasks that can be done by unskilled personnel, larger investments are made in more conspicuous initiatives with more public visibility. Furthermore, in many places and institutions around the world resources allocated for conservation are diminishing [20]. So, despite the serious problem of materials contamination with traditional methods of biodeterioration control, the increasingly strong voices calling for the implementation of sustainable methods that consider cultural heritage, final users and the environment, as well as the proved cost-effectiveness of preventive conservation, it is difficult to convince decision-makers of its importance in relation to other institutional expenditures.

This reality requires serious reflection supported by a historical review of the main practices in dealing with the biodeterioration problems at national institutions (section Biodeterioration and pest control: management strategies), so as to identify a clear trajectory and to discuss the factors that contributed to the present situation in Portuguese institutions. Information about biodeterioration and how pesticides, fungicides and fumigants were applied to archive and library materials is important to fully understand historical treatments and methods of care, but also for a better perception of chemical alterations and current health hazards posed by contaminated items with chemical residues. There are surely strong parallels with the cultural heritage institutional situation of other countries with similar economic paths. Thus, we believe other institutions or actors can benefit from the analysis of the Portuguese case-study, hereby described and presented.

## Early curative conservation praxis versus preventive conservation strategies

### The restoration manuals approach

Textbooks and manuals on restoration emerged in the nineteenth century in par with collectors' manuals [21] and art catalogues when auction houses were gaining popularity [22]. They were basically published for collectors and focused on procedures used in the treatment of paintings and works of art on paper and rare books, thus enabling us to trace the sequence of events that led to the emergence of the conservation practices used in graphic documents [18]. During the nineteenth century and first half of the twentieth century, this process was seen as a means of restoring works of art to their "pristine state", following the aesthetic standards of this period [18]. From a collector's point of view, the importance ascribed to the appearance of an object resulted in the application of rather invasive methods. In paper works, this practice was facilitated by the availability in the market of chemicals used in bleaching [23], which involved the direct use of dangerous and unstable chemicals. This is seen today as an improper and unethical approach, but at the time ethical concerns were secondary to the principles of "mimetic restoration". In paper objects, this was achieved essentially by two means: cleaning and bleaching stains to restore the original whiteness; perfect re-integrations to match new and old papers, making the restoration as invisible as possible [19]. Despite some variations in the procedures, different manuals from this period show that the removal of stains and perfect reintegration were the ultimate goals of restoration. The most extensive restoration manual portraying this ideal in works of art on paper was authored by Bonnardot and dates from the mid-nineteenth century. Based on his own experience, the author placed great emphasis on cleaning as a way to improve the appearance of the artwork. Bonnardot devoted five complete chapters to this topic [18]. For fungal stains, considered by the author as one of the most difficult to remove, he recommended the use of bleaching, starting with a weaker formula and increasing it according to the intensity of the stain, but taking into consideration the paper quality and its fragility [14]. Several other authors addressed this issue in their publications, i.e. Ris-Paquot [24], Gunn [26], Beaufort [27] and Lucanus [28], as well as the Portuguese artist and writer Manuel de Macedo [15].

Although less complete in their explanations, they all recommended the same type of methods and products and followed identical principles. Macedo's unique Portuguese manual of this kind followed closely the textbooks of Ris-Paquot and Bonnardot, reflecting the French influence in the Portuguese cultural scene. His main concern was also to restore the antique paper to its original appearance. Bleaching was one of the procedures used to clean paper, followed by toning down to confer a uniform aged tone. Other procedures included reintegration with a paper as similar as possible to the original [18]. To in-fill the missing areas from heavy insect attack, again Macedo recommended the use of paper pulp following Bonnardot's formula, to mask all anomalies and create, as much as possible, invisible joints [15].

Although all these invasive treatments envisaged a "mimetic intervention" that obeyed an aesthetic ideal, the authors also mentioned some preservation requirements. Bonnardot cautions the reader for the importance of humidity and temperature control. He defines, as the general rule, a need for books and prints to be kept in dry rooms with low heat, "since moisture causes mould in the papers and excess heat promotes the development of worms, sometimes deposited in glues and skins" (authors' translation) [14]. Macedo also recommends avoiding temperature and humidity, and draws attention to the importance of ventilation. He advises the reader about the choice of good materials for the folders and the boxing process, since some materials react strongly to humidity [15].

Textbooks like Bonnardot's manual still constituted a reference in the twentieth century [29] but various changes occurred in the first half of that century. In the mid-twentieth century, the engraver-restorer Schweidler, while continuing to defend the idea of an invisible restoration of art on paper, directed his textbook to the expert technician instead of the amateur collector, which suggests the emergence of a new professional: the paper conservator [18, 30]. On the other hand, the manual of Morgana (1932) [29] and of Plenderleith (1937) [31] written in the 1930s mentions new products that had meanwhile invaded the market, such as synthetic products, and new equipment like the sterilization chamber, which were to play an important role in disasters such as the floods which occurred in Florence in 1966 [29]. Plenderleith's book also outlined a new methodology for the conservation of works of art on paper similar to that used in museum objects. The author begins by describing the composition of different materials and defines the main causes of their deterioration, including the biologic action. He dedicates a chapter to fungi and characterizes types of staining and deterioration, explaining the role of environmental conditions and lack of ventilation. A further section is dedicated to aspects like storage conditions and exhibition facilities, inspired by the work that was being carried out at the British Museum by Alexander Scott (1853–1947), founder of the scientific laboratory [20]. Regarding the praxis of conservation, the author emphasizes the need for a full diagnosis and introduces a new mandatory step: the use of a sterilization fumigation chamber to be applied prior to traditional procedures such as bleaching, which was by then considered accessory [31]. But in terms of remedial conservation and restoration procedures, such as cleaning with strong bleaching agents, repairing, and in-fill, there was no innovation. In fact, Plenderleith follows the philosophy and methods of intervention mentioned by previous authors [18, 31]. So, for the first half of the twentieth century, the art collectors' world still maintained the ideal of "mimetic intervention" and valued the pristine appearance of the artwork after restoration.

## Technical bibliography for archives and libraries

Faced with a growing concern for the physical and chemical stability of paper objects, librarians and archivists were the ones who led the way to the first conferences on conservation and restoration of documents. The first was the *Internationale Konferenz zur Rrhaltung uns Ausbesserung alter Handschrifen*, held in St. Gall, 1889, followed by an archivist's meeting, 1899, Dresden, and the Librarians International Conference, 1900, Paris, [32]. These professionals were also the first to implement ethical principles of restoration carried out on this type of material, considering their historical nature and probative value, namely archive documents. For example, one of the main concerns of Sir Henry Cole (1808–1882), who since 1840 was in charge of the Public Record Office, in London, was to ensure that the restoration process did not alter the integrity and the legal value of documents [22]. These professionals revealed great concern and in-depth knowledge of preventive conservation, including early pest control. The subject was widely emphasized in their professional compendia, such as the *Manual on Archive Administration* [33] published in the early twentieth century. This publication followed closely the ideas of Sir Henry Cole and dedicates a full chapter to the "enemies of the manuscripts" and their management [33]. Other examples are the *Manuel pratique du bibliothècaire* [34] and the *Bibliothéconomie* [17]. The latter, written in mid-twentieth century, included a full chapter about conservation in which the author claims that worms and humidity are one of the most common and difficult problems to solve in an archive. He also points out some solutions, such as improving air circulation and using a methodology developed years prior, that involved the use of essential oils and camphor [17]. In the *Manuel pratique du bibliothècaire*, Maire dedicated a section to the fundamentals of conservation and elaborates on the biggest enemies of books: insects, dust deposits, humidity and temperature. He advises against deterioration processes and recommends adopting good practices such as the ventilation of rooms, cleaning and using good storage materials and procedures [34]. This author goes even further and addresses safety and disaster planning, starting with the actual construction of a building and protection against external threats [34].

In Portugal, the management of bibliographic and archival heritage has involved, for a long time, its physical and material care, with particular emphasis on preventive conservation measures. This is directly associated to the conditions of the buildings and storage facilities, as well as the presence of pests, which were considered one of the main causes of deterioration in the literature of archives and libraries during the nineteenth and twentieth centuries. A small group of intellectuals, usually associated with the humanities, i.e. librarians, archivists, curators and scholars, who were also often themselves collectors of rare books and artworks and held administrative positions in cultural heritage institutions, were the first to turn their attention to the issue of preventive conservation [35]. Several authors defined the ideal conditions of the buildings that housed archives: they had to be resistant to fire, dry, and free of pests. João Pedro Ribeiro (1758-1839) was one of the first scholars to address the issue in his publication: *Observações historicas e criticas* [16]. His work was based on a survey on the state of Portuguese archives, a study carried out upon request of Queen D. Maria I of Portugal for the Science Academy of Lisbon (*Academia* *das Ciências de Lisboa*), which had been founded under her patronage. According to Ribeiro, the place where the archives were stored, did not comply with recommended international management methodologies and did not offer safe conditions. The main problems detected were: lack of adequate human resources, lack of an accurate and detailed inventory, improper storage conditions (i.e. high levels of humidity and no ventilation), and absence of adequate means to ensure that books and documents were free of "animals and insects, which everyone knows how much they can destroy (...)" (authors' translation) [16]. To deal with this pest problem, Ribeiro recommended "neatness, cleaning and supervision" (authors' translation) [30], procedures suggested by any current Integrated Pest Management (IPM) policy. During the nineteenth century, several authors reinforced this stance. For example, Fr. Francisco de São Luís Saraiva (1766-1845), supervisor of the National Archives (ANTT, *Arquivos Nacionais – Torre do Tombo*) between 1834 and 1836, wrote a manuscript where he defined three main dangers: fire, humidity, and insects. He recommended "sweeping the house frequently, dusting the cabinets, and from time to time leafing through the books to shake off the dust" (authors' translation) [36]. The author also talks about storage practices (i.e. the use of protective folders glued with a paste containing "vinegar" to repel pests, shelves of good quality wood that should also be oiled to prevent insect attacks) following the recommendations in international textbooks written by the field professionals. At the turn of the nineteenth century, the historian Pedro Azevedo, who held various positions in renowned institutions in Portugal, such as the ANTT and the National Library (BNP, Biblioteca Nacional de Portugal), wrote a publication about the Portuguese context entitled *Meios de defesa dos archivos*. In his work the author explains the effects of humidity on paper and the relationship between air volume, temperature and water vapour (i.e. absolute and relative humidity), advocating the use of a hygrometer. He associated humidity to the harmful action of micro-organisms, alerted his readers about the problem of insects, and recommended the use of metal shelves [37].

From the late nineteenth century until the end of twentieth century the situation of the BNP became a major concern, particularly since the extinction of the religious orders in 1834 that resulted in many of their works being increasingly integrated into this public library. The library was relocated in 1836 to the damp Convent of S. Francisco and in 1844 the Library's director, José Feliciano Noronha (1810-1879) sent a report to the Minister of the Republic, Costa Cabral (1803-1889) drawing attention to the "most terrible enemies" present in this public library: dust, humidity and insects. He concluded that "whatever the point of view is, everything in the Convent of S. Francisco is unsuitable for its current intended purpose" (authors' translation) [38]. But it wasn't until the early twentieth century that the situation was made public with an event called "A sad but necessary exhibition" (i.e. *Uma exposição triste mas necessária*) on April 26, 1920. This exhibition was organized by a group of intellectuals that included librarians and archivists, founders of the Library Friends Society (*Sociedade dos Amigos das Bibliotecas*). Having proven the importance of their professional class, they soon expanded it to the Archives [39]. In fact, by the late nineteenth century, librarians and archivists were already a skilled professional class. In 1887, under the sponsorship of the Archives and Erudite Libraries Inspection (*Inspecção das Bibliotecas Eruditas e Arquivos*), a higher education course was created for archivists and librarians. The course included the discipline of Bibliology and encompassed the care and preventive conservation of collections [40]. In 1918, the course was reorganized, and the BNP was put in charge of coordinating a seminar on the "hygiene of bibliographic species" [41]. It is important to note that the discipline was taught by a natural scientist, reinforcing the importance given to biological questions and showing that interdisciplinary teamwork was taking its first steps. Problems, especially with insect control, justified the involvement of experts who were not confined to the humanities, and naturalists began to assume a position in the field. The phenomenon was well underway across Europe in areas such as paintings and museum objects but, in Portugal, given the poor condition of archives and libraries, graphic documents seem to have taken precedence over other cultural heritage sectors.

Later, with the creation of an official professional body of librarians and archivists in the twentieth century, and the founding of a professional association (1973), a forum of discussion was initiated through regular national conferences and the participation of Portuguese professionals in international events. In the early 1970s Lisbon hosted the IIC's International Congress, "Conservation of Paintings and Graphic Arts", and at the end of that decade, a Working Week in the Conservation of Graphic Documents was held, congregating, for the first time in Portugal, librarians and archivists, scholars, curators, cultural heritage managers, chemists, biologists and conservators. In this forum, preservation issues such as environmental conditions, disaster planning, and biologic causes of deterioration were central topics of discussion. The main points stressed by the participants were: urgency in establishing a preventive conservation policy founded on a national plan to upgrade existing facilities and build new ones; the need to define priorities based on a systematic survey of the conservation condition of collections; the creation of a research centre for the study of conservation problems and causes of deterioration, and to help establish rules. However, despite the awareness of specialists in Portugal, lack of support from the political sphere and decision-makers will persevere, and the research centre was never created [35].

## Biodeterioration and pest control: management strategies

**Policies and surveys**

Since the mid-nineteenth century, different approaches for biodeterioration control and pest eradication have been employed in Portugal's National archives and Library. These methods are reviewed and presented alphabetically in Table 1. Fungicide, pesticide and fumigant use by the collections' management staff is documented chronologically, characterizing the most important trends in library and archive management during the late nineteenth and twentieth centuries in Portugal.

Historical information was collected mainly from archival written sources (i.e. survey records, products acquisition; management records) combined with oral information for recent periods, in four representative institutions: the BNP and the ANTT (as the main reference institutions in Portugal), the latter including the management of the eighteen district archives; the Overseas Historical Archive (AHU, *Arquivo Histórico Ultramarino*), one of the first institutions to face serious pest problems due to the origin of the archives (i.e. records from the ex-colonies in tropical regions); and the Calouste Gulbenkian Foundation (FCG, *Fundação Calouste Gulbenkian*), a private institution with an important role in the field due to the floods of 1967 in the greater Lisbon (a year after the floods in Florence), which seriously affected its collections. In fact, a laboratory for specialized conservation and restoration was created specifically to treat the affected collections, and official training for paper conservators was initiated. Until then, the only paper conservation workshop that ran on a regular basis, was the one set up in the AHU by a bookbinder trained in Rome at the Institute of Book Pathology (*Instituto di Patologia del Libro*) to deal with the aforementioned serious biodeterioration problems (Figure 1).

The great concern with biodeterioration, particularly pest control, led management staff to carry out several surveys in public institutions. In 1946, the already mentioned Archives and Erudite Libraries Inspection endorsed an inquiry on the conditions of the inventory, the building (environmental conditions), measures for the prevention of fire and theft, and other preservation conditions such as handling procedures, dust and hygiene methods and, of course, biodeterioration control [40]. New surveys were conducted in 1957 and 1968, the last totally focused on the problem of insects [39]. The inspector intended to set up a department for the study of the sanitary conditions of libraries and archives where a policy against biodeterioration could be developed [42]. The intention was to conduct a rigorous survey of the prevailing pest species, to analyse their habitat and to investigate how they acted in different environments, as well as to make a statistical assessment of how the attacks occurred [43]. However, the results of this research are not known. An attempt to establish a national policy for chemical pest control in archives and libraries was undertaken again in the 1980s in the Department of Libraries and Archives of the Portuguese Institute of Cultural Heritage (IPPC, *Instituto Português do Património Cultural*) [44] but at the time many alternative methods for pest control where already being set up at an international level. A last survey of the

**Figure 1.** AHU, Governo Geral da Índia, Junta da Fazenda – 17th century book showing heavy biodeterioration caused not only by woodworms but also by microorganisms. This particular book was under extremely high humidity and its support has suffered intense acidification.

**Table 1.** Chemical products used in libraries and archives at Portugal along the 20th century [4, 7, 91, 92].

| Common name | Chemical formula | Application method | Application purpose | Reference/ use evidence | Health risks | Side-effects on documents | Persistence | CAS # |
|---|---|---|---|---|---|---|---|---|
| Benzene | $C_6H_6$ | n/a | Insecticide | 1938 | Carcinogen; chromosomal damage. | Staining; oxidation | High | 71-43-2 |
| Benzene hexacloride (Lindano) | $C_6H_6Cl_6$ | Dust | Insecticide | 1950 | Carcinogen; Causes neuropathology; Skin irritation. | Oxidation | High | 58-89-9 |
| Carbon disulfide | $CS_2$ | Gas | Fumigant | 1914 | Cardiovascular disease. | n/a | Low | 75-15-0 |
| Chlorine gas | $Cl_2$ | Vapor fumes | Fumigant | 1914 | Attacks the respiratory system | Increase deterioration rate; Oxidation Discoloration | Low | 7782-50-5 |
| Dichlorophen (Preventol GD or Panacide) | $C_{13}H_{10}Cl_2O_2$ | Liquid form | Fungicide and germicide | 1960 | Skin and eyes irritation | Increase deterioration rate; Yellowing | Low | 97-23-4 |
| Dichloro diphenyl trichlorethane (DDT) | $C_{14}H_9Cl_5$ | Dust | Insecticide | 1950 | Carcinogen | Oxidation | High | 50-29-03 |
| Ethanol | $C_2H_5OH$ | Liquid form (70 % to 90 % v/v) | Fungistatic | 1970 | n/a | Gloss loss and increase of opacity in transparent papers | Low | 64-17-5 |
| Ethylene Oxide | $C_2H_4O$ | Gas | Fumigant | 1970 | Carcinogen | Change in mechanical properties; polymerization; Oxidation; Yellowing | Moderate | 75-21-8 |
| Formaldehyde | $CH_2O$ | Vapor fumes Liquid form | Fumigant Fungicide | 1914, 1920 1960-70 | Carcinogenic causes irritation by inhalation and dermatitis by direct contact | At low RH precipitates: causes cross-linking and loss of flexibility; Iron gall ink corrosion | Low | 50-00-0 |
| Hydrogen cyanide | CHN | Gas fumes | Fumigant | 1950 | Lethal toxicity under exposure | n/a | Low | 74-90-8 |
| Methyl Bromide | $CH_3Br$ | Gas | Fumigant (insects and rodents) | 1975 | Respiratory, kidney, and neurological effects; potential carcinogenic | Affects all Sulphur containing materials and protein-based materials | Low-moderate | 74-83-9 |
| Naphthalene | $C_{10}H_8$ | Solid form Sublimation | Insets repellent | c.1940 | Can cause anemia; Potential carcinogenic | Discoloration; may dissolve fats on skin materials | Low-moderate | 91-20-3 |
| Thymol | $C_{10}H_{14}O$ | Sublimation | Fumigant fungistatic | 1938 | Genotoxic risk | Decreased mechanical properties; Yellowing; risk of ink dissolution and deterioration of iron gall inks | Moderate | 89-83-8 |

national archives was carried out in the early nineties by the National Archives Institute (IPA, *Instituto dos Arquivos Nacionais*) [45]. The main target of this survey was the evaluation of preservation and conservation conditions at district archives and it was divided into three key topics: (i) general condition of the archives, from buildings to storage facilities; (ii) major deterioration processes observed in the documentation; and (iii) different solutions and treatments frequently carried out. A preservation course for collection managers was organized by the IPA prior to the survey and all eighteen district archives in the country completed it. Biodeterioration was identified as one of the primary problems faced by archive management teams resulting in regular use of chemical products. The main pests found are presented in Table 2.

During the survey, very poor environmental conditions were observed, and usually, the unsuitability of installations included infrastructure problems. The relative humidity registered was as high as 80 % to 90 % with oscillations of 20 % in a single day, and many problems were found in the buildings, such as poor construction materials used, lack of insulation, deficient plumbing and electrical power, etc. Archives used fumigation products on a regular basis (once to twice a year); after the fumigation treatment, storage areas were ventilated, but no monitoring of the air quality was done [45]. In short, no significant changes seemed to have occurred throughout the twentieth century. A preservation policy was finally defined for the National Archives starting with the building itself, which resulted in the PARAM programme (*Programa de Apoio à Rede de Arquivos Municipais* – Support Programme for the Municipal Archives Network), initiated in 1998, for the improvement and requalification of archives, where IPM strategies were implemented.

Although preventive conservation recommendations have circulated among archives and libraries for a long time and there have been many preventive conservation recommendations throughout the twentieth century, we realize that the main methods employed in biodeterioration control until the end of the twentieth century involved the use of chemical products, i.e. poisons and pesticides (Table 1). Different methods for disinfestation as a way of exterminating insects and rodents, and disinfection or sterilisation to control and eliminate microorganisms were implemented based on the use of toxic products.

Cost and lack of immediate and obvious alternatives seem to have conditioned the choice of pest control techniques. Human health and safety concerns were sometimes mentioned, but in the early days of the twentieth century, information about the long-term side-effects of the use of chemical products was not available and the public health authorities allowed their use [35]. In the late nineties, this became a concern and gradually some changes were made thanks to both increased consciousness and new facilities. But due to lack of regular funding and steady investment this problem still prevails.

### Chemical options for biodeterioration and pest management

As mentioned above, the curative treatments recommended by Macedo, following Bonnardot and other European

**Table 2.** List of most common insects affecting books found in libraries and archives in Portugal [45, 87, 93].

| Order | Family | Genus | Species | Common name | Affected Materials |
|---|---|---|---|---|---|
| **Blattodea** | Ectobiidae | *Blattella* | *Blattella germanica* (Linnaeus) | Small cockroach | Affects mostly binding materials but can also bite the paper leaving an irregular contour on the edges. |
| | Rhinotermitidae | *Reticulitermes* | *Reticulitermes lucifugus* (Rossi) | Termite | When it reaches collections it can severely affect all kind of materials. |
| **Coleoptera** | Ptinidae | *Anobiidae* | *Anobium punctatum* (De Geer ) | Furniture beetle | Affects wood boards and paper causing large perfect circular holes and tunnels. |
| | | *Stegobium* | *Stegobium paniceum* (Linnaeus) | Drugstore beetle | Affects wood boards and paper causing also perfect circular holes and tunnels, usually smaller than Anobium. |
| | Dermestidae | *Dermestes* | *Dermestes maculatus* (De Geer ) | Leather beetle | Affects parchment and leather materials in books. |
| **Lepidoptera** | Tineidae | *Tineola* | *Tineola bisselliella* (Hummel) | clothes moth | Affects mainly cloth and silk bindings and endpapers. |
| **Psocoptera** | Liposcelididae | *Liposcelis* (Motschulsky) | n/a. | booklice | Affects mainly glue or paste of bookbindings and glazed paper. |
| **Zygentoma** | Lepismatidae | *Lepisma* | *Lepisma saccharina* (Linnaeus) | Silverfish | Affects paper leaving a grazing effect on the surface; it can bite through the paper leaving an irregular contour on the edges. |

authors, also had a disinfection function. Cleaning with chlorine and other bleaching agents for the removal of stains, namely fungal stains, was done not only for aesthetic purposes but also to prevent biodeterioration from spreading. Another chemical substance recommended by early Portuguese bibliography of archives and libraries (Technical bibliography for archives and libraries section) was the use of essential oils [36] again following European references, i.e. Constantin's manual and his preservation measures [34]. The Portuguese author does not specify the type of oil to be used, but he recommends its application on wooden bookshelves to repel insects [36]. The fumigation of spaces, introducing chemical substances such as a toxic gas in a confined area was mentioned for the first time in a nineteenth century document written by João Campanha, head of the Royal Chemical Laboratory of *Casa da Moeda* [39]. Campanha recommends the use of heated sulfuric acid over salt to form hydrogen chloride gas, and closing the space for 24 h, although it is not clear how this exothermic reaction could occur safely. However, the use of chemical products to halt biodeterioration is, in fact, a twentieth-century trend. The Book Disinfection & Sanitation Station (*Posto de Saneamento e Desinfestação de Livros*) was established by 1914 [35, 46] under the aegis of the aforementioned Archives and Erudite Libraries Inspection. This public entity recommended the use of gaseous fumigants such as chlorine gas (a common disinfectant also used for paper bleaching by oxidation reactions) and carbon disulphide (used at the time as an insecticide for the fumigation of food) [47] in a fumigation cabinet or box; and formaldehyde in a fumigation chamber [39]. Further evidence of the use of formaldehyde is mentioned in the cleaning, sterilization and disinfestation of the archive collections of the S. José Hospital in Lisbon [48]. In libraries and archives environment, this carbon compound was advocated for a long period. Maire's nineteenth-century manual already mentioned it, and in 1971 the British Museum pamphlet on biocides for archival and library materials still recommended formaldehyde [49]. Nevertheless, as early as the 1960s, Gallo mentions the difficulty in eliminating its residues [50]. It is recognised that formaldehyde has strong microbicidal properties, but also low penetration capacity for library and archival collections [51], and thus is not always effective. Formaldehyde has also been reported to cause several deterioration problems to archival and libraries materials such as cross-linking of cellulose, loss of flexibility in paper and skins, and corrosion of iron gall inks [4]. In terms of public health, it causes irritation to the eyes and mucous membranes, and in 1978 it was declared to be a carcinogen [4].

In the late thirties, we also find a reference to the use of thymol (5-methyl-2-isopropyl 1-phenol) and benzene (aromatic hydrocarbon) which, according to Sampaio, served "to kill and repel insects and to clean the books" (author's translation) [53]. As mentioned above, Plenderleith's manual also recommends the use of thymol as a topical fungicide in the sterilization fumigation cabinet on a regular basis [31] and in the eighties, it was virtually the only fumigant used in archives in the United Kingdom [54]. Several studies advocated its qualities as a fungicide and bactericide, but others reported its ineffectiveness in tackling paper fungi infections [4, 54]. Secondary effects were also reported by different authors after the treatment of papers with thymol, such as decrease of mechanical resistance and folding endurance [55] discolouration and yellowing of paper [58] and the general degradation of paper, binders, glues and inks [58, 60]. Regarding toxicity, some authors suggest it has a destructive capacity to alter genetic material [61].

In the 1950s the use of chemical materials directly on, or next to documents to avoid insects spreading was advised and documented. This is the case of naphthalene (solid polycyclic hydrocarbon), a product recommended in the late nineteenth century for cultural heritage objects [62]; and insecticides of the organochlorine group, such as DDT (Dichloro-Diphenyl-Trichloroethane) at 20 %, and lindane (*gamma*-hexachlorocyclohexane). Following instructions from the National Civil Engineering Laboratory (LNEC, *Laboratório Nacional de Engenharia Civil*), the last two were applied in the AHU where, as mentioned before, a serious problem with biodeterioration was felt [35]. DDT was also used in the BNP, where some contaminated documents still have residues and exhibit strongly oxidised and deteriorated cellulose (Figure 2).

DDT became popular as an insecticide after the Second World War, and it began to be produced industrially around 1945. It was used in agriculture and later in the cultural heritage sector. However, in the sixties, voices were raised against its frequent use. Here we must refer to the early work of Carson [63] about the deleterious effects of this pesticide in the environment. In fact, this pesticide requires safe handling to avoid being absorbed by the skin and through inhalation [64]. Also, it is a very persistent substance that results in bioaccumulation and biomagnification along trophic chains, leading to the contamination of both top predators and humans [65].

By the mid-twentieth century, fumigation with hydrogen cyanide gas was encouraged by fumigation companies to treat the storage areas of the Overseas Historical Archive (AHU). According to the records, this was also in use in the National Archives and Library [35]. This is an extremely poisonous and flammable material, so the AHU management team asked for advice. They consulted the Institute of Agriculture (ISA, *Instituto Superior de Agronomia*) about insect characterization and LNEC for information about the product. The Portuguese National Health Service was also asked for authorization to apply the substance. LNEC and ISA advised against its use, but the Health Services authorized the procedure. So, despite the dangers and risk of toxicity to neighbours, staff and users, the treatment was performed on a regular basis for several years. The alternative suggested by LNEC was either

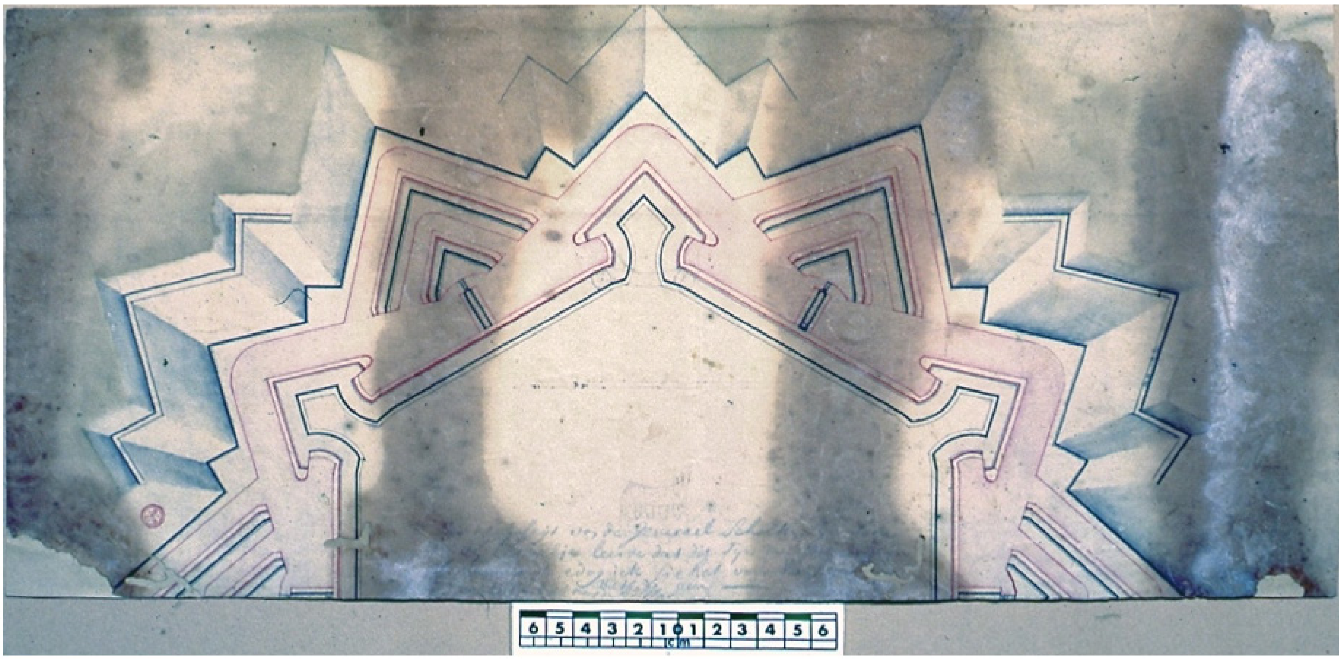

**Figure 2.** BNP, Iconography collections, 17th-century architectural drawing revealing deposits of DDT powder, according to BNP information.

ethylene oxide (EtO) or methyl bromide in a fumigation chamber. The AHU did apply methyl bromide in the late seventies, and again in the nineties, but not in a fumigation chamber. In fact, the Archive applied it as a fumigation gas in open storage areas, when alternative solutions were already being studied all over the world. Its hazardous effect on sulphur-containing materials, such as photographic collections and most contemporary papers (i.e. sulphate and sulphite process papers) [66], as well as leather book bindings and any protein-based material, was soon recognised, as it causes serious damage to the protein structure [67]. Finally, methyl bromide was banned from the market when it was identified as noxious and detrimental to the ozone layer. Methyl bromide was also used in a fumigation vacuum chamber by FCG, after the Lisbon floods of 1967.

Ethylene oxide was adopted by the BNP, where a fumigation vacuum chamber was installed in the seventies in its new building. Ethylene oxide was developed in 1859 but it was in the following century that became widely used in museums, libraries and archives [68]. Due to its high capacity of penetration at room temperature, it has excellent microbicidal properties as well as very good insect elimination qualities that made it a very popular disinfestation and sterilization method [4]. But some authors refer that after treatment paper documents become more susceptible to microbial attack [54, 69]. In the eighties, new studies brought to light its harmful effects both on materials and on human health [70] and, more recently, EtO has been declared a carcinogenic, mutagenic, genotoxic and neurological hazard [4, 68]. Usually mixed with $CO_2$ to reduce flammability and explosiveness, it remains on paper and on protein-based materials for long periods where it reacts with cellulose causing loss of strength. In paper containing chlorine, it reacts forming ethylene chlorohydrin or glycol ethylene, toxic products that remain on the paper, affecting users [4, 71]. For circa three decades the fumigation chamber was in use in the BNP but the chemical persistence on documents was finally considered a serious health hazard and it closed in the nineties. In the last decade of the twentieth century, the National Archives moved to a new building where a classic fumigation chamber was installed but due to a succession of difficulties, the equipment was never operating. Nevertheless, ANTT faced a big challenge: they moved to the new, more comfortable building, but without taking any precautions. They occupied new storage rooms with infested items and the insects (*Stegobium paniceum*) developed twice as fast than in the previous cold environment of the old stone building.

Meanwhile, conservation labs were set up in the major institutions in Portugal and new chemicals were introduced for curative treatments on biodeteriorated items. This was the case of the original conservation laboratories of graphic documents in the AHU and FCG established in the 1960s, where Dichlorophen (4-cloro-2-[(5-chloro-2-hydroxyphenyl) methyl] phenol), whose commercial name is Preventol GD or Panacide, was used for cleaning infected objects over several decades, namely documents affected by the Lisbon floods, where fungi quickly developed. These chemical substances are usually applied in organic solvents and have a strong effect on yeast and filamentous fungus [4, 72]. But an increase in the paper deterioration rate after its use was observed [73], as well as the fact that it could cause health problems, such as eye and skin irritation [72]. In 2009 it stopped being sold in the European Union free market as a biocide [4].

It is known that in the AHU conservation workshops a fumigation box was improvised for systematic use in documents prior to their full conservation treatment. The chemical product applied was carbon disulphide, recommended since 1914 by the Portuguese authorities through the Book Disinfection & Sanitation Station and in use at the Vatican Archives laboratory in Rome.

In the 1980s, a conservation-restoration laboratory was set up in the BNP, and in the early nineties, the conservation services of the ANTT were established. In both locations, a membrane-active microbicide, ethanol at 70 %, was adopted to treat documents affected by fungi. In fact, some authors stated that aqueous solutions from 50 % to 80 % (v/v) are more effective than pure alcohols, with the maximum efficiency at 70 % [74]. Recently, Sequeira showed that a 70 % ethanol solution displayed fungicidal properties on four out of five tested fungal species (sporulating fungi) and proved that none of the ethanol solutions tested (from 5 to 100 %) promoted conidia germination but rather delayed or inhibited it entirely, depending on concentration and duration of contact [76]. Ethanol is mainly applied by spraying or by immersion in a bath, which is reported to be a more effective treatment [74], although it can cause opacity and deformation to documents, as well as dissolution of certain types of inks [75].

### Non-chemical option for biodeterioration and pest management

Regular hygiene was recommended from very early on, as an important way of controlling biodeterioration. In Portugal, like in other countries, archivists and librarians have always advocated regular cleaning of collections and preservation measures, starting with storage areas and buildings. According to Pinniger, 90 % of successful pest control depends on good hygiene [1, 77]. Pests develop with unsuitable environmental conditions, but they also thrive on dirt and rubbish which provides them with shelter, as well as food.

The enforcement of an Integrated Pest Management in museums, libraries and archives was imported from the agricultural sphere. Although this management program includes pesticides, the better and recommended approach is to choose the method of lowest risk for people, collections and the environment [78].

As mentioned, cleaning is probably the most important part of any IPM Program [77]. FCG was one of the first institutions to develop a cleaning programme for the collections. This institution also used freezing facilities right after the Lisbon floods of 1967. The freezing process was done as an intermediate method to prevent micro-organism growth until further conservation treatments were done, but it is not totally innocuous. Some changes in the characteristics of the most fragile paper substrate, such as chemical reactions induced by an increased concentration of solutes; and physical damage caused by the formation of ice crystals, can occur during the freezing process. Furthermore, some micro-organisms' cells may still be viable after normal conditions arise [76]. However, freezing does present itself as a non-toxic alternative, namely for insect control. As explained by Strang, the problems around pesticide use, particularly environmental impact, increased awareness and lead to studies on thermal efficacy to reduce pest action on cultural heritage; although this area of study "can still benefit from efforts to obtain efficacy data for species, aimed towards minimizing treatment times or increasing confidence around undocumented species" [80].

In 1997, the National archives were the first institutions to adapt the traditional vacuum chamber to a low oxygen chamber. This modified atmosphere method provides an anoxia environment for the pests by total exclusion of oxygen and its substitution for nitrogen or carbon dioxide. The latter is more efficient than nitrogen, namely for fungus growth control [81] but nitrogen atmospheres do not interfere with the pH of paper like carbon dioxide sometimes does. When the relative humidity is also controlled, very good results can be achieved, not only for most insects but also for micro-organism control [76, 82]. As reported by several authors it is environmentally friendly, very effective and safe for sensitive objects [82]. The drastic situation of pests' invasion at the new storage areas experienced at ANTT resulted in the setting up of an IPM programme to prevent it, based on monitoring with traps and building maintenance, and avoiding the use of chemical products. At the end of the century, in 1998, BNP also changed the circuit of the EtO vacuum chamber into an anoxia nitrogen system and runs a regular cleaning programme for documents in storage areas. However, in these institutions due to financial constraints, the various steps were taken slowly.

### Sustainability and management of pests and biodeterioration

The topic of sustainability within Biodeterioration and Pest Management must fulfil two different needs: the conditions needed to sustain a program making it long-lasting, effective and safe for objects and users; and the choices made to tackle this issue on the face of our current environment needs.

The effectiveness of any management option is dependent on the support given by the administration. Success stories in tackling the problem of pests under any IPM program have been partially awarded to its centralisation on one staff member in a dedicated job post [85]. This is not the case for the large majority (or even all) of Portuguese institutions where all the IPM related tasks (assessment, implementation, monitoring, evaluation, reporting, communication and compliance to current norms and legislations) are additional to other daily activities. Another important aspect to be considered is the lack of awareness that decision-makers reveal as some seem to be totally oblivious to the harmful effects of the past and present use of chemical products. Contaminated materials require great precaution to be safely accessible, though how this can be done is still a demanding field of study. And if all of these were not enough already, climate change demands even more attention. Not only must the last-resort chemical options be sustainable and respectful of the environment as preventive measures – such as temperature and relative humidity control – must also comply with energy-saving goals [78]. Also, the expected global temperature rise means the world will experience higher temperatures and microorganisms and pests we are now acquainted with may become more aggressive or disappear and give rise to other different species with different behaviours and demanding different management approaches [86]. In fact, at Portugal, the struggle caused by the spreading to the whole country of some species, such as the subterranean termite (*Reticulitermes lucifugus*) affecting several historic buildings [87]; and the Silverfish (*Lepisma saccharina*) [88] affecting mostly textile and paper collections, is becoming a big problem that it seems we are not exactly prepared for.

As mentioned in the previous section, the displacement of atmospheric oxygen is a well-established method included in the European Standard EN 16790:2016 *Conservation of Cultural Heritage – Integrated pest management for protection of cultural heritage* (CSN EN 16790). Portugal has done some investments in this type of treatment. It plays a vital role in eliminating insect infestation on cultural heritage objects, movable or immovable and represents one of the best options available, both on efficacy and health or environmental concerns. However, the EU included nitrogen in Annex I of the Regulation (EU) No 528/2012 of the European Parliament and of the Council of 22 May 2012 [89] which concerns the market availability of biocidal products. With the extension of mandatory registration of on-site generated nitrogen from September 2017 by the biocidal products regulation EU 528/2012 these facilities can no longer be operated and there is a real danger, if this position is not reverted, that this could lead to the resurgence of all those dangerous (for both health and heritage) chemicals used in the past. This was the main argument used by the ICOM and ICOMOS joined statement (supported also by the Network of European Museum Organizations) requesting the repeal of the classification of nitrogen as a biocide so that it can remain as the safest option now available to Cultural Heritage preservation across the European Union (ICOM-ICOMOS, 2012) [90]. To build the case to revert this situation, a public consultation on derogations for the protection of cultural heritage was in place at the European Chemicals Agency website until January 18th. At the moment of submission of this article, the final decision is still pending.

## Discussion and final conclusions

During the nineteenth century, and throughout the twentieth century, there was a general concern with biodeterioration caused by micro-organisms and insects, and ways to mitigate them. This preoccupation is evident in restoration manuals, archives and libraries' technical bibliographies and in the records of important institutions operating in the field of archives and libraries.

The evolution of intervention principles and methods that have guided the conservation of graphic documents lies between two very distinct worlds, requiring a multifaceted reflection ranging from the analysis of the procedures adopted in the conservation/restoration of art on paper, to treatments applied in archives and libraries, including common treatment methods used in books and documents. On the application of chemical products both Bonnardot and Macedo resorted to the chemical means available in the market, such as bleaching and disinfection agents, with a single purpose: the perfect, unnoticeable intervention. Nevertheless, preventive measures to maintain the restored/conserved items in good conditions are also mentioned by the several authors, gaining momentum with Plenderleith.

A strong tonic on prevention has always been present on the methodologies to avoid and solve the biodeterioration problem. Among us, like abroad, archivists and librarians were a well-organized class and played a prominent role in the preservation policies of the graphic cultural heritage, during the nineteenth and twentieth centuries being the ones who first referred to the conservation problems affecting graphic documents and trying, early on, to define conditions for their preservation. Archives and library compendiums, were, apart from the technical aspects of archival organization and management, also at the centre of conservation issues and the discussions about the conditions for safeguarding archival cultural heritage. Until the mid-twentieth century, Portuguese authors always refer to the ideal conditions of a building and identify pest control as a powerful tool to master in archives and libraries. The various surveys carried out, first at the Archives and Erudite Libraries Inspection and later at the IPPC and the IPA, speak to the awareness in these professionals. Among us, they led the way for an interdisciplinary team by involving natural scientists in their education (i.e. libraries and archives professional course and seminar), setting up a discussion forum through the organization of conferences (i.e. Working Week in the Conservation of Graphic Documents) and asking for advice from other specialists (i.e. LNEC, ISA).

However, less than ideal situations affected paradigmatic institutions: the first location of the BNP in an unsuitable building; the regular arrival to the AHU of infested material from the colonial administration; the floods that affected the FCG collections; the transferral of the national archives to a new building without the previous disinfestation and quarantine of its records, are several of the disasters and singular events in the history of Portuguese National Archives and National Library of Portugal that contributed to an increase in professional awareness and the development of preservation initiatives. The tenacity with which the early defenders of preservation tried to show the positive impact of preventive conservation in collection's management was followed by a more definitive integration of preservation means into the institution's practices. Nonetheless, the twentieth century history of archives and libraries saw very modest preservation achievements, and experienced, rather, a prevalence of easier options that were also the least effective ones in the long term. These entailed the indiscriminate use of chemical products. Again, this was the trend all over Europe, but in Portugal these options showed circa a decade of delay, undoubtedly due to lack of financial resources, as well as bad management decisions, particularly in the public archives and Library. The heavy use of toxic chemical products documented in the archival sources, and oral information gathered from interviews with older workers and retired staff is quite impressive, especially if we attend to the current knowledge in the new millennium about the effects of these products and the imperative need of sustainable managing at a large scale. Many institutions with archive and library collections probably have similar histories of fungicide, pesticide and fumigant use. But the quantity of chemicals products which were used at Portuguese institutions, leaving inorganic and organic residues, such as dangerous insecticides like naphthalene and DDT among others, with a high persistence, are certainly troublesome. The historical summary presented here provides a basis for further investigations into the potential health hazards for users in reading rooms and individuals entrusted with the care of archives and libraries. The goal of such research is mainly to detect and establish the levels of contamination and its relation to health risks; to define its effects on items, typology and amounts of damage; to develop mitigation methodologies. This requires more investments and a serious plan to solve recognised problems.

Although in the two decades of the second millennium new approaches spread among Portuguese institutions allowing a better control of the situation, the implementation of preventive conservation strategies continues to be unsatisfactory. Also, no evidence of real collaboration between research groups and heritage institutions has resulted in improvements to the present situation where pest problems tend to subsist and there is no evidence of measures being taken on a regular basis or the development of a true strategy for the future. The increase shift of managers from professionals of the area to communication and economic backgrounds and politicians, with little preservation policies culture, raises new concerns. The tendency to invest more on initiatives with public visibility as opposed to preservation policies needs to change if current societies really intent to pass on to next generations the cultural heritage richness, values and identity. The presented Portuguese case study emphasizes that not only it is urgent to increase the awareness of institutional and political decision makers about preventive conservation but also to find new and sustainable ways to maintain our cultural heritage. This requires more investigation and a transversal dialogue between all partners: cultural heritage professionals (conservators, librarians, archivists and curators), managers, politicians and final users. The whole community needs to become more aware of the unsolved problems but also of the ones to be faced in the near future. Decisions such as the introduction of on-site generated nitrogen into the biocidal products regulation EU 528/2012 represents a setback. Thus, we argue that it is mandatory that heritage professionals are able, once again, to raise their voices against ill-informed managers or politicians and increase the awareness for sustainable management and reinforce the need for more research in the field. Only then will it be possible to recognise and honour those professionals who for over a century have defended preventive conservation and were well aware of its merits.

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# Clothed wax effigies: construction materials, challenges and suggestions for preventive conservation

# Efígies de cera vestidas: materiais de produção, desafios e sugestões para a conservação preventiva

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**Abstract**

Wax effigies, fully dressed life-size models of human figures, have been constructed since the medieval times. The construction materials of historical effigies differ to the contemporary ones, yet the construction process of the wax parts has more or less remained unchanged over the centuries. This paper starts with the history, construction materials and manufacture techniques of wax effigies. The inseparable relation of the wax effigies and their costumes is explained, and the characteristics and deterioration agents of their most important construction materials are presented in order to understand their needs for preservation, with emphasis on wax and fabrics. The aim of this paper is to suggest preventive conservation guidelines for wax effigies, with proposals for appropriate environmental conditions during display and storage, and suggestions for proper handling, storage and transportation. Advice for disaster preparedness and actions in cases of emergency situations is also provided.

**KEYWORDS**
Wax
Wax deterioration
Textile
Garments
Wax museums
Conservation

**Resumo**

As efígies de cera, modelos de figuras humanas completamente vestidas em tamanho real, foram criadas desde os tempos medievais. Os materiais de produção de efígies históricas diferem dos contemporâneos, mas o processo de produção dos componentes de cera manteve-se mais ou menos inalterado ao longo dos séculos. Este artigo começa com a história, materiais e técnicas de produção de efígies de cera. Explica-se a relação inseparável das efígies de cera e os seus trajes, apresentam-se as características e os agentes de deterioração de seus materiais de produção mais importantes, de modo a compreender as suas necessidades de preservação, com ênfase na cera e nos tecidos. O objetivo deste artigo é sugerir procedimentos de conservação preventiva para efígies de cera, com propostas de condições ambientais adequadas durante a exposição e armazenamento, e sugestões para manuseamento, armazenamento e transporte adequados. São também fornecidos conselhos para a preparação para desastres e ações em casos de situações de emergência.

**PALAVRAS-CHAVE**
Cera
Deterioração da cera
Têxtil
Vestuário
Museus de cera
Conservação

## Introduction

The use of wax dates back to ancient Egypt, Greece, Rome [1-4] and possibly in prehistoric times [5]. Children in ancient Greece and Rome played with wax dolls, and knowing the model casting skills of ancient Greeks who employed the lost-wax technique [6], and after noting findings of small moulds exhibited in several museums, it could be assumed that a great deal of ancient Greek votive offerings were made of wax. During the medieval times, statues of saints, miniature portraits, dolls, and other items were made of wax [7]. From the sixteenth century onwards, framed relief wax portraits, busts, life sized effigies, and smaller artefacts such as statuettes were made. Eighteenth century Italian wax portraiture heads and busts of capuchin monks are dressed in Franciscan cowls and bear coloured glass eyes and real beards and hair [1]. Waxen botanical models appeared in the sixteenth century and became widespread as a hobby in the eighteenth-nineteenth centuries [8]. In the end of the seventeenth century, Italian abbot Gaetano Giulio Zummo or Zumbo (1656-1701) collaborated with surgeon and anatomy professor Guillaume Desnoues (1650-1735) to create anatomical wax models [9]. By the eighteenth century, scientific and medical modelling had become popular [4], and in the nineteenth and twentieth centuries, thousands of wax moulages -three-dimensional wax models of pathological conditions- were made for educational purposes [10-11]. Natural history museums soon became interested in wax. The Natural History Museum in Florence hosts over 2000 models of anatomy, zoology and botany made of wax mixed with resins and colourants, created by Gaetano Zumbo, Clemente Susini (1754-1814), Francesco Calenzuoli (1796-1829), Luigi Calamai (1800-1851) and Egisto Tortori (1829-1893), who worked under supervision of anatomists [12-14]. In Paris and Turin, wax display stands were used to display clothes at international exhibitions in 1900 and 1911 respectively [15]. Biographies of renowned wax modellers were published by Pyke in 1973 [16].

This paper focuses on a more complex category of wax objects, namely clothed wax effigies, historical and contemporary ones. In the field of invasive or preventive conservation, the knowledge and information on the suitable preservation of effigies is limited. The combination of their construction materials, including wax, textiles, metal, wood, glass, real human hair, plastic, paints, etc. is challenging for conservators and curators wishing to establish good preventive conservation practices for such collections on display, in storage, and during transportation.

## History and construction technology of wax effigies: from ancient Greece to the twenty first century

The use of wax for human effigies is attributed to many reasons: wax is easy to find; it has a reasonable price; it has good workability; it can be modelled, cast, carved and sculpted; it permits corrections, changes and additions at any stage; it has a naturally convincing colour; it can be mixed with hardeners, plasticisers, solvents and pigments; it takes paint very well, can depict the human skin better than most materials that have been tested and used, and can be adorned with real hair and other organic materials to produce a realistic representation of the human body [1, 4, 17].

The technique of wax-casting a person's face has remained more or less the same since the antiquity. Our knowledge on the construction of historical effigies is mainly restricted to the observations of conservators who undressed historical effigies in order to restore them, and on historical sources. Direct modelling of soft wax, heating and fusing of separate wax parts, moulding and casting, and finishing by carving and scraping with ivory and heated metal tools have been reported [4].

### Waxen face and head casts in ancient Greece and Rome

Pliny (23-79 CE), in his Natural History book XXXV, LXIV [18] attributes the method of the making of wax casts of people's faces to Greek sculptor Lysistratus of Sicyon (fourth century BCE), who created plaster moulds of a living person's face, poured wax into them and made final corrections to the wax cast.

In the end of the third century BCE, and until close to the time of Pliny [19], wax effigies of faces attached on boards were carried in funerals and exhibited in the halls of ancestors, as Pliny states in his book XXXV, II [18]. Mazzeri [19] claimed that these were rather three-dimensional wax heads, and presented the outcomes of her research through the study of Latin literature, publishing images of sculptures depicting such objects, the casts of ancestors' imagines, and the photograph of a second century CE wax head of a man, discovered in Cuma, Italy. This is the oldest known life-size wax head, hollow, impressively realistic, with open glass-paste eyes and traces of colours on its surface [19].

### Votive wax effigies in the Renaissance

Models of parts of bodies were and are still offered in churches as ex-votos: gifts to a saint asking or thanking for a miracle. In Italy, the custom of making votives of parts of bodies out of wax led to the creation of full body wax votives [20]. From the thirteenth century and through the Renaissance, life-sized clothed wax mannequins were dedicated, with Cennino Cennini (1360-1472) detailing the stages of the cast production [21]. In the fifteenth century, life-size votive effigies were very popular at the church of Santissima Annunziata in Florence [20]. After a murder attempt against him in 1478, Lorenzo de Medici (1449-1492) ordered Orsino Benintendi (1440-1498) who was guided by Andrea del Verrocchio (1435-1488) to create three life sized wax votive effigies, with hollow wax heads, hands and feet, portrayed from life and painted with oil colours, attached on wooden skeletons interwoven with splint reeds covered with waxed cloths, and dressed with his own garments [21]. Over the following centuries, churches became packed with waxen votive effigies, cast in life or death, fully dressed in clothes or armour, and positioned closer or farther from the altar, depending on the status of the portrayed personality [21].

**Seventeenth-eighteenth-centuries funerary wax effigies**

In the seventeenth century, a new wax item category appears: wax funeral effigies. Funeral effigies had been constructed since the fourteenth century [22-23] to be displayed in funeral convoys, palatial or church settings in England, France, Italy and Prussia until the eighteenth century [24]. This follows the ancient – and still surviving – funeral practice of placing the deceased in common view for the last farewell; yet, when royal funeral ceremonies lasted for weeks, the disintegration of the body did not allow for its long-term public exhibition [25], resulting in the construction of mannequins to be used instead. The first reported use of a waxen effigy dates in 1612: Italian doge Leonardo Donà was buried privately the night of his death and a wax effigy was employed for the funeral rituals [1]. Although complete Italian funeral effigies have not survived to this date, funeral heads or wax death masks have survived. Such items, kept in gilt wooden cases or standing on bases, are modelled with cloth soaked in wax according to the Venetian carnival mask-making technique, and bear human hairs or present several small holes on the eyebrows, indicating the use of real hairs to enhance resemblance to the deceased [1].

Westminster abbey has a respected collection of wax funeral effigies. The oldest ones were made of wood or plaster, but after 1660 effigies with waxen heads and hands – and occasionally waxen legs – were made [26]. Most effigies were particularly constructed for the portrayed person, yet in some cases older figures were reused with additions and extensions to fit the new role and new head and hands were added [27]. The fully dressed effigies, with their multiple layers of clothing, accessories, jewellery, weapons, wigs, colouration of the face so that they consisted of vivid representations of the deceased once they were alive, render them unique artefacts that portray not only the person, but also their social status and personality. The clothes on the effigies are in most cases the ones that the portrayed person wore on a special occasion, such as their coronation day, providing further information of a historical value. In some cases, parts of clothing or accessories were particularly made just to be used on the effigy. Regarding jewellery, fake stones were used instead of the original jewels. The construction of the figure varies from one wax modeller to another. The effigies are therefore not just mannequins for the display of flamboyant costumes, neither just artworks of wax sculpture vividly representing known historical personalities. All of the features of these complex objects comprise an inseparable entity providing valuable information on the depicted person, their costume, status, but also information of the development of the effigy manufacture techniques. The habits of the deceased are also represented, as effigies often bear favourite items, or they are presented in the wax cast figures. One example is the bitten nails of the 1735 effigy Prince Edmund Duke of Buckingham, which also presents sunken cheeks, indicative of his health condition before his death [1, 27].

The waxen parts were based on death masks, cast from the corpse, or modelled from the corpse or the living person, and overpainted to imitate human skin [27]. Often the effigies were constructed while the portrayed people were alive, enabling them to oversee the procedure and approve the final outcome. For example, the 1775 effigy of William Pitt, Earl of Chatham was publicly presented as soon as it was finished, three years before the Earl's death [27].

The heads, fixed on wooden posts or cardboard strips, bore glass eyes and painted or real eye-lashes and eyebrows [27]. An interesting case is the wax effigy of Queen Elisabeth I: the original 1603 effigy was wooden, yet in 1760 the head and hands were replaced by thin wax casts set on plaster bases [27]. Wax was also used on features requiring more detailed work, such as ankles and calves of otherwise wooden limbs [25]. The torsos were made of wood or canvas or other cloths stuffed with straw, hey, tow and sacking, and stiffened with wooden posts or/and wire; or built up by card and nailed on the effigy [25, 27-28]. The limbs were wooden and attached to the wooden base with wires, string, or handmade screws; or padded about iron wires and glued on the central skeleton; or made of canvas, plaster and glue and bound with woollen cloth; or made of wax resin reinforced with cloth and covered with silk [27]. When legs or feet were not meant to be viewed, they were simply not constructed, such as in the case of the 1740 seated Queen Anne effigy [27].

Several layers of original clothing dressed the figures, including armour, human hair wigs, leather shoes, jewellery, weapons, undergarments and accessories [27-29] made of various materials such as silk, velvet, wool, cotton, linen, canvas, lace, kid, goatskin, fur, ostrich feathers, glass, silver, iron, gilt copper, pastes, artificial pearls and gems, and even the oldest known stuffed bird surviving today [27]. Interestingly, the 1702 effigy of Duchess Frances of Richmond wears woollen inner stockings, claimed to have been put to prevent the wax of the legs from staining the silk stockings [27], rendering it an interesting example of early preventive conservation attempts.

Wax modellers known to have created funeral effigies are Mrs. Goldsmith (active 1695-1703), American Patience Lovell Wright (1725-1786), Catherine Andras (1775-1860), and possibly Mrs Salmon (1650-1740) and her employee Thomas Bennier [27].

In the end of the eighteenth century, the Westminster Abbey funerary effigies were used as attractions [22]. In the early nineteenth century visitors paid to see them [22, 28], and collection keepers started paying for their conservation [29-30].

It is worth mentioning that one more funeral effigy, belongs to non-royalty Sarah Hare (1689-1744), permanently exhibited in Stow Bardolph church, Norfolk, UK [27, 31], as the sole testimonial of "the spread of the tradition for effigial representation" [27].

**Wax effigies as portraits: sixteenth-nineteenth centuries**

French aristocracy commissioned the creation of wax portraits and busts in the sixteenth century [15]. French court artist Antoine Benoist (1632–1717), commissioned by King Louis XIV (1638-1715), produced forty three wax effigies, known as *Le Cercle Royal*, exhibited for a fee throughout France since 1668 [32-33]. King James II (1633-1791), triggered by his work, invited him to England in 1684, to create effigies of the British aristocracy [33]. In London, Mary Salmon (1650-1740) created at least 140 wax figures, exhibited for a fee in fairs and in her *Mrs. Salmon's Waxworks*, from 1710 up until her death [34]. Some were able of moving, thanks to inbuilt clockwork mechanisms [15, 34]. In 1721, Italian sculptor Bartolomeo Carlo Rastrelli (1675-1744) created the wax effigy of Russian Tsar Peter the Great (1672-1725), using wood, wax, metal and enamel [35], and 19 years later, Danish court painter Johann Salomon Wahl (1689-1765) created wax figures of the Danish Royal couple [15]. Wax modelling was not restricted in the European continent. In 1771 Patience Wright and her sister Rachel Wells held a successful life-sized wax figures exhibition in New York [27].

**Curtius, the French Revolution and Madame Tussaud**

Swiss physician Philippe Mathé Curtius (1737-1794) initially created anatomical wax models, yet in 1765 abandoned medicine to practice wax modelling as an artist, establishing his *Cabinet de Cire* in 1776, soon flooded with visitors [36]. Curtius taught Madame Tussaud (1761-1850) who in 1793 was forced to create wax death masks of the nobles executed during the French Revolution [37]. In 1794 she inherited Curtius's wax exhibition, moved the best exhibits to Britain in 1802 [7] and established her own exhibition in London in 1835.

The procedures followed by Curtius and Madame Tussaud started by applying oils and ointments on the face of the subject, and straws in the nostrils of living individuals for breathing purposes. A mask was then created by applying fine plaster of Paris. Clay was squeezed in it to produce a model, and a clay mould in two pieces was made out of it. Hot wax was poured into the mould, creating the final hollow product which was coloured and finished with human hair, human teeth and glass eyes [7].

**Modern wax effigies**

In the nineteenth century the popularity of wax effigies was such that an exhibition was on permanent display in nearly every major European city [15].

Mid-twentieth century recipes known for casting from the skin include paraffin, bayberry wax, carnauba and stearic acid. For the separation of the plaster negative, yellow beeswax and carbon tetrachloride, or paraffin in benzene were used. Known recipes for the waxen parts are the Douglas formula (white wax, paraffin, talcum, cornstarch and yellow beeswax); the Ziskin formula (refined paraffin, pale and dark carnauba wax, and beeswax); and resin-wax formulas. To strengthen the casts, cotton, wood, jute, hemp, cheesecloth and burlap were used [38].

Today, the use of wax continues for hyper-realistic human sculptures exhibited in modern museums worldwide. Wax effigies represent important historical, political or artistic personalities and replicate activities and historical moments for educational or commercial reasons. Historical, Natural History and other types of museums use wax mannequins in dioramas as exhibition tools to spur the feelings of the museum visitors and enhance the museum experience, motivating them to become part of the depicted scene and take pictures among the free standing wax models [39]. At the Melody World Wax Museum in Mysuru, India, wax figures are used to display musical instruments, rather than the instruments being displayed in showcases, enabling visitors to see the cultural context within which the instruments were played. As it has been beautifully expressed by Varutti [39], body reproductions "facilitate the connection between the present and the past by endowing the past with physical features and by enabling the establishment of new, personal, and emotional relationships with a past no longer distant and authoritative, but approachable". Well-known wax museums operating today include Madame Tussaud in 23 cities; the Hollywood Wax Museum in 4 cities; the National Presidential Wax Museum in Keystone, South Sakota, USA; Dublin's National Wax Museum; the Pavlos Vrellis Wax Models Museum of Greek History, Ioannina, Greece; the Siddhagiri Gramjivan Museum, Kaneri, Kolhapur, India; and many more.

Creating an effigy does not always require a large amount of wax, since only the body parts visible to the audience are made of this material. The materials of the non-wax parts of the effigies vary. Wax artist Pavlos Vrellis for example, made skeletons of fine iron rods, and built up with "plaster and sackcloth, or matting, or flax, or wood shavings" [40].

Some wax artists work solely based on photographs or paintings depicting their subject, and on their sculpting skills and their osteology, myology and physiology knowledge [40]. For more lifelike effigies of living people, the wax artist meets with them to take numerous measurements. Over 200 face measurements have been reported, non-including those required for other body parts [41]. Along with drawings, photographs and additional research, the measurements are used to sculpt a clay body on a metal skeleton, to create a mould later [41].

The sculpting of the head, performed in several stages, requires about six weeks and employs careful comparison of the sculpture to the measurements taken during the previous stage. The plaster mould of the head is prepared


**Figure 1.** Contemporary hyper-realistic wax effigy by Madame Tussauds during painting of the skin. Note the custom-made glass eyes and the hair on the eyebrows. Source: Insider, 'How Madame Tussauds Creates its Realistic Wax Figures' (2018-08-03), video uploaded at https://www.youtube.com/watch?v=CQ9knHW6LIY (accessed 2019-11-25).

in sections – fourteen different sections have been reported – which are then assembled together. The mould is rinsed clean, and placed into a *wax bench*, a specially prepared table that keeps it stable while melted wax is poured into it. Beeswax is still used for the creation of wax effigies, following the tradition of centuries. Japanese beeswax has been reported as a material. The wax solidifies within an hour, forming a thick crust in the interior of the cast, the thickness of which measures only a few centimetres. The crust at the area of the neck is cut away, and the remaining liquid wax is poured out, leaving a hollow wax head, which is allowed to solidify for a further hour, after which the plaster mould is removed piece by piece. The production of hands and other wax parts follows different procedures, with hands often cast from the subject [41].

While creating wax figures, deformations may occur, that can be retouched by artists later. Molten wax flows in small niches of the mould and after its removal, distinguishing lines from the mould connections appear all over the figure. The sensitivity and brittleness of the wax can easily result to more deformations. Finally, the addition of powder pigments in the wax creates different colour and texture variations [42].

The skin tone of the casts is matched according to charts [41]. Oil colours are most often used due to their compatibility to the wax. The paint is not brushed straight onto the wax surface, but splattered against it, then blotted to blend in, creating a speckled look to imitate skin texture and pores [41] Figure 1. Knuckles, veins and other features are painted, nails are manicured, and after the insertion of eyes and hairs, extra paint is added on the face like makeup [41]. In total, over thirty five layers of colour are applied to achieve a vivid effect [7].

Ready to use glass eyes [40], acrylic [7] and custom-made eyes that imitate the uniqueness of the person's iris [41] are used. As a medical glass eye spins on a wheel, the artist blots on a white pupil. The surface is over-painted while the eye stays still, with colours of the portrayed person's iris. The eye is then placed back on the wheel, the black pupil is added, and the spinning of the wheel blends the liquid together. Red silk threads are adhered on the sclera to imitate blood vessels [41].

The eyes are placed on the head, and synthetic or actual human hair are added [40-41]. Hairs, eyebrows and eyelashes are inserted individually by piercing the wax with a hot needle, melting the wax, and enclosing the hairs, in a lengthy process that can last for four weeks [41].

Apart from sculpting and colouring, realistic quality is also achieved through the dressing with appropriate costumes. Clothing is a basic element of an individual's identity and an important feature of wax effigies. The garments are in many cases authentic clothes donated by the depicted person, replications of the originals, contemporary custom made, or modified old pieces [40].

The recipes of contemporary wax effigies and the rest of the materials are not widely available, apart perhaps in exhibition catalogues where the materials of the artworks are written down. For example the materials listed for Maurizio Cattelan's 2001 effigy of Hitler entitled *Him*, are wax, human hair, suit and polyester resin [43].

A whole setting may be created around the effigies, using various materials Figure 2. Vrellis lists real and artificial rocks "made of sackcloth, glues, colors and plaster", cement, wood, leaves, grass, canes, branches, original historic artefacts, and props made of plaster, fibres, flax, cloth, clay, tempera colours etc. [40].

## The composition and nature of wax used for effigies

The wax employed in the making of wax effigies from ancient times until present is mainly European and Asian

**Figure 2.** *The slaughter of Ali Pasha* at Pavlos Vrellis Museum of Greek History. The building façade and props are not just a setting to highlight the wax effigies, but part of the wider personal artwork by artist Pavlos Vrellis, who wished to transform the museum interior so that the visitors themselves can immerse into it and live a unique experience by becoming part of the represented scene. Image courtesy Pavlos Vrellis Museum of Greek History.

beeswax. European wax producing bee species are *Apis mellifera*, and Asian ones are *Apis florae*, *Apis dorsata* and *Apis cerana* [44]. Different bee species produce wax with different compositions and melting points [44-45]. Asian beeswaxes have a shorter carbon chain length, lower melting point, higher ester/acid ratio, reduced free fatty acids, increased hydrocarbons, and are softer and more plastic than European waxes [44-45]. The colour of honeycomb beeswax varies from white when first produced, to yellow, brown and black, as the wax ages, due to the relative amounts of propolis and pollen colorants [44]. Different beeswax subtypes in the beehive serve as cues for bees to recognise bases, sexes and comb age [44]. The more larvae excrements, pupae skins and propolis rests accumulate over the years, the darker the wax [44, 46] and the higher the protein content [44].

Worker bees secrete wax from the abdominal wax glands, plasticize it by chewing, and then use it as a building material for combs and honeycombs [5]. Wax is traditionally extracted from the honeycombs through heat direct from the sun or from boiling [5, 44]. Heating in iron, zinc brass or copper containers results in the production of dark wax, therefore stainless steel and aluminium containers are contemporarily used [44, 46]. Traditionally wax is bleached by exposure to the sun [44]. Modern bleaching methods include the use of citric acid, oxalic acid, hydrogen peroxide and potassium permanganate [5, 44, 46].

Chemically, beeswax is an inert complex material of a crystalline structure, comprising of over 300 different substances: saturated and unsaturated hydrocarbons, saturated and unsaturated monoesters, diesters, triesters, hydroxyl monoesters, hydroxypolyesters, acid esters, acid polyesters, free fatty acids, free fatty alcohols, glycerols, palmitates, oleates, paraffins, alkanes, iso-paraffins and various other substances and volatile aroma components [5, 42, 44-45]. Beeswax becomes plastic at 30-35 °C, and begins to melt at 60-70 °C [44]. Heating at 120 °C for over 30 minutes removes water content and increases the wax hardness [44]. Long heating or higher temperatures lead to degradation and loss of esters influencing the physical characteristics of the wax, changing the wax structurally and altering the characteristics of many of its minor compounds [44]. After cooling down beeswax shrinks by about 10 % [44].

Chinese insect wax from *Ericerus pela*, and vegetable waxes carnauba from the Brazilian *Copernicia cerifera* palm and candelilla from American plants *Euphorbia* and *Pedilanthus*, were introduced in Europe in colonial times [5]. Vegetable waxes form as a layer on the leaves, limiting the diffusion of water and solutes, while controlling the release of volatile substances [47]. From the nineteenth century onwards, beeswax was often mixed with other waxes including candelilla, carnauba, ceresin produced since 1875 by refining fossil wax ozocerite [5], Japan wax, paraffin, spermaceti and stearin [48] to alter the wax properties or reduce the cost. In example, carnauba, one of the hardest and highest-melting natural waxes [5] increases the hardness and raises the melting point [42]. Paraffin, a mixture of alkanes obtained from crude petroleum distillation, and stearin, synthesized from animal fats saponification, were introduced in the mid nineteenth century as beeswax substitutes [17, 42, 49]. Fully synthetic waxes have been produced since 1935 [5].

The beeswax employed for historical wax effigies was probably bleached, with additions of pigments and inerts [4]. Various wax modellers used different recipes [8, 49]; in example, Anne Marie Carl-Nielsen (1863–1945) mixed potato flour, olive oil, Venetian turpentine, Burgundy pitch, butter and colour in her wax pastes [48]. Starch has been reported to assist removal from the mould [38]. Lead was added to colour the wax, and reduce its shrinkage and hardening to ease carving [4]. Lead white, zinc oxide and Spanish white were added to decrease transparency [48]. It should be noted that heavy pigments gravitate during the cooling of the wax, and thus the colour gradually darkens towards the higher parts of the relief, also creating textural variations [4, 42]. The addition of animal fat, castor oil, pitch, tallow, lard, Canadian balsam, linseed oil and olive oil, composed of triglycerides, esters of glycerol, saturated and unsaturated fatty acids, increased malleability at room temperature [4, 42, 48]. Natural resins such as Venice turpentine and rosin (composed of abietanes, pyrans and labdanes) were added to increase the hardness of wax and add colour [42, 49]. Starch (composed of amylose and amylopectin) and flour, were also added in the nineteenth century wax mixtures as fillers to reduce the cost of the model since beeswax was expensive [4, 42, 48-49]. Glycerol and talcum powder have also been reported [48].

## Deterioration agents of clothed wax used for effigies

Wax effigies are constructed by a variety of organic and inorganic materials, in contact to one another: the wooden parts to the filling material, the metal skeleton and the wax; the wax to the fabrics, glass eyes, hair etc. In most cases, the construction details only become known during conservation treatments, during which the effigies are undressed and disassembled [25, 27, 50].

In general, damage to effigies may take many forms, as a result of poorly controlled ambient environment, inadequate maintenance, improper handling during exhibition, storage and transportation, inadequate packing for transportation or shipping; and insufficient measures for disaster preparedness. The agents that affect wax effigies the most are light, temperature (T), humidity, pollution and pests. Due to the mixed materials used in their making, and due to the factors listed above, effigies can present physical damage, chemical deterioration, weathering, mechanical and biological damage.

Wax effigies, their deterioration factors and conservation-related issues have not received adequate scientific attention, resulting in a lack of relevant publications. Reported damage on the wax components of effigies includes cracks, breakages and losses; white bloom due to the drying out of the wax; surface dirt; surface cracking and penetration of dirt in the wax; and loss of the colour that was originally applied on the wax [27, 51] Figure 3. Reported damage of other materials includes instability of effigies due to loosening of the joints of the torso and limbs; rotting and weakening of the armature and binding holding the arms in position; insect damage on hair, textiles and whalebone; hair losses including eye-lashes and moustache; oxidation and losses of metal parts; loss of gilding; holes and losses of fabric including loss of clothing elements such as tassels; fading of silk- in some cases due to washing; discolouration of threads of embroidery; weakening of threads resulting to loose pearls and stones; losses of smaller elements such as buttons; dirt on fabrics, fur, hairs and leather; rodent attack on the clothes and storage cabinet; rotting of fabrics due to moisture; and insect remains on clothing [27, 31, 51-52].

**Wax ageing and wax bloom**

Information on the deterioration of wax can be retrieved from papers on wax objects other than effigies, yet it should be stressed that different types of objects present different degradation problems [53]. Non-pigmented wax objects have been reported to exhibit flaking and delamination due to the impression and kneading methods involved in their making which led to the creation of a fine, layered microstructure [53]. Known problems with wax are its sensitivity to many solvents; susceptibility to damage by heat and pressure; shrinkage, hardness, brittleness and susceptibility to breakage due to ageing; and white surface bloom [4, 53]. Wax discolouration may occur in cases of waxes mixed with pigments, plasticisers or hardeners [4].

Wax bloom does not seem to affect beeswax mixed with inorganic pigments [54]. It is a layer or crystal aggregations that develops over weeks or months on newly created beeswax surfaces, considered as aesthetically unacceptable, and the compounds forming the efflorescence are sometimes regarded as beeswax plastifiers, and their depletion as an embrittlement cause [55]. Wax efflorescence is composed of aliphatic hydrocarbons and alkenes [54, 56] or palmitic, stearic and other fatty acids naturally occurring in beeswax [57-58], or beeswax sometimes combined with a small amount of water [59-60]. A study on beeswax seals [55] revealed that wax bloom composition was similar, regardless of origin, age and storage history and comprised of linear alkenes naturally occurring in recent Mid-European beeswax, while historical beeswaxes contained only traces of unsaturated hydrocarbons. Wax bloom is caused by a variety of factors, including the wax composition and manufacture procedure, and external environmental parameters. The first group of factors includes higher cooling rates during solidification [61], the presence of impurities in the


**Figure 3.** Damage on the waxen parts of the 1744 Sarah Hare's effigy: breakage on one finger *(a)*, wax discolouration and degradation *(a,b)*, mould *(a,b)*, loss of hairs *(b)* and surface colours *(a)*. Details from photographs uploaded on twitter by Brown, J. (2019-08-09) at https://twitter.com/dr_jrbrown/status/1159907535509446656 (accessed 2019-11-29).

beeswax [62], the presence of admixtures such as stearine or resins [56-57, 63], and wax degradation processes [58]. The migration of aliphatic hydrocarbons towards the surface is possibly promoted by the recrystallization of beeswax at temperatures below 12-16 °C [54], or as a result of an outflow of volatile unsaturated compounds at a 38 °C melting point [55]. The high fatty acid content is caused by the hydrolysis of esters due to ageing or the presence of stearine mixtures [56, 64]. Environmental factors causing wax bloom include extreme temperatures [54, 60] or temperature fluctuations – also possibly exposure to fire – [54, 56-57, 61], and lower or higher relative humidity (RH) [59].

High quantities of starch in the wax mixture lead to structural weaknesses [42]. The ageing of the wax alters its chemical composition. Esters hydrolise, flavonoids are chemically transformed, alkanes undergo changes affecting the lighter hydrocarbons, unsaturated hydrocarbons are reduced, and the hydrolysis of low molecular weight esters leads to an increase of acids and free alcohols [42]. The increase in acidity leads to an increase in polarity and hardening [42]. The ageing of the fatty acids in tallow and lard used as additives leads to partial hydrolysis of esters and the formation of palmitic and stearic acid, diglycerides and monoglycerides, and exudation of oils [42, 65]. The degradation of abietadienic acids results to the presence of dehydroabietic acids [42]. In turn, free acids in wax can cause corrosion on the copper elements [48] of wax effigies, which will lead to wax discolouration if the two materials are in contact with one another. In addition, Cu ions act as catalytic pro-oxidants and cause chain scission, hydrolysis, lipid oxidation, deterioration and liquidation of the wax mixture [48].

**Problems caused by unstable environmental parameters**

Organic materials share common characteristics such as complicated molecular structures, susceptibility to deterioration due to extremes and changes in RH and T, hygroscopicity, sensitivity to light and high risk of microbial and insect attack. The textiles employed in wax effigies as clothing or as sacking materials may be made from animal, vegetative materials or synthetic fibres, and their deterioration is accelerated by external factors which cause significant reduction in strength and elasticity [66]. Their main physical and chemical deterioration factors are light, humidity, temperature, air pollution and pests [67].

Climatic fluctuations result in the formation of cracks in the wax, leading to fragility [42]. Big temperature and humidity fluctuations increase the deterioration rate and promote pest activity.

**Problems related to temperature (T)**

Low, and abrupt falls in temperatures can be destructive, as materials, including wax, contract and harden, become brittle, more fragile, vulnerable to vibration and susceptible to breakages and losses due to mechanical stress and vibrations [42].

Temperatures above 20 °C result in sticky surfaces of the wax [48]. The softening of wax at temperatures over 30 °C [42] leads to the entrapment of dust, dirt and pollutants within the tacky surfaces and render it more sensitive to handling [57]. Depending on the type of wax mixture, temperatures over its glass transition temperature, can cause permanent wax deformations and oily stains on the textiles in contact to the wax.

High temperatures cause evaporation of the water molecules of hygroscopic materials, resulting to a dry and weak structure causing mechanical damage and formation of cracks, and create an environment suitable for the growth of insects and micro-organisms.

**Problems related to relative humidity (RH)**

RH plays a significant role in chemical and physical forms of deterioration. Organic materials in wax effigies, such as fabrics and wood, absorb and lose water and therefore swell and shrink respectively along different directions. Such dimensional alterations among the materials cause a continuous pushing and pulling against one another, resulting in structural cracks and gaps in joints.

Humidity can promote hydrolysis of the ester bonds in wax, and saponification in the case of alkaline humidity, which particularly affects aged materials [42]. High humidity levels cause metal objects to corrode faster [68] and biological activity to increase. Poor ventilation and RH > 65 % results in an increase of the humidity content of hygroscopic materials, attracting microorganisms, which generate metabolic water further increasing the water content [42]of textiles, leather, wood, and other hygroscopic materials present in wax effigies.

Low moisture levels can cause shrinkage, dryness and brittleness to materials. Dryness results to the loss of light hydrocarbons in wax as a result of sublimation reactions [42].

Continuous and large fluctuations of humidity can be destructive to wax effigies. Hygroscopicity results fabrics to readily take up and lose moisture directly connected with fluctuations of relative humidity and temperature. This can cause dimensional change and mechanical stress that can lead to breakage and structural damage as fibres gradually lose their elasticity and resilience.

**Problems caused by light**

Visible light, infrared (IR) and ultraviolet (UV) radiation triggers a series of photochemical, photolytic and thermochemical reactions resulting in the physical and/or chemical composition [42] of several of the materials present in a wax effigy. In addition, lamps and direct natural light may comprise a heat source. The photochemical effect of light is a process by which the absorption of photons from the surface of the object provides its molecules with energy triggering chemical reactions [42].

Light radiation in any form can cause the fading of textile dyes and brittleness of the fibres [69]. Damage from photochemical reactions is irreversible and can cause fading, bleaching, colour changes, change the crystal structure of wax [70-71] and can make organic materials dry and brittle [72]. Smaller wavelengths result in greater discolouration [42].

Damage induced by light on wax is often localized on the surface due to loss of tone in the organic dyes in the wax mixture, or due to the presence of plasticizers and hardeners [42].

Daylight can cause fading to the pigments on wax, paper and textiles, and the pigments or dyes that fade can disappear within as little as a few hours of direct sunshine [73]. UV causes yellowing, chalking, weakening, and/or disintegration of wax, leather, glass, plastic and other materials [73]. IR heats the surface of the wax surface, becoming a source of local exposition to high temperatures that may exceed the 30-35 °C in which beeswax becomes plastic, or even the 60-70 °C at which it begins to melt.

**Problems caused by pollutants and surface deposits**

Pollutants and surface deposits result not only in the degradation of the aesthetic quality of effigies, but their presence involves a series of alterations of the physical, mechanical and chemical properties [42] of the various materials they are composed of. Pollutants in wax museums derive from the external environment; the construction materials of the museum, exhibition or storage areas; and the materials of the wax effigies and their settings. Their concentration varies among the various museum areas depending on the climate and geographic location of the building [74], its vicinity to roads, industry and farms, the outdoor concentration levels and the air exchange rates, and fluctuates throughout the year and time of the day due to open doors and windows during visiting hours [75].

Pollutants deriving from outdoor sources include sulphur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), nitrogen oxide (NO), ozone ($O_3$), hydrogen sulphide ($H_2S$), reduced sulphur gases [74-75], pollen and dust. Vehicles, industrial activity, sea, soil and biological organisms are some of their sources [76]. Visitors and museum staff transfer dust particles and fibres through their clothes and shoes. Indoor induced pollutants derive from various materials such as building materials, wood, wool, carpets, paints, composite boards, cleaning products etc. and include acetic acid ($CH_3COOH$), formic acid ($CH_2O_2$), acetaldehyde ($C_2H_4O$), formaldehyde ($CH_2O$), $H_2S$, carbonyl sulphide (COS) and $O_3$ [74].

Dirt particle accumulation due to inadequate exhibition and storage has been reported as a deterioration cause in wax objects, leading to darkening of the surface, from a grey colouring to a dark brown tone, exacerbated by the thickness and density of the dirt layer, and compromising the aesthetic, plastic and perceptive value of the objects [77]. Part of the dirt becomes embedded in the upper wax layers, due to the thermoplastic and electrostatic nature of wax [48, 77]. Surface deposits can trigger further reactions with the wax components, as pigments can react with the sulphur compounds of the atmosphere. Soft dirty surfaces can result to pest attraction and along with high humidity can increase the action of biological agents [42]. Abrasion of wax surfaces due to friction with solid particles on the surface has also been reported [42].

Deposited dirt and dust can embed into the textile fibres, causing discolouration, obscuring the appearance of the exhibits and damaging fibres by causing cuts and abrasions. Pollutants settle in the textile structure, causing disfigurations and affecting dyes, finishes and embellishments. The sharp edges of particles such as salts and pollutants that can be carried onto the museum exhibits through the air, including COS, $SO_2$, $NO_2$, etc., can cause mechanical damages to the textile fibres, cutting and abrading them, especially when the fibres expand and contract in response to changes in RH [78-79].

Pollutants are also harmful to effigy materials such as pigments, glass eyes, metal and leather accessories, paper labels etc. $O_3$ causes pigments to fade [74, 80-81], organic dyes to discolour or blacken [42] and double bonds between C atoms to break down [42]. $SO_2$ and nitrogen oxides cause degradation to vegetable-tanned leather [82], paper [83] and artists' colourants [84]. Organic carbonyl pollutants, mainly $CH_3COOH$, $CH_2O_2$, $C_2H_4O$, and $CH_2O$, have been accused for efflorescence on glass [85] and corrosion and degradation of copper [86], bronze [87] and paper [88]. Reduced sulphur compounds are related to silver tarnish [89].

**Problems caused by biodeterioration and pests**

The organic materials present in wax effigies such as wax, textiles, paper, wood, starch, binding media for pigments, soils, and stains are an excellent source of food for microbes and insects.

Wax containing starch is prone to mould and fungal attack, the latter causing flaking, whitening in appearance, and powdering, apart from wax pastes that include vermillion or verdigris in their composition [42]. Mould and bacterial spores can be airborne or carried along with other particulates [90]. The presence of carpets in the museum increases the concentration of micro-organisms. Bacteria are commonly brought into a collection area by contaminated floodwater or grow in standing water in buildings [90]. High RH increases the risk of bacterial and microorganism infection, with mould being less constrained by lack of water compared to bacteria, and mould growth being limited by the water available in the substrate material [90].

Insects use wax and textiles for food, shelter and breeding. The Hemipheres family can consume wax and lay their eggs on it, and *Lepidoptera* such as moth and *Lepismatidae* such as silverfish, feed on fabrics, leather, wool and feathers [91]. Darker wax is more prone to *Galleria mellonella* L. wax moth attack [44]. Insect biological residues are acidic and can change the pH of the objects, causing physical and chemical alterations [91].

Rodents have been reported to have chewed on the clothes and the cabinet housing an effigy [31].

**Problems due to handling and transportation**

Wax effigies are particularly vulnerable to damage during handling and transportation. Given the complexity of clothed wax effigies, damage may occur both on their surface, as well as in their structure. Typical damage includes soiling, greasing, staining, scratching, surface abrasion, small or large tears in the textiles, loss of decorative elements, and wax breakages and losses. Handling objects with bare hands can leave greasy stains on the surface of objects.

**Disasters in wax museums**

Effigy collections are susceptible to disasters as any other museum, yet the nature of such exhibits makes them more prone to damage and harder to recover after a disaster. Known disasters in wax effigies collections trace back in 1630, when a fire at the Chiesa della Santissima Annunziata in Florence and neglect of the remaining works resulted in the destruction of all of the Renaissance wax effigies [21]. The Madame Tussaud's in its over 250 years of its existence, has suffered from disasters including a shipwreck in 1822, a fire in 1925, wartime bombing in 1941 [15] and several vandalism attacks, mostly against the figures of Hitler and Osama bin Laden.

Fire is the greatest threat for wax effigies collections due to the highly flammable and heat sensitive materials that effigies are made from. In 1988, a fire destroyed the Southwestern Historical Wax Museum in Texas, USA, founded in 1963, and among losses were the Bonnie and Clyde wax figures and the original Death Car that had been used in the homonymous film Figure 4. It should be noted that objects are not only at risk of flames and high temperature, but also from smoke and its products.

Natural flood and leaking are another threat to wax effigies. Problems of the building design, poorly made installations and pipelines, inadequately maintained roofs and draining systems are some of the causes of flooded areas [92]. Naturally caused floods are more frequent nowadays as climate change is producing more intense natural phenomena including elevated humidity, higher water levels and more frequent flooding [93]. Older buildings are not usually flood-proof, and some are built below sea


**Figure 4.** The Southwestern Historical Wax Museum in Texas *(a)*. The same museum under the 1988 fire *(b)*. It housed Bonnie and Clyde wax figures and the Death Car used in the homonymous *(c)*. The fire destroyed the wax figures completely, and caused severe damage to the car *(d)*. Original photographs from Ballinger, F.R. 'Bonnie and Clyde wax display-the Southwestern Historical Wax Museum' (n.d.), in Bonnie & Clyde's Hideout, http://texashideout.tripod.com/wax.html (accessed 2019-12-01).

level, rendering them vulnerable and prone to flooding [92]. Water damage can lead to biological damage if not treated urgently, especially to the organic materials of wax effigies, such as textiles, wood and leather. Other damage due to flooding and leakage includes dampness, mud or soiling, swelling, discolouration, rust on the metallic parts, etc.

Wax effigies, made from a really fragile and brittle material – wax – and comprising of many different parts, are very prone to earthquake damage. Objects respond in four different ways to earthquake activity: remain stable, rock, slide or overturn [94]. Vibrations can be disastrous for the various parts of the effigies, causing mechanical damage, cracks, surface flaking, breakage and detachments.

## Guidelines for the preventive conservation of wax effigies

Preventive conservation is the mitigation of deterioration and damage to cultural property through the formulation of procedures for setting and controlling appropriate environmental conditions, integrated pest management, control of pollutants, handling procedures, guidelines proper storage, exhibition, packing, transport and a plan for preparedness and response to emergency situations and disasters. Preventive conservation is an on-going process that continues throughout the life of cultural property and does not end with interventive treatment. It is intended to minimize the negative effects of poor environmental conditions to which objects are exposed, and to reduce the probability of future damage by creating a suitable, steady environment, where the external environmental conditions do not disturb the internal ones, which in turn are set and controlled according to the needs of the exhibits. Microclimates could be created for the most delicate wax objects, the term referring to the composition of the environmental physical state of an area, resulting both from the natural atmospheric conditions such as humidity, sunshine, temperature and air, as well as from human activity including body heat, artificial air conditioning and lighting [95]. The various parameters that may cause damage to the wax effigies should be identified, evaluated, detected and controlled regularly [42].

The main and interrelated elements of managing museum collections according to ICOM (International Council Of Museums) [96] are the recording of each object, the protection and preventive conservation of objects and the controlled access of viewers to the collections. First, the materials present in the objects need to be recorded and understood. Secondly, the environment in which each effigy is stored or exhibited should be studied for parameters known to affect museum objects. Thirdly, one should study how these parameters interact with all of the materials present in each effigy. Then, harmful conditions should be minimized or eliminated. Finally, basic guidelines for care, handling and cleaning should be followed and access of the visitors to the collections should be controlled.

A challenge to the preventive conservation of clothed wax effigies is the fact that they comprise a variety of construction materials, clothing items and accessories, each having different needs. In historical, fully dressed effigies, most of the garments are completely invisible to the museum visitors, as they are covered by other clothing items, yet they are not displayed separately, following the decision that the figures should be dressed with all the garments they wore when they were produced [25]. Contemporary wax effigy artists should be able to produce guidelines on their display and environmental conditions for their proper future preservation.

### Recording of the materials of wax effigies

To understand the causes of deterioration of clothed wax effigies in a collection, it is important to first understand the construction technology of each individual effigy and record the materials present and the ways they interact to one another. The complex nature of effigies makes the process of preservation more complicated since it needs to include and work equally protectively for all the materials: wax, textiles, pigments, acrylics, glass, metals, etc. and other materials present having a historical value such as old paper labels and inks, and also conservation materials such as adhesives applied in previous treatments, each of which has different needs and require different environmental conditions. Each effigy in a collection should be studied individually in order to propose a preventive conservation plan tailored to its needs. Detailed record drawings, X-rays and CT-scans can be employed to reveal a great amount of information without the need for disassembling. Optical microscopy (OM) can be used to identify the nature of starch in the wax mixture [48] and the types of fibres on the costumes. Fourier transform infrared spectroscopy (FTIR), direct inlet electron ionisation mass spectrometry (DI EI-MS), high temperature gas chromatography (GC) [5], and micro-chemical tests can be employed to determine the precise composition of the organic substances in wax mixtures [49]. X-ray fluorescence (XRF), micro-Raman spectroscopy, FTIR, micro-chemical tests and scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDX) can be employed for the identification of inorganic components in the wax [48-49] and the inorganic materials of the effigy, costume and accessories.

### Creating and controlling a stable environment

First, the museum building should be completely insulated from the external destructive factors such as atmospheric pollutants, humidity, temperature and insects. Walls, ceilings, roofs, windows, doors, pipelines and other elements should be inspected to see if improvements can be made to eliminate deterioration factors.

Then, the appropriate conditions need to be created for each exhibit, depending on the materials of each effigy, and the props and exhibition setting. The presence of conservation materials on the effigies should also be taken into consideration. The preservation proposal plan should focus on environmental parameters such as RH, T, light, atmospheric pollutants and biological agents including insects, rodents, fungi and microbial attack. These parameters need to be constantly or regularly recorded, with data loggers, pest and dust traps to check on the effectiveness of the measures applied, allowing for museum keepers and conservators to interfere and proceed to changes when necessary. High-resolution microphotography on the exhibits, superimposition in a computer program and mathematic estimation of the occurrence of small differences can be a valuable tool for the detection of alterations not immediately visible [42].

The number of visitors entering the museum should be controlled and limited to the internationally accepted number of one person per 3-5 $m^2$ [96].

**Suggested measures for temperature**

Wax objects must not be placed near heat sources such as radiators or air conditioning units, nor in front of windows, and must not be in contact with external walls as the T and humidity of the wall can pass directly to the object. To maintain an appropriate T, central heating or air conditioning can be used to supply air at the desired T levels. T suggested for wax are 10-20 °C [48] and 15-20 °C [42] with a daily variation of ± 1.5 °C. However, the rest of the materials of an effigy should be taken into consideration. T suggested for glass, plastic [97], paper and wood are 18-20 °C, 18-21 °C for textiles [98], < 20 °C for bone and ivory [99], < 25 °C for bone and fur [99], 21-25 °C for leather [99], and 15-23 °C for feathers [99].

**Suggested measures for relative humidity**

40-50 % RH has been suggested for wax [48], levels also suitable for wax effigies comprised of a diversity of materials, with a maximum fluctuation of ± 3 %. Yet, RH for mixed objects containing organic materials and metals should not exceed 40 % [100]. Different than the above values are the suggested RH levels of 45-55 % for bone and ivory and 45 % for fur [99], whereas plastics usually require RH of higher values, i.e. > 50 % for rubber, > 55 % for casein and > 60 % for keratin and shellac [97].

RH indicators and humidity buffering materials such as Art-sorb, Pro-sorb or silica gel can be placed in showcases, according to the air volume of each cabinet [42].

**Suggestions for light**

Exposure to sunlight should be avoided by installing blinds or curtains and placing filters or protective films on the windows [42].

Using low wattage lights, eliminating UV radiation, reducing the number of lamps, diffusing the light, limiting the exposure time using motion sensors or by switching off lights when the gallery is empty of visitors, and using dimmer switches are principal rules for the use of artificial light in museums [42, 101]. Attention should be given to the choice of light, as filters may influence colour temperature and colour index [42] obstructing the correct display and enjoyment of the collection. Lamps inside showcases or close to their glass surfaces must be avoided, due to the absorbance of heat that will create a dangerous microclimate for wax [42] and silk.

Some of the preferred artificial light sources for museum collections are halogen lamps [102] with UV-stop systems and built-in dichroic quartz tubes capable of absorbing large percentages of UV and heat emissions [103]. Halogen lamps have the advantage of producing adjustable, clear, bright light that brings out the natural colours of the objects. However, from September 2018, halogen lamps are no longer sold across the European Union, as energy intensive and inefficient and are gradually removed from the market [104]. Cold light such as optical fibres or LED can be used to illuminate large surfaces in open areas, work excellent for heat-sensitive materials and have the capacity to filter UV and IR radiation [105]. Light transmission systems such as optical fibres are best for wax artefacts [42]. PMMA LED optical fibres with halogen generators with a colour temperature close to 3000 K equipped with IR and UV filters can transmit light without loss of intensity through the glass of the showcase, with negligible heat transmission [42].

The standard values for wax are maximum light intensity around 150 lux and maximum UV-radiation level at 75 μw/lm [48]. Maximum allowed direct exposure time for wax is 3000-5000 hours per year [42]. These levels should be adjusted according to the needs of each effigy, taking into consideration the light absorbency of the exposed surfaces, the presence of unstable dyes, pigments, degraded layers, sensitive textiles such as silk, etc. It should be kept in mind that in 1986 [106], it was established that 50 lux are enough to ensure that the visitor is operating well inside museum collections, therefore preventive conservation and museum standards have since adopted these levels for a variety of materials. Light intensity in general, for items such as wax, textiles, paper, plastics, glass and wood should not exceed 50 lx. Annual light exposure should not exceed 10,000 lx • h/a, and UV radiation should not exceed 10 μW/lumen.

**Suggestions for pollutants**

Standards in the air quality of the wax museums and acceptable pollution levels have not been yet established. Several researchers have studied the deposition velocities of key museum pollutants onto various materials [75], yet a study especially made for wax museums has not been yet performed. Therefore, in order to understand pollutants that may affect a wax effigy collection, a study should be performed to list the pollutants present in the external and internal museum environment, and the ways they interact with the effigies, based on known studies.

Some meteorological stations provide readings of pollutants in the air of big cities. A simple method to record indoor pollutants is to apply dust traps, small pieces of a sticky material, at various rooms at different heights, and analyse the trapped particles using SEM/EDS. Passive monitoring of pollutants can be achieved through commercial passive sampling devices (PSD) the function of which is based on a colour indicator that changes colour when in contact with the examined pollutant [74]. Environmental dosimeters can measure various organic and inorganic pollutants and assist in the study of the degradation [107] of the various materials present in an effigy.

The first step to reduce pollutants is making the museum building as airtight as possible, in example by installing double doors to reduce the inflow of air from outdoors. Materials for sealing windows, doors and also showcases to act as barriers to gas contaminants are Marvelseal 360 (layers of aluminium film sandwiched in nylon and polyethylene) or polyethylene film, that for aesthetic reasons can be coated with polyester laminate, Mylar, Melinex R, pH neutral cardboard, cotton, linen with an appropriate colour and texture for the design of the exhibition [42].

The air within the museum environment should be chemically filtered through the museum ventilation system and removed through ventilation exhausts, to avoid internally generated pollutants from building up [75]. Air filters which retain relatively large particles, such as dust and pollen, HEPA filter or bag filter systems that hold particles up to 0.1 microns and carbon filters or special filters that neutralize organic matter could be used, preferably in each air duct [76]. Alternatively, elements reacting with the detected contaminants could be placed inside showcases; in example, activated carbon to block acid emissions [42].

The flow of air pollutants towards the wax effigies and their settings should be limited. The air flow can be controlled through mechanical ventilation, directed to rooms or zones as desired [75]. Chemical air-filtration, e.g. by the use of activated carbon can improve indoor air pollution levels [75, 108] and chemically-filtered air could be re-circulated, thus not only reducing the levels of both externally and internally produced pollutants, but also the cost of internal T and RH control as well [75] .

To keep exhibition areas clean, vacuum cleaning must be daily performed. Provided that storage areas are not frequently accessed, cleaning should be performed regularly, such as once a week. For various surfaces, such as shelves, electrostatic cloths should be used to avoid dust dispersion. Frequent site control for the presence of dust particles may be achieved through the installation of collectors, such as glass microscope slides or aluminium substrates coated with a sticky substance, at various points and heights [109]. Cleaning materials should be carefully selected so that they do not include acidic or basic compounds that can damage the wax effigies [42].

**Pest management and control of bioinfestation**

It is preferable to act proactively in order to avoid the stage of an insect infestation, as the process of disinfecting a site is difficult, expensive and dangerous for the objects. Insulating the interior of the museum, maintaining stable environmental conditions to avoid the creation of a fertile environment for reproduction and living, and performing frequent controls, are highly recommended. The establishment of a number of air changes per hour can inhibit fungal and bacterial growth activity [42]. Avoiding food sources in the exhibition areas and maintaining regular housekeeping is essential for preserving and minimising the likelihood of pests. Birds, rodents and nests should be controlled and removed from the museum surrounding area as they disperse a large number of blood-emitting ectoparasites, which in turn attract other species of insects. Monitoring by using insect traps in places such as the corners of the floor and window frames is essential [91].

**Suggestions for the display and storage of wax effigies**

Wax effigies are usually free standing objects and the most common way for exhibition is by placing on a base, the protrusions of which enter the interior of the feet or the torso if the figure wears a long dress. When the effigies are seated, counterweight or different kinds of mounting are placed at their back as a support. The base must provide balance to the object according to its gravity centre, should be mechanically attached to the object, and not just glued and must be constructed in such a way that will allow the ease of handling and transferring. Its construction materials should be chemically inert. Glass and polymethyl methacrylate (PMMA), also known as acrylic glass, and known under trade names such as Plexiglas, Perspex etc., are inert materials with a sufficient hardness and non-porous surface that makes them ideal for display use. PMMA is a light, hard, stiff material, resistant to fire, striking, UV radiation and inorganic acids [110].

Maintaining the clothes on the wax effigy should be preferred in order not to disrupt the entity of the object. In doing so, the three-dimensional fabrics are protected, as folds and creases on the textiles are avoided in a similar way as when using mannequins or three-dimensional hangers to exhibit or store heavy garments. It should be kept in mind that direct contact of fabrics with the wax, metal, plastic, rubber or any other material used to make the body of the effigy, consists of a possible threat for the clothing, and friction may also occur in the case of historical effigies that wear multiple layers of clothing. The body of the effigy must therefore be insulated before the fitting of the costume, and each clothing layer must be supported and protected, respecting its integrity and avoiding altering the volumes on the effigy [50]. Down-proof

**Figure 5.** Rachel Rhodes at Zenzie Tinker Conservation covering Charles II effigy from the Collection of Westminster Abbey with down-proof cotton and Tyvek for preventive conservation purposes. Image courtesy of the Dean and Chapter of Westminster.

cotton to contain the dust and residues of the filling of the torso, cotton jersey to isolate wooden parts, Tyvek to isolate the wax have successfully been used on wax effigies [50] Figure 5. Acid free tissue paper would not be a proper idea as it can stick on the wax surface and also absorb acids very quickly. Polyester film such as Melinex, or polyester wadding, are not suitable materials either, as during hot periods these materials can actually stick on the wax surface.

The environmental conditions of the storage and exhibition rooms and the way that clothed wax effigies are placed in it are important. Underground levels or floors closer to the roof that usually exhibit higher humidity levels and higher temperature levels respectively, must be avoided. An annual stable storage climate at approximately 40-50 % RH and 20 °C is desirable.

It is generally advised that the effigies be stored as a whole, particularly when dealing with historical objects. Each effigy should be placed on a specially designed base that will offer ease of handling and transferring. Covering with Tyvek or cotton fabric will protect effigies from dust and contaminants.

There are cases however that a historical effigy may be displayed in parts. An interesting case is the 1603 effigy of Queen Elisabeth I, the original wooden head and hands of which were replaced by waxen ones in 1760. When in 1994 dismantling for the needs of its conservation revealed that the wooden figure, corset and drawers were original to the 1603 effigy, conservators decided to display them separately and constructed a totally new figure to display the costume, head, hands and feet [27].

In cases where only parts of the effigies have survived i.e. the wax parts of the heads and limbs, or parts of the clothing, the different parts may be treated separately. Using appropriate construction materials for creating shelves and boxes in which the objects will be stored is important. Small parts such as hands and feet may be stored in groups placed into boxes. Each object should be wrapped in acid free tissue or Tyvek, and mounted on packing materials which can provide shock protection. Additional insulation materials are desirable if the environmental conditions are unstable. Three-dimensional parts should be placed on storage materials, such as Ethafoam, conformed to the shape of each object. Heads could be stored using specially formulated polyethylene foam sleeves such as Ethafoam or Plastazote LD45 and placed into individual boxes made of acid free cardboard or polypropylene (PP) and always on a lower level within the storage area, to avoid possible fall. Storage on metallic shelves can be employed to place the boxes, preventing future damages that could occur from possible fall, and protect the objects from dust and dirt.

In cases where only the garments have survived, storage methods vary depending on the type of each garment. Three-dimensional textiles that are in good condition and do not carry heavy decoration such as metallic or plastic decoration can be placed on suitable padded hangers and be covered or placed in clothes storage bags made of non-woven materials i.e. Tyvek. Heavily decorated garments should be stored horizontally, to avoid damages to the textile structure induced by weight. These should be placed in drawers or boxes, after placing rolls of free acid tissue at the folding points, to soften and loosen the creases. Accessories should be stored separately from the garments, placed in cases of Ethafoam or Plastazote LD45, in special cabinets or boxes.

**Suggestions for handling and transportation**

Minimising handling and unnecessary moving around of clothed wax effigies is highly important. Handling complex wax effigies should be done with care and attention. The waxen surface should never be touched with bare hands. Latex, nitrile or vinyl gloves must always be worn, and jewellery, woollen or fuzzy clothing should be avoided.

General principles for object handling and transport should be followed. A plan should be prepared and rehearsed prior to the day of transfer. This should include the number and roles of the people involved, the way that each object is to be transferred, the route to be followed, the sequence of actions and the time needed. The place where the object will be moved to must have been already prepared prior to the object reaching its destination. Prior to moving an effigy, its stability should be checked and possible risks identified. Fragile parts should be protected accordingly using chemically inert polyethylene foam and acid free tissue paper. The stability of each object should be secured with straps and padding material to minimise pressure and abrasion. Arrangements for the use of appropriate equipment such as trolleys, platforms, boxes, packing materials etc. should be made in advance. Before moving the effigies, the people involved should each be assigned with a specific role, such as opening doors or pushing trolleys and should have rehearsed to check the efficiency of the plan in terms of safety and time required. The moves needed to be made, and the distance to be covered should be studied and minimised to reduce the time needed and the risks involved. Items are to be held firmly with both hands, wearing the appropriate gloves, only from their solid parts, avoiding touching fragile areas such as face, fingers and delicate clothing.

The objects should be placed in properly designed boxes according to the dimensions and needs of each item using acid-free materials, ensuring elimination of object movement due to vibrations during transport. Appropriate labelling must be placed both inside as well as outside the box, preferably with photographs, so that the items can be easily identified before opening, avoiding unnecessary handling. Opening instructions should be provided.

Historical effigies should be transferred cautiously as one piece since the risk of breakage during the dismantling is high due to the materials' brittleness.

Contemporary effigies could be dismantled, with each part packed separately. Their sensitive construction materials, large size and protruding parts like limbs, can make lifting, packing and transfer in one piece quite challenging. Dismantling may take time and effort but can make the whole process of transferring easier and safer. Heads should be handled from the back to avoid touching the delicate painted faces and the sensitive areas of eyes and mouth, always with as less pressure as possible and careful movements. Costumes can be transported horizontally inside boxes, using internal support especially at the crease points, using acid free tissue, polyester pad or white cotton cloth. For transporting lighter costumes in a vertical position, cardboard boxes can be used with Tyvek padded hangers and covers.

**Risk management, emergency cases and first rescue measures**

The dangers that need to be taken under consideration when proposing a preventive conservation and risk management plan include natural, man-made and mixed risks and disasters. Fires, floods, earthquakes, tidal waves, landslides, volcanic eruptions, technological accidents, car accidents, vandalism, wars and terrorist attacks are some of the likely scenarios that could damage wax effigies on display, on storage, or during transportation. To evaluate the risk that each museum may face, it is important to first identify the risks likely to cause damages, estimate the probability of the occurrence of a disaster, and the consequences it may have for the exhibits. The conduction of a study will lead to results that will indicate the actions that may be repeatedly applied by a group of museum staff, before, during and after a disastrous event. The vulnerability of the individual museum -meaning the ability of its staff and facilities to face, resist and recover from the effects of a disaster- should be thoroughly studied. Vulnerability is different for each museum: the risk of destruction may be the same for two museums, yet the wealthiest one is more likely to have better premises, infrastructure, insurance policies etc., and more likely to have cared for alternative solutions to continue its operation in the case of a disaster, making it less vulnerable than a poorer museum.

There are two main kinds of risks: manageable and pure. Pure risks cannot be avoided while manageable ones can be diminished [111]. Wax effigy collections should manage these risks in the best possible way in order to protect their housed objects from the above dangers, and have their own emergency planning handbook step by step demonstrating the actions needed for its individual needs and facilities [112], including safeness of the workforce, visitors, collections and building, and reassuring return to normal the soonest possible [113]. Evacuation procedures for staff and the public, handling procedures, medical and disaster supplies need to be recorded, and the plan needs to be often reviewed and tested through exercises and checklists. Each staff member needs to be trained and prepared for the task for which they are responsible. Object transportation in case of an emergency should be already agreed and organised with a shipping company, the place where the objects will be transferred should be known in advance, and specially organised to store affected or not artefacts [114].

In case of an emergency, depending on the scale of the disaster, it may be necessary to first secure the building itself before undertaking any type of salvage operation [114]. Some objects may not be immediately movable and may need to be stabilised *in situ* [114]. During evacuation, be realistic, as unnecessary caution may require too much time and acceptances should be made that not all objects are equally valuable and important [92].

International Organisations and institutes such as ICOM, ICOMOS (International Council on Monuments and Sites), ICCROM (International Centre for the Study of the Preservation and Restoration of Cultural Property), AIC (American Institute for Conservation), Getty Institute, etc. support and train museum professionals to plan an efficient response to all kinds of disasters. ICOM conceived the Museum Emergency Planning for museum professionals and experts in emergency-related fields to overcome potential disasters through the forward planning of emergency situations such as earthquakes, fires, flooding, hurricanes or war [115]. Furthermore, a network of Cultural committees created the Blue Shield [116], dedicated to protecting heritage in armed conflicts and natural disasters, and to providing post-crisis support.

***Fire***
The building must be equipped with fireproof interior lining materials, automatic fire and smoke detection systems and sirens, fire alarm buttons, fire retardant display materials, fire doors, appropriate extinguishing systems [117], fire fighting equipment, emergency lighting, fire exit signs and fire escape routes. All of these must be regularly maintained and tested, and staff should be trained in their use. Power sources should be installed in accordance to regulations and should include maintenance and inspection records [117]. Good housekeeping is essential and includes regular cleaning of waste at the coffee/restaurant areas, laboratories, chemical stores; external smoking areas; and correct disposal of smoking materials. Gaseous systems are recommended in wax effigy collections instead of sprinkler systems, to avoid a reaction with the materials [118]. Wax fire reaction can take place when water is poured on burning wax, similar to when water is poured on burning oil, due to the hydrocarbon molecules that both contain; hydrocarbon fires are greater in intensity, reach a high temperature really fast and continue until exhausted [118].

***Floodw***
Leakages can be avoided by continuous checks at the drainage systems and replacement of damaged parts, such as pipes. Effigies in exhibition or storage should preferably not be in direct contact with the ground, but rather placed on elevated bases. Storage in basements should be avoided, as these are the first to be affected by floods.

Effigies affected by leakage or flood should be treated within 48 hours to prevent mould growth and deformation of their organic components, to ensure their safety and minimise further deterioration. Good ventilation and a clean environment should be maintained. Objects that have been exposed to water must not come into direct contact with the ground but should be placed on elevated bases to ensure ventilation. Fans and hair dryers with cool rather than warm air, and controlled air flow can be used to dry paper, textiles and hair. Damaged and folded areas can be supported using polyester sheets (i.e. Melinex) or corrugated plastic sheets. Blotting papers, sponges, clean white towers can be used to absorb the water. Textiles and paper should be reshaped while still damp to approximate the original shape [120].

***Earthquake***
Protecting wax effigy collections and the building they are housed in from earthquakes requires the cooperation of different professionals including seismic engineers, structural engineers, building designers, curators, technicians and conservators. To find the best ways for collections' protection, the tolerance and response of the objects to vibrations [121] should be taken into account.

Effigies could be secured with a variety of passive mounts [94]: added weight on their base or lower parts; form fit insert into hollow part of the objects base or feet; form fit clips; extra support in the interior of the effigy; contour mount on the back side; mono filament tie to secure parts from breaking towards different directions; support either against the wall or on the floor, but never both on the same effigy. A safe way to mount wax effigies can be the use of isolation bases which absorb and neutralise every kind of vibration, alongside extra internal support at the connections of the main body and the protruding parts.

The position of the exhibits inside the building is also important: they should be placed away from items that can fall on them and break or deform them [122].

## Conclusion

Clothed wax effigies are complex objects consisting of various materials depending on the time they were produced and the artist that created them. Although the manufacture technology has remained more or less the same, historical wax effigies consist of very different materials employed for the non-waxen parts, and modern effigies may be made of both traditional and contemporary materials. The various materials in an effigy, the variety of construction techniques in one sole collection, and the nature of the different recipes employed for modelling wax, known to be made up by a mixture of organic and inorganic substances, makes the task of proposing a preventive conservation plan quite challenging. Each effigy should be studied individually, its construction materials recorded, and the deterioration factors understood prior to the proposal of preventative measures that can guarantee safe conditions for their exhibition, transport and storage. The construction techniques, materials, deterioration factors and preventive conservation proposals listed in this paper, can assist the keepers of wax effigy collections into formulating an efficient preventive conservation strategy to suit each item's and collection's needs, determining the appropriate environmental conditions for storage and display, formulating an efficient handling and transportation plan, and creating a risk management plan to eliminate the effects of emergency situations.

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# O reentelamento com compostos de cera-resina: o aprendizado de Edson Motta no Fogg Conservation Center e a adaptação à realidade brasileira

# Wax resin lining techniques: Edson Motta's training at the Fogg Conservation Center and its adaptation to the Brazilian reality

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**Resumo**

A experiência de Edson Motta (1910-1981), após sua formação no Fogg Conservation Center, ofereceu à prática de restauro no Brasil o uso de novos materiais e a introdução da técnica de reentelamento a cera-resina. Tal processo levanta o debate acerca das vantagens e desvantagens da utilização desse método, no contexto de um país tropical e com poucos recursos. Para pensar tal problemática, configura-se como importante ferramenta a abordagem da história e razões que levaram esse processo técnico a ser, muito provavelmente, a melhor opção para a preservação do vasto patrimônio de pinturas sobre telas no Brasil.

**PALAVRAS-CHAVE**
Edson Motta
Fogg Conservation Center
Brasil
Conservação de pinturas
Reentelamento à cera-resina

**Abstract**

After Edson Motta's graduation from the Fogg Conservation Center, his experience contributed to the practice of conservation in Brazil through the introduction of new materials and the technique of wax-resin lining. However, this technique has drawbacks when applied in a country of tropical climate and few resources. It is important, when considering the use of this approach, to be mindful of the conservator's historical role, which can reveal why this technique was, very likely, the best choice for the conservation of the vast patrimony of canvas paintings in Brazil.

**KEYWORDS**
Edson Motta
Fogg Conservation Center
Brazil
Painting conservation
Wax-resin lining

## Introdução

Edson Motta (1910-1981) inicia seus estudos de pintura em 1927 como aluno livre na Escola Nacional de Belas Artes (ENBA) do Rio de Janeiro. Em 1931 funda, com outros artistas, o Núcleo Bernardelli, do qual foi o primeiro presidente. A formação do Núcleo foi a resposta dada por alunos pobres e jovens da ENBA, inconformados com o ensino acadêmico e conservador da mesma, diante das conquistas trazidas pelo Movimento Modernista, e, por meio dele, ofereciam uma opção de renovação do ensino nas artes plásticas no Brasil [1] e tendiam a um maior interesse por técnicas pictóricas alternativas àquelas ditadas pelo protocolo acadêmico. Essa experiência marcou profundamente a carreira do futuro restaurador, na medida em que o levou a explorar materiais e métodos não convencionais.

Outras oportunidades de conhecer caminhos técnicos novos viriam a surgir em 1939, quando Motta foi agraciado com o Prêmio Viagem ao Exterior, oferecido pelo Salão Nacional de Belas Artes. O salão propiciava ao artista contemplado a experiência de se aperfeiçoar nos principais centros de produção artística da Europa [2]. Na Itália, Motta estuda uma variedade de técnicas pouco usadas no Brasil, como a pintura a fresco e a têmpera a ovo. Ao retornar a seu país de origem, seu interesse pelos aspectos materiais da pintura chamam a atenção da diretoria do recém-criado, Serviço do Patrimônio Histórico e Artístico Nacional (SPHAN), que o contrata, em 1944, para atuar nesta instituição na área de conservação e restauro de pintura, escultura e talha.

No mesmo ano, a Rockefeller Foundation (EUA) lhe concede uma bolsa de estudos para o programa de treinamento profissional no Fogg Conservation Center, instalado no Fogg Art Museum, o museu de arte da Universidade de Harvard, onde em 1928, Edward Forbes, então diretor desse museu, fundou o Department of Technical Research – primeiro desse tipo nos EUA. Mais tarde o mesmo recebeu o nome de Straus Center for Conservation and Technical Studies, em homenagem a Philip A. e Lynn Straus.

Esta instituição foi pioneira na abordagem científica do ensino e da sua prática na área da conservação nos EUA e já havia angariado bastante renome por suas publicações, pela participação de seus especialistas em eventos nacionais e internacionais e pela atuação de George Stout no resgate de inúmeras obras de arte durante a II Guerra Mundial. As instituições europeias equivalentes – mas, certamente mais tradicionais – encontravam-se a recuperar das adversidades da guerra e sendo assim, é provável que não tenham sido consideradas como destino viável para a formação do jovem conservador-restaurador.

A criação de um Centro dedicado à tecnologia da arte e à conservação decorreu da necessidade de preservar a crescente coleção de obras adquiridas na Europa para o Museu, pelo magnata Edward Waldo Forbes (1873-1969) [3]. Nele, passou a trabalhar um grupo seleto de profissionais da área de artes plásticas, química, restauro e radiologia, como George Stout (1897-1978), Rutherford Gettens (1900-1974), Morton C. Bradley, Jr (1912-2004) e Alan Burroughs (1897-1965), respectivamente, formando um dos polos responsáveis pelo surgimento de uma moderna – e ainda atual – filosofia no tratamento de acervos museológicos [4].

O ideário que determinava as escolhas de tratamento no Centro advinha da crença de Forbes de que o valor das obras de arte derivava da autenticidade da matéria. Princípio em sintonia com o que defendia John Ruskin, amigo do professor de arte medieval de Forbes na classe de 1895, Charles Eliot Norton [4]. Portanto, o que não fizesse parte da criação original do artista deveria ser removido durante o processo de tratamento, mesmo que isso significasse torná-la uma ruína ao deixar grandes áreas de lacuna expostas, naqueles casos nos quais não restasse muito do original sob as intervenções anteriores. Forbes denominou essa abordagem "*the honest style of restoration*" [4].

Uma outra característica técnica do Centro – tema deste artigo – era a de se recorrer a misturas de cera-resina para a quase totalidade das operações de consolidação e fixação de camadas pictóricas em destacamento, transposições e reentelamentos.

Portanto, educado para entender o restauro de pinturas sobre tela e madeira como uma operação de eliminação da imagem de todas as adições posteriores e treinado em processos de aderência e selagem dos suportes com adesivos impermeáveis, Edson Motta retorna ao Brasil, em 1947, como o primeiro conservador-restaurador com formação acadêmica em um país que o aguardava para uma missão gigantesca: o restauro de um patrimônio composto por esculturas e talha em madeira, além de um acervo de obras pictóricas sobre tela, todos em péssimo estado de conservação.

A partir de 1951, Edson Motta assume também o magistério, na qualidade de professor de conservação e restauro da Universidade Federal do Rio de Janeiro, Brasil, e se torna responsável pela disseminação desse saber para toda uma geração que o seguiria.

## A lógica do uso de adesivos de cera-resina e seu uso no Fogg Conservation Center

A técnica de reentelamento adotada pelos restauradores do Fogg que recorriam à cera-resina como adesivo oferecia enormes vantagens para o restauro estrutural do acervo pictórico acumulado nos diversos museus, igrejas e conventos. Estes materiais já eram utilizados para esta finalidade desde o século XVIII, sendo o caso mais bem documentado o do reentelamento da obra de Rembrandt, a *Ronda da Noite*, em 1851. Conhecido como o *método holandês*, sua invenção e aperfeiçoamento é atribuída aos restauradores Nicolaas Hopman (1794-1870) e seu filho Willem Antonij Hopman (1828-1910) e, no final do século

XIX, restauradores deste país praticavam o método, regularmente [5, p. 24], embora, como afirmam Rushfield e Stoner, ele não tenha tido:

> *muita aceitação logo após seu surgimento, provavelmente porque durante o século XIX, o restauro era, usualmente, realizado em oficinas isoladas. No final do século XIX, apenas alguns restauradores haviam aprendido o método de reentelamento com cera-resina diretamente de Hopman Jr., incluindo Alois Hauser e H. Heydenrijk. A partir dos manuais e outras publicações da viragem do século, supõe-se que esses restauradores introduziram o método a outros colegas fora da Holanda, que por sua vez o disseminaram. A partir desse momento, o reentelamento com cera-resina aparece com crescente frequência na literatura internacional. Hauser introduziu o método na Alemanha e Wild, na Áustria e, provavelmente, mais tarde nos E.U.A.* [6, pp. 427-428] (tradução da autora).

Carel de Wild (1870-1922), ficou conhecido como o primeiro a trazer o método holandês de reentelamento com cera-resina para fora da Europa. Estudou restauro em Viena e Berlim e trabalhou em um estúdio em Haia de 1895 até 1911, quando partiu para os EUA [7].

Ao longo do tempo as fórmulas do adesivo variaram, porém todas tinham em comum o uso da cera de abelha associada a uma resina. Segundo Alois Hauser Jr. (1857-1919), a fórmula utilizada por Hopman continha uma mistura de colofonia, cera branca (provavelmente, cera de abelha clarificada) e terebintina de Veneza [6, pp. 426-427]. As propriedades adesivas da cera são conhecidas há muito tempo, mas a sua força moderada e seu baixo ponto de fusão levaram à adição de resinas para produzir uma mistura para reentelamento que fosse mais adesiva e mais resistente a temperaturas ambientais elevadas. Em contrapartida, a cera proporcionava uma maior plasticidade à mistura, sobretudo quando as resinas usadas eram mais duras [6, p. 427], como o breu.

Uma extensa investigação feita por Gettens e Stout, publicada no *Technical Studies in the Field of Fine Arts* de 1933 [8, pp. 83-84], discute quais as propriedades que uma mistura de cera-resina para reentelamentos deve possuir e conclui que deve proporcionar firme aderência entre a pintura e o novo suporte têxtil; ser flexível e capaz de manter essa flexibilidade ao longo do tempo; ser capaz de isolar o têxtil e a camada pictórica do meio ambiente; ser solúvel em solventes que não causem danos à obra; poder penetrar na estrutura da obra a uma temperatura que não danifique a pintura, porém, suficientemente alta para não ser afetada pelo calor ambiental. Tampouco deve ser corrosiva ou meio de cultura adequado para o desenvolvimento de fungos ou outros agentes de deterioração biológica; por fim, não manchar nem causar mudanças de cor ou escurecimento da camada pictórica.

No Fogg Conservation Center foram testados diversos materiais para a avaliação dessas propriedades: reentelamentos com pasta de farinha, com adesivos de poli(acetato de vinilo) (PVAc); assim como compostos contendo cera de abelha e parafina. O comportamento destas misturas, quando expostas a condições extremas de umidade, também foi testado. Com relação à cera, os autores citam a falta da força adesiva como desvantagens no seu uso e confirmam a necessidade da adição de resinas e bálsamos para que seja apropriada na função. O artigo traz como conclusão a constatação de que uma mistura ideal jamais seria encontrada, mas, mesmo assim, declara que:

> *não há dúvidas de que as misturas mais seguras e eficazes [...] são os adesivos do tipo cera ou cera-resina.* [8, p.103]

Em data posterior, 1950, Bradley, restaurador de pinturas sobre tela do Fogg, se preocupa em evidenciar no seu manual, *The Treatment of Pictures*, os prováveis perigos trazidos por este tipo de operação, como o uso da pressão e temperatura inadequadas, além de uma possível interação química entre os compostos utilizados nos adesivos e a celulose da tela original. Salienta, ainda, a sua apreensão quanto à reversibilidade e enfatiza que este deve ser o fundamento principal a ser considerado [9] (Figura 1).

Apesar destas ressalvas, o motivo da escolha do uso desta técnica de reentelamento de pinturas no Fogg Art Museum parece ser justificado, desde o início, pela grande preocupação com o controle de umidade nesse espaço [3, p. 144]. O Fogg Art

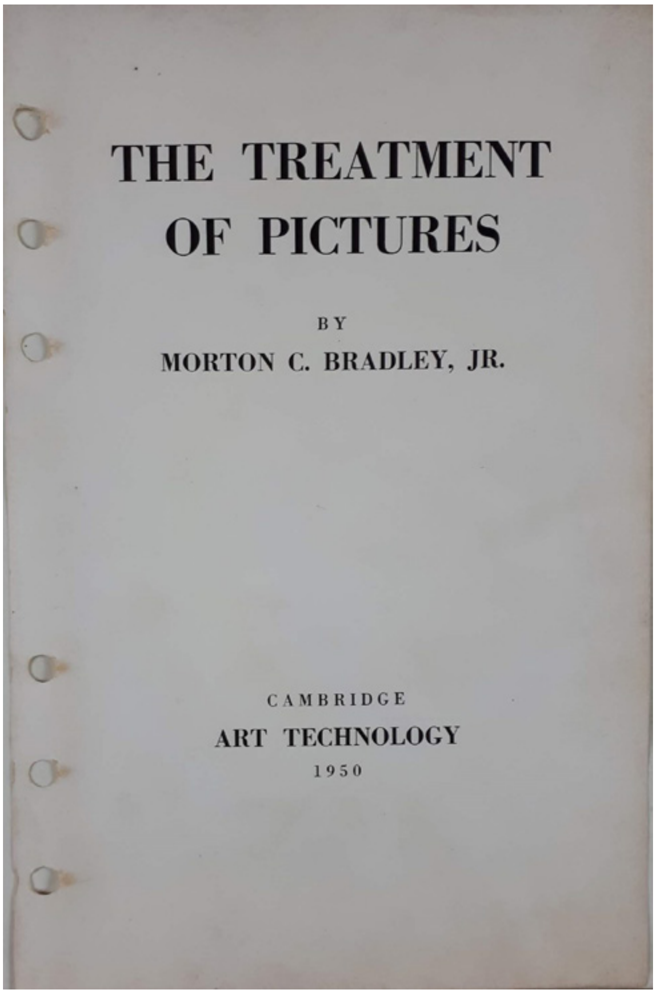


**Figura 1.** Folha de rosto do manual de Bradley, *The Treatment of Pictures*, 1950.

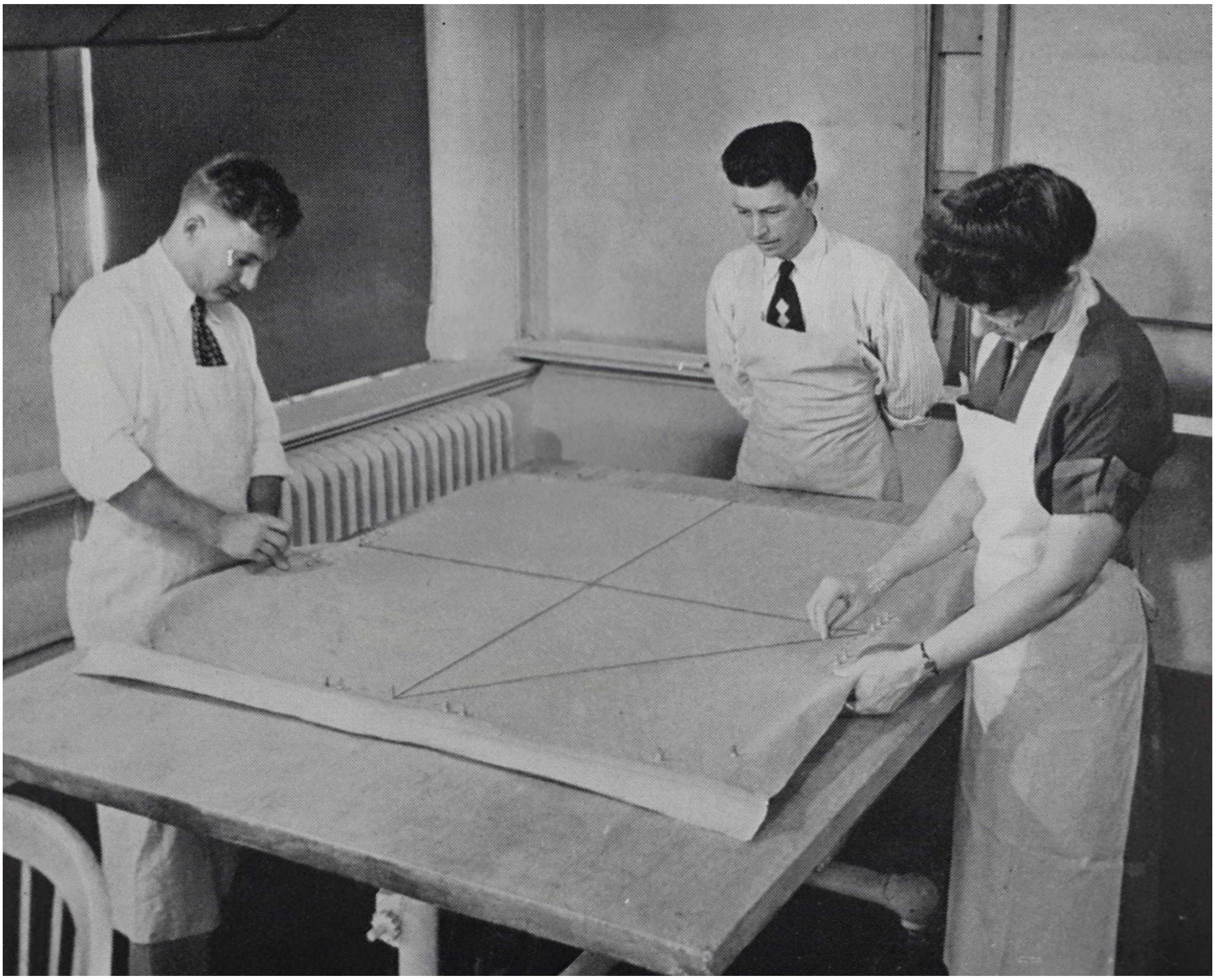

**Figura 2.** Estiramento de linho em bastidor provisório e alinhamento dos fios da trama têxtil [9].

Museum não havia sido projetado para abrigar obras de arte sensíveis às mudanças ambientais, como as que aconteciam, drasticamente, de uma estação para outra [4, pp. 27-34].

## A técnica de reentelamento à cera-resina no Fogg Conservation Center

No Fogg Conservation Center a técnica de reentelamento seguia um protocolo simples. Um tecido de linho era esticado num bastidor de madeira mantendo os fios alinhados (Figura 2). A pintura original, solta e previamente faceada com cola de amido, era impregnada, pelo verso, com o composto de cera-resina. A seguir, uma folha de papel de trapos macia (provavelmente de algodão ou linho) era aderida ao verso da tela original cortada na exata medida da obra e fixada a esta com a mesma mistura, com o propósito de conferir maior rigidez ao suporte. Em seguida, o tecido de reentelamento era impregnado, também com cera-resina, a tela original era posta com a face pintada para baixo e os dois suportes unidos pela fusão da mistura. Recomendava-se que a temperatura do ferro deveria ser apenas a suficiente para manter a cera derretida, recorrendo a um graduador de temperatura; um movimento constante do ferro elétrico deveria ser mantido para evitar qualquer dano à pintura [9, p. 1.22; 10, pp. 113-118].

Os técnicos do Fogg Conservation Center adotavam a seguinte fórmula: 2 kg de cera de abelha, 1 kg de resina damar, 1,5 kg de parafina e 0,5 kg de goma elemi, para se obter 5 kg de composto [9, apêndix c, 120.10].

## Método de reentelamento a cera-resina utilizado por Edson Motta no Brasil

A razão pela qual o método com cera-resina teria sido adotado por Edson Motta no Brasil é simples de justificar: ele regressa imbuído de todos os argumentos favoráveis ao uso desta técnica, que aprendera e praticara. O reentelamento de cera-resina era muito comum no Fogg Art Museum e Richard Buck, conservador-restaurador especialista em tratamentos estruturais de painéis, também aí, levou a cabo uma série de pesquisas e ensaios sobre a cera, como barreira para a umidade [4, pp. 224-225]. Ademais, em 1950, Edson Motta receberia de presente do próprio Bradley um exemplar de seu manual, *The Treatment of Paintings*, o qual viria a ser seu guia prático por seguidos anos.

Devido à ausência de registros documentais, o que sabemos dessa prática de Edson Motta no Brasil, foi obtido através de entrevistas realizadas, no decorrer do ano de 2017, com alguns de seus discípulos diretos, tais como: Claudio Valério Teixeira, conservador-restaurador independente e atual professor do Curso de Conservação e Restauro de Bens Móveis da Universidade Federal do Rio de Janeiro e Edson Motta Jr., conservador-restaurador, professor da Universidade Federal do Rio de Janeiro e filho de Edson Motta.

O método convinha a um país tropical como o Brasil, onde são constantes as flutuações de umidade relativa. Esta caraterística era muito considerada por Edson Motta que a usava como justificativa para rejeitar os procedimentos aquosos tradicionais, sugeridos a ele por outros colegas restauradores, durante seus trinta anos de carreira subsequentes. Segundo Motta, após aquecido, o adesivo de cera-resina era capaz de permear a estrutura da obra promovendo, a um só tempo, a consolidação das diversas camadas pictóricas em destacamento, assim como a aderência da tela nova à antiga. Ele afirmava ainda que, quando comparado a métodos aquosos, apresentava menos riscos de danos, pois a pintura não corria o perigo de encolher [11, p. 15].

Desde que a mistura adesiva possuísse um ponto de fusão baixo, um novo tecido poderia ser aplicado ou removido com segurança e facilidade durante o processo. A desvantagem do uso da cera-resina era que, nem sempre, o método era forte o suficiente para manter a pintura plana [11, pp.13-15] e Motta não seguia as recomendações do Fogg de adicionar papel de trapo ao verso, reservando recortes de papel somente para as áreas rasgadas ou perfuradas. A lógica subjacente, de se aumentar a resistência à flexão, no entanto, era a mesma, embora a compreensão desse fenômeno fosse somente empírica.

Motta também substituiu o tecido de linho pelo tafetá de algodão cru, já que aquele não se encontrava à venda no Brasil nos primeiros anos de sua atuação e só após a II Guerra Mundial se reiniciaram as importações. O custo de importação do linho cru de elevada qualidade era demasiado alto, o que teria inviabilizado o seu uso para o restauro. Já o algodão, era facilmente obtido no Brasil, por um custo muito menor. Desde o período colonial o país detinha uma cultura algodoeira bastante lucrativa, passando a exportador desse tecido na primeira década do século XX [12], p. 161]. Exemplo desta adaptação é a fatura encontrada nos arquivos do Instituto do Patrimônio Histórico e Artístico Nacional (IPHAN) [13] onde, na décima primeira linha da mesma, é referido o tecido de algodão usado por Motta (Figura 3); distinto da tela de linho usada no Fogg Conservation Center (Figura 4), cujas amostras fotografadas pertencem ao Arquivo de Materiais Didáticos do Professor Edson Motta, e fazem parte da coleção particular da família do mesmo.

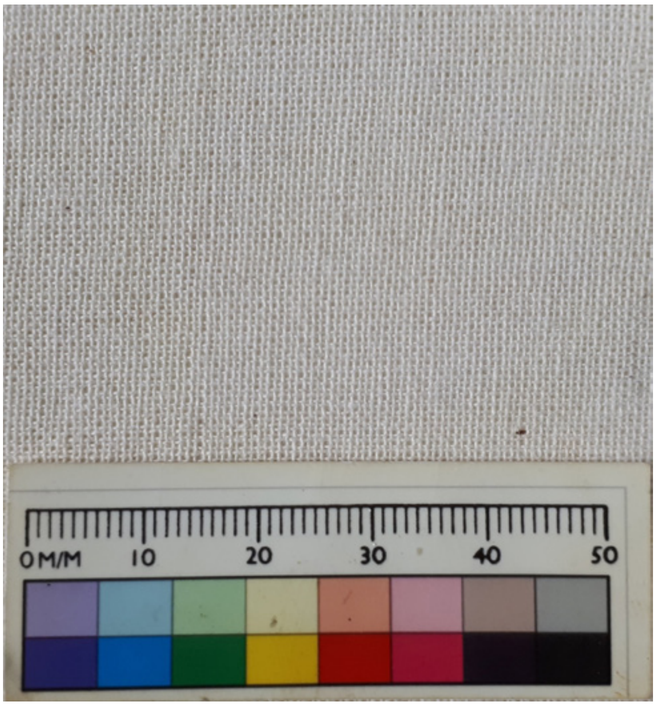

**Figura 3.** Tecido de algodão usado por Edson Motta. Acervo particular da família de Edson Motta.

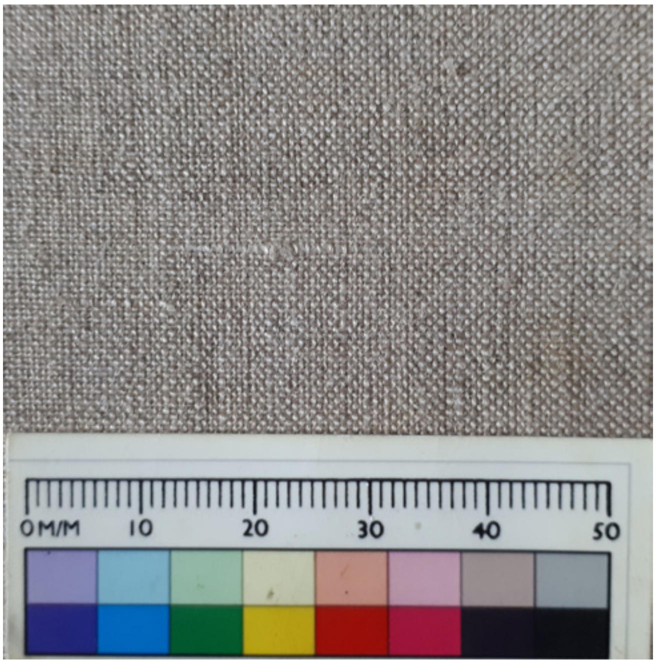

**Figura 4.** Tecido de linho usado no Fogg C.C. Acervo particular da família de Edson Motta.

De início, Motta procurou praticar o método conforme as orientações do seu aprendizado, mas em curto tempo notou que tinha nas mãos uma quantidade muito maior de obras que demandavam cuidados emergenciais. Ademais, se viu em uma situação totalmente diferente da que conheceu no Fogg, onde não faltavam recursos humanos, tecnológicos, financeiros e facilidade de acesso aos materiais.

Quanto ao composto adesivo, Motta reduziu o custo elevado e aumentou a temperatura de fusão da fórmula aprendida no Fogg, substituindo a resina damar por breu e adicionando à fórmula cera de carnaúba, conforme se verifica na segunda linha da fatura relativa à compra de breu [14] e nas notas manuscritas, pelo próprio Edson Motta, sobre as propriedades da cera de carnaúba [15], ambas arquivadas no IPHAN. Nestas, referia que a cera de carnaúba possuía intervalos de fusão mais elevados que os da cera de abelha, 83 °C a 86 °C contra 63 °C a 70 °C, o que era contrabalançado pelas menores temperaturas do breu, de 100 °C a 130 °C, contra os 100 °C a 150 °C, da resina damar [8, p. 79; 15, p. 17]. Se compararmos a fórmula original do Fogg com a utilizada por Motta notamos que no Fogg utilizavam-se 2 partes de cera de abelha para 1,5 de parafina, 1 parte de resina damar e 0,5 de bálsamo de elemi [9, appendix c, 120.10], enquanto Motta misturava 12 partes de cera de abelha, 9 de parafina, 2 de carnaúba e 6 partes de breu [10, p. 207]. Edson Motta justifica essa mistura como sendo mais adequada para uso em um país de clima tropical, já que a carnaúba, com ponto de fusão elevado, aumentava o ponto de fusão do composto adesivo.

Ao calcularmos o ponto de fusão de ambas as fórmulas, percebemos que o resultado obtido na composição usada por Motta é, de fato, maior, já que o composto segundo o método do Fogg funde a 72,5 °C, enquanto o utilizado por Motta se fusiona a 75,5 °C. Uma diferença de 3 °C que reforça o argumento do restaurador brasileiro (Tabela 1).

No entanto, se levarmos em conta somente os constituintes de cera de cada combinação (abelha, parafina e carnaúba), ignorando o percentual de resinas e bálsamo, encontramos uma diferença muito pequena entre seus pontos de fusão. O composto do Fogg funde a 63,7 °C e o formulado por Edson Motta alcança 65,1 °C, diferença de 1,4 °C (Tabela 2).

Isso nos fez concluir que a premissa de Edson Motta estava correta em parte, posto que a carnaúba realmente se funde a uma temperatura maior e, o raciocínio lógico indicaria que seu uso aumentaria o ponto de fusão do composto. Por outro lado, ao desconsiderar o baixo ponto de fusão do bálsamo de elemi, e removê-lo da fórmula junto com a resina damar para promover a redução de custos, passou a Motta despercebido o fato de que o aumento do ponto de fusão do método por ele empregado se deu muito mais por conta da não utilização desse constituinte do que pela adição da carnaúba. O que nos faz pensar que a "lógica" de sua premissa foi baseada, em parte, em um raciocínio empírico.

Embora existam referências da utilização do tecido de linho em algumas obras e publicação de fórmulas de mistura de cera de abelha com resina de damar, depoimentos de seus alunos e a documentação do IPHAN indicam que, no cotidiano, ele usava a mistura citada acima, onde substituía a resina por breu e o linho por tafetá de algodão cru. Motta reservava o linho e a fórmula de cera-resina ensinada por seus mestres nos EUA para algumas obras mais relevantes, como as do Museu Nacional de Belas Artes, no Rio de Janeiro [16].

Quanto à técnica, Motta também a simplificou e muniu-se de equipamentos acessíveis. Por exemplo, deixou de estirar a tela com o rigor recomendado no manual e abandonou o bastidor provisório. A pintura, com a face pintada para baixo, era estirada numa mesa sobre papel parafinado acolchoado com papel de jornal e, sobre ela, era estirado o tecido de algodão cru, fazendo coincidir a trama e o urdido. Deste modo, reduziu duas etapas, diminuindo o custo da operação e abreviando o tempo de tratamento, questão crucial para quem tinha a responsabilidade de intervir em numerosas obras, altamente deterioradas, antes que se perdessem. Também deixou de fazer o controle de temperatura através de um graduador e passou a utilizar a sua própria sensibilidade para avaliar a fluidez do adesivo. Este procedimento

**Tabela 1.** Cálculo do ponto de fusão das fórmulas de adesivos compostos de cera-resina.

| Origem | Compostos em partes \| Ponto de fusão | Ponto de fusão dos compostos |
|---|---|---|
| Fogg Center | 2 × Cera de Abelha \| 66,5 °C<br>1,5 × Parafina \| 60 °C<br>1 × Resina Damar \| 125 °C<br>0,5 × Goma elemi \| 29 °C | [(2 × 66,5) + (1,5 × 60) + (1 × 125) + (0,5 × 29)] / 5 = **72,5 °C** |
| Edson Motta | 12 × Cera de Abelha \| 66,5 °C<br>9 × Parafina \| 60 °C<br>2 × Cera de Carnaúba \| 80 °C<br>6 × Breu \| 115 °C | [(12 × 66,5) + (9 × 60) + (2 × 80) + (6 × 115)] / 29 = **75,5 °C** |

**Tabela 2.** Cálculo do ponto de fusão das fórmulas constituídas somente de cera.

| Origem | Compostos em partes \| Ponto de fusão | Ponto de fusão dos compostos |
|---|---|---|
| Fogg Center | 2 × Cera de Abelha \| 66,5 °C<br>1,5 × Parafina \| 60 °C | [(2 × 66,5) + (1,5 × 60)] / 3,5 = **63,7 °C** |
| Edson Motta | 12 × Cera de Abelha \| 66,5 °C<br>9 × Parafina \| 60 °C<br>2 × Cera de Carnaúba \| 80 °C | [(12 × 66,5) + (9 × 60) + (2 × 80)] / 23 = **65,1 °C** |

permitiu economizar em recursos, mas tinha a desvantagem de depender da experiência do operador para não danificar a pintura com excesso de calor. A simplificação do método continuou ao introduzir a prática de impregnar a obra com o composto de cera-resina e aderir o novo suporte em uma só operação, reduzindo o tempo de trabalho e a quantidade de adesivo usada.

## Considerações finais

Devemos entender que as escolhas de Edson Motta foram determinadas histórica e geograficamente e que a insistência no seu uso por décadas (mesmo após o surgimento de alternativas menos invasivas) se justifica e se explica pelo excessivo volume de trabalho sob seus cuidados, além dos parcos e incertos recursos materiais e humanos de que dispunha. Suas escolhas, como vimos, sempre visaram o corte de custos e a redução de tempo, a fim de que mais patrimônio pudesse ser salvo da completa destruição. Aliar os ensinamentos recebidos nos EUA à sua criatividade simplificadora era a única maneira que via de conseguir arcar com as inúmeras responsabilidades depositadas em suas mãos. Se não fosse por seu esforço e dedicação, muito do patrimônio brasileiro não existiria mais hoje.

Também há que considerar que Edson Motta foi o primeiro restaurador com formação acadêmica no Brasil, tendo essa sido obtida em uma universidade de reconhecido valor e prestígio e que, por outro lado, não havia no país uma tradição na área da conservação, o que facilitava a aceitação de novas técnicas, ao contrário do que ocorria nos países europeus.

Vale ainda salientar que, apesar deste processo de reentelamento não ser mais praticado diante de evidências científicas de que o respectivo composto escurece a tela e aumenta a translucidez do fundo de preparação e, que embora outras técnicas já tenham surgido em sua substituição, nenhum método de tratamento deve ser desconsiderado, mesmo sendo antigo ou por demais invasivo. A campanha de impregnação com cera-resina levada a cabo em Florença após a enchente de 1966 é prova disso [17]. Muitas vezes, estes são os únicos e últimos recursos que nos restam para impedir a perda de uma obra de arte. O importante mesmo, é que se tenha o devido conhecimento acerca dos vários tratamentos – incluindo vantagens, desvantagens e riscos – para que se possa ser capaz de discernir qual o melhor para determinada obra em questão, já que cada uma tem sua especificidade, independente de apresentarem danos similares.

Este foi mais um legado deixado por Edson Motta, já que, mesmo após sua aposentadoria em 1976, o método permaneceu em uso até o início dos anos 90 no Brasil e na Bélgica – informação obtida através de entrevista realizada, em 2017, com o conservador-restaurador Silvio Luiz Rocha Vianna de Oliveira, professor do Curso de Conservação e Restauro de Obras de Arte, na Fundação de Artes de Ouro Preto, no Estado de Minas Gerais, Brasil. Esta mesma prática também seguiu sendo utilizada até os anos 80, na França [18, pp. 57-61].

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# Caracterización del viento y temperatura aparente en los cañones urbanos del centro histórico de Cuenca, Ecuador

# Caracterização do vento e temperatura aparente nos desfiladeiros urbanos do centro histórico de Cuenca, Equador

# Characterization of the wind and apparent temperature in the urban canyons of the historic center of Cuenca, Ecuador

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**Resumen**

El estudio tiene por objetivo evaluar el comportamiento del viento y su efecto en la sensación térmica de cañones urbanos del centro histórico de Cuenca. La metodología se basa en la selección de casos de estudio de la unidad funcional del centro histórico para armar modelos simplificados según la relación de aspecto alto/ancho (H/W) y de orientaciones este-oeste y norte-sur. Estos modelos son simulados mediante la aplicación de Dinámica de Fluidos Computacional (CFD), cuyo cálculo usa valores del viento para el mes de mayor intensidad y de acuerdo a velocidades y direcciones predominantes. Los resultados demuestran que la relación geométrica incide en la modificación de la velocidad de viento y por lo tanto varia la temperatura aparente al interior del mismo, que puede incrementar o disminuir hasta 4 °C dependiendo de la relación H/W, orientación y hora del día.

**PALAVRAS-CLAVE**
Cañones urbanos
Viento
Morfología urbana
Patrimonio
Dinámica de fluidos computacional
Cuenca-Ecuador

**Resumo**

O estudo tem como objectivo avaliar o comportamento do vento e o seu efeito na sensação térmica em desfiladeiros urbanos do centro histórico de Cuenca. A metodologia baseia-se na selecção de casos de estudo da unidade funcional do centro histórico para a montagem de modelos simplificados de acordo com a relação altura/largura (H/W) e as orientações Este-Oeste e Norte-Sul. Esses modelos são simulados por meio da aplicação da Dinâmica de Fluídos Computacional (CFD), cujo cálculo utiliza os valores do vento para o mês de maior intensidade e de acordo com as velocidades e direcções predominantes. Os resultados mostram que a relação geométrica influencia a alteração da velocidade do vento e, portanto, a temperatura aparente no seu interior varia, podendo aumentar ou diminuir até 4 °C dependendo da relação H/W, orientação e hora do dia.

**PALAVRAS-CHAVE**
Desfiladeiros urbanos
Vento
Morfologia urbana
Património
Dinâmica de Fluídos Computacional
Cuenca-Ecuador

**Abstract**

The study aims to assess the wind behavior and its effect on the thermal sensation in urban canyons of the historic center of Cuenca. The methodology is based on the selection of case studies of the functional unit of the historical center to assemble simplified models according to the height/width (H/W) ratio and east-west and north-south directions. These models are simulated through the application of computational fluid dynamics (CFD), whose calculation uses values from the wind for the month of greater intensity and according to prevailing speeds and directions. The results show that the geometric relationship affects the change in wind speed and therefore modifies the apparent temperature inside it, which may increase or decrease up to 4 °C depending on the H/W ratio, orientation and time of day.

**KEYWORDS**
Urban canyons
Wind
Urban morphology
Heritage
Computational fluid dynamics
Cuenca-Ecuador

## Introducción

Las ciudades de América latina y del caribe son afectadas directamente por el cambio climático, cuyo incremento en la altura del nivel de mar pronostica un incremento térmico de hasta 2 °C, que sumada la extensiva urbanización provocan impactos negativos para los elementos físicos del patrimonio histórico [1]. Pero esos impactos también están asociados a variaciones térmicas como islas de calor en ciudades pequeñas e históricas [2], que a más de contribuir en el daño estructural de los materiales, también ocasionan malestar en el confort urbano.

El estudio del confort urbano considera elementos del clima como el sol y viento, cuya segunda variable puede demandar un estudio más complejo [3]. Esto debido a dos características. Primero, el viento se ve condicionado por el esquema geográfico que puede variar en el perfil montañoso [4]. Por ejemplo, el flujo del viento se modifica en las ciudades próximas a la cordillera de los Andes [5]. Y segundo, el viento en la escala edilicia se ve influenciada por la tipología del paisaje local [7].

En el contexto del paisaje local la variación morfológica se puede centrar en el estudio de los cañones urbanos. Estos elementos constituyen la unidad básica de análisis de una ciudad, cuyo coeficiente geométrico puede resumirse a partir de un descriptor morfológico conocido como relación de aspecto que es el alto de fachada dividido para el ancho de la vía (H/W) [8]. Este descriptor ha servido para evaluar centros urbanos en ciudades de Sudamérica complementado el estudio del clima urbano [9].

En general Tumini (2013) señala que el estudio del clima urbano puede resumirse en técnicas como mediciones in situ, teledetección térmica y modelos matemáticos [11]. La primera técnica hace empleo de variables climáticas como temperatura, humedad relativa y viento obtenidas a partir de estaciones meteorológicas con registros de tiempo prolongado, y mediante equipos móviles para muestreo de datos in situ. La segunda técnica emplea imágenes satelitales que permiten calcular diversas situaciones climatológicas y mapas de interés basándose en el tipo del sensor espacial. La anterior técnica suelo usarse en estudios de mayor escala. Finalmente, los modelos matemáticos para el estudio del microclima han tomado protagonismo por que permiten detallar la geometría urbana en menor escala y el estudio del confort peatonal.

El uso de modelos matemáticos puede abordarse en el estudio de las variables climáticas de interés, como el viento que se puede estudiar mediante el uso de modelación y simulación por Dinámica de Fluidos Computacional (CFD). Esta herramienta se ha utilizado para aplicaciones de estudios de edificación con efecto de túnel de viento tanto en edificios aislados [12], así como para el análisis de cañones urbanos [13]. De lo anterior, los estudios de micro escala pueden ser simulados mediante un amplio repertorio de *software* para evaluar el microclima en cañones urbanos y efectos en las edificaciones.

Tumini hace uso del *software* ENVI-met para simular el comportamiento climático del espacio urbano a micro escala con estudios de caso en la ciudad de Madrid [11]. Por otra parte, Colomer estudia cañones urbanos de la ciudad de Valencia, cuyos criterios de selección considera valores de compacidad para evaluar varias configuraciones morfológicas mediante el modelo *CFD Flow Vector* de Ecotect que destaca la modificación climática [14].

El estudio experimental de Christen [15] para la ciudad de Basel analiza de manera detallada los procesos de intercambio energético y de turbulencia con distintas situaciones morfológicas, para casos tipo calle en diferentes usos de suelo (urbano, suburbano y rural). Tal investigación emplea torres reticuladas metálicas con anemómetros ultrasónicos a distintas alturas que proporcionan información sobre los perfiles verticales para procesos de intercambio de calor así como de energía cinética de turbulencia (TKE). Este último estudio muestra que al nivel de la rugosidad urbana, el comportamiento térmico permanece inestable la mayor parte del tiempo. Además, los casos analizados varían su comportamiento térmico dependiendo de las distintas configuraciones morfológicas y de las situaciones locales de viento [15].

Sumada a las situaciones de viento y de microclima en el tejido urbano, Echave se enfoca en la habitabilidad térmica, estudiando el cañón urbano en situaciones de calle normal, de calle con vegetación, y con tipos de pavimento [16]. Este emplea el *software* Radtherm que simula la radiación y además considera la geometría del espacio y propiedades de los materiales. Este estudio, entre otros aspectos considera a la orientación como un factor fundamental para conseguir más horas de confort.

Por otra parte, el estudio de Rajagopalan, Lim y Jamei en la ciudad tropical de Muar [17] concluye que edificios en altura (torres de hasta 20 pisos) con calles estrechas y caótico desarrollo urbano, pueden ocasionar una reducción en la ventilación de los cañones urbanos y por tanto un incremento en la isla de calor urbana. Para lo cual, mediante el empleo del *software* IES y morfologías propuestas se concluye que la ventilación máxima se puede alcanzar situando las torres en el lado de barlovento, y cuando los edificios se sitúan en forma dispersa para el mejor paso del viento.

Otro estudio de ciudad tropical y húmeda (Barranquilla) considera vegetación y emplea el uso de CFD [18]. Este destaca efectos importantes desarrollados por la presencia del árbol que provocan aceleración y que canaliza el flujo del viento a lo largo de la calle. Además, dependiendo de las configuraciones (con o sin árboles), la velocidad de viento puede mantenerse o variar.

Desde otra perspectiva, un estudio con geometrías experimentales de un par de viviendas con ratio H/W menor a 0,3 y mediante un código Fortran y ecuaciones numéricas evalúan el accionar del viento. En este caso se analiza el viento en dirección perpendicular a las geometrías con velocidades simuladas de 1,5 m/s y 5 m/s que muestran un mayor desprendimiento o vórtice a mayor velocidad de viento [19]. También, Amri y Syukur desde una perspectiva de daños estructurales emplean el *software* Flow Design para evaluar el efecto del viento y la inclinación del techo. Este estudio concluye que los techos con mayor inclinación tienen mayor susceptibilidad a riesgos estructurales [20].

Finalmente, se menciona un estudio local y experimental sobre morfología urbana e isla de calor en Cuenca, Ecuador [9]. Tal estudio trabaja con datos in situ tomados a 3 m desde el suelo, donde las mayores intensidades de viento son próximas a los 2 m/s en el horario de 12 h y 15 h. Además, la incidencia de radiación solar puede tener mayor repercusión en el confort exterior para cañones urbanos de ciudades con clima cálido entre las 12 h y 15 h [21].

Por todo lo anterior, el análisis del cañón urbano asociado al estudio del viento resulta fundamental para valorar el diseño urbano, que puede complementarse en dimensiones como: calidad del aire y confort peatonal [22]; ventilación natural [23]; y para mitigar la isla de calor con base en la exposición del viento local [24].

El efecto del viento debe asociarse al fenómeno térmico, similar a la evaluación por islas de calor o por situaciones del grado de confort. Es decir, el viento debe incluirse para la caracterización de la temperatura de sensación o temperatura aparente. Esto permite asociar el rol de los cañones urbanos del centro histórico de altura baja y homogénea que permiten el paso del viento y la generación de ventilación.

La finalidad de esta investigación es analizar la modificación microclimática del casco histórico de Cuenca en la escala peatonal. De este modo, el presente estudio evalúa la intensidad y dirección del viento en periodos específicos, para simular estos en cañones urbanos de diferentes configuraciones y orientaciones que permitan caracterizar una condición microclimática a partir de la temperatura aparente.

**Área de estudio**

La presente investigación se desarrolla en la ciudad de Cuenca ubicada al sur de la República del Ecuador que está atravesada por el sistema montañoso de los Andes, en las coordenadas 2°54´08´´Sur y 79°00´19´´Oeste (Figura 1*a*) y con una altitud promedio de 2550 m.s.n.m. Según Köppen y Geiger, el clima de la ciudad se clasifica como Cfb [25] que puede ser templado y cálido con una temperatura media anual de 14,7 °C. La Figura 1*a* muestra el área de interés en la unidad funcional del centro histórico delimitada: hacia norte con la calle Rafael María Arízaga; al sur con el río Tomebamba; al este con la avenida Huayna Cápac; y al oeste con la calle Coronel Talbot [26]. La anterior delimitación contiene parte de la zona catalogada como patrimonio cultural de la humanidad a finales de 1999, la misma que cuenta con especial normativa que enfatiza el control de la tipología y altura de los bienes inmuebles, y que además se caracteriza por el uso de cubierta con teja (Figura 1*b*).

La clasificación del tejido urbano a partir de la situación topográfica puede tener la situación plan [27]. El área de estudio de Cuenca destaca tal situación (superficie horizontal) que tiene un alto grado de cobertura de edificaciones formando un tejido regular el que puede romperse parcialmente con la presencia de vegetación en las plazas o parques. Además en algunos casos el tejido urbano se adapta de acuerdo al margen del río Tomebamba como límite sur.


**Figura 1.** Área de estudio: *a)* Ubicación de Cuenca en Ecuador y área de estudio; *b)* Vista del centro histórico de Cuenca hacia el norte de la ciudad. Fotografía: Proyecto Cuenca Ciudad patrimonio Mundial.

## Materiales y métodos

### Caracterización morfológica

Se mapea la unidad funcional del centro histórico que cuenta aproximadamente con 5000 predios albergados en 170 manzanas, que mediante colores clasifica los niveles de altura por edificación (Figura 2). Además, el área en su extensión posee una altitud homogénea y contiene la estación meteorológica situada en la parte céntrica en un radio de influencia próximo a los 900 m.

Para definir el mapeo como una geometría de acuerdo a medidas horizontales y verticales se hace uso de: la ordenanza local; información de la base predial de la ciudad; y de la herramienta *Google Street View*. Las dimensiones en planta de los bloques o manzanas van de 60 a 100 m. Por su parte las dimensiones horizontales que constituyen los anchos de circulación, tienen una dimensión promedio de 10 m tanto en las vías norte-sur como en las este-oeste, mientras que las plazas o parques pueden constituir una circulación más amplia que en algunos casos ocupa toda la dimensión de una manzana. Finalmente, para las dimensiones verticales predomina la altura de 2 y 3 pisos (6 a 10 m), sin embargo existen edificaciones que superan los 6 pisos de altura, y las iglesias constituyen los elementos de mayor altura que pueden superar los 40 m en la parte más alta.

### Caracterización climática

El estudio del microclima en el centro histórico usa información de la estación M5103 [28] (Figura 2) que está en el radio de influencia inmediato del área estudiada y cuenta con registros horarios de información para los últimos cuatro años. Tal información considera variables de promedios

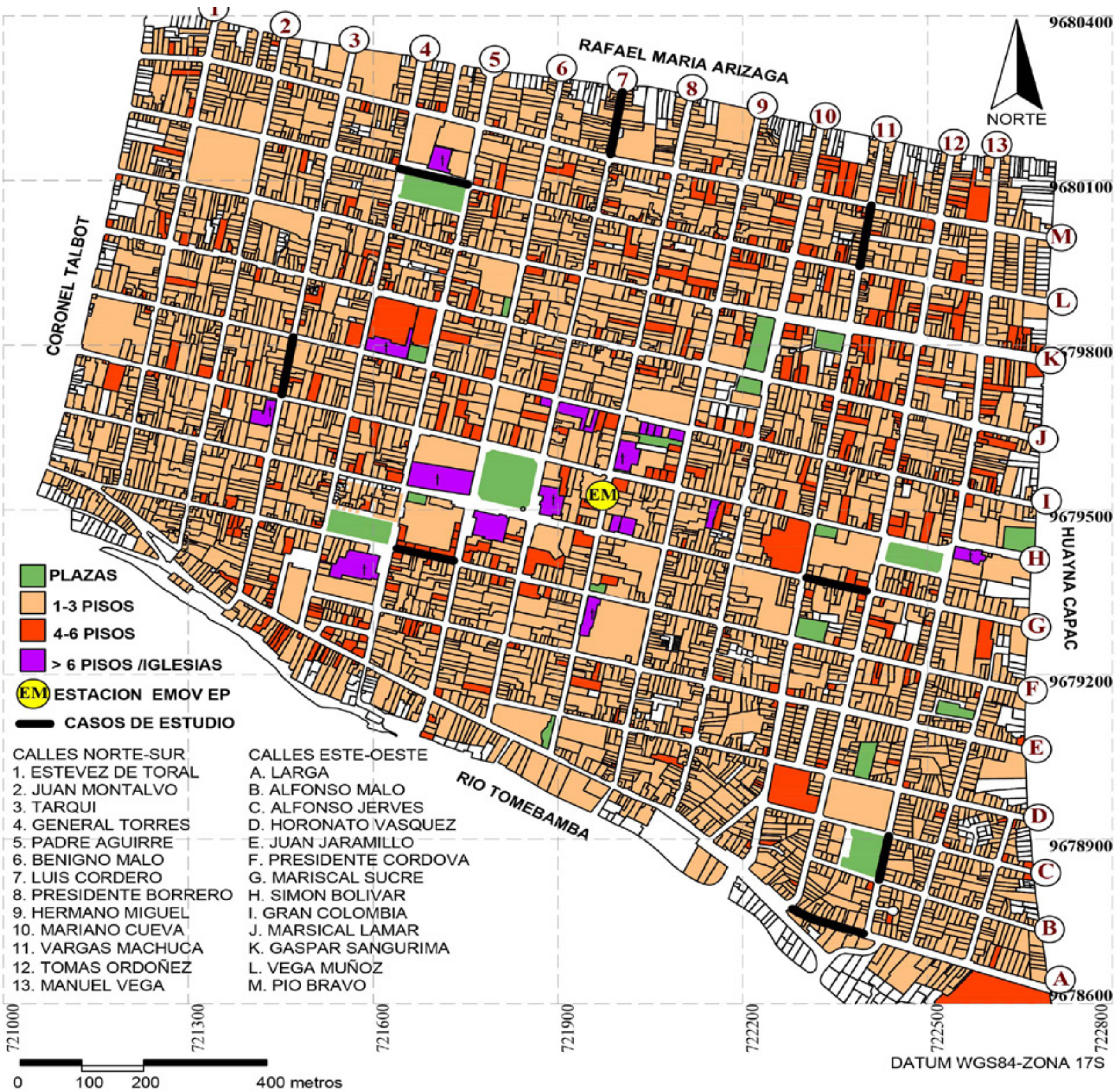


**Figura 2.** Mapeo de morfologías en la unidad funcional del centro histórico de Cuenca.

**Tabla 1.** Variables climáticas promedio tomadas a 10 m en el período 2015-2018.

| Mes | Temperatura °C | Humedad Relativa % | Viento | |
|---|---|---|---|---|
| | | | Velocidad de Viento m/s | Dirección Predominante |
| enero | 15,60 | 65,39 | 1,88 | E, N* |
| febrero | 15,90 | 65,78 | 1,90 | E, S, N |
| marzo | 15,65 | 70,35 | 1,75 | E, S, N |
| abril | 15,49 | 69,91 | 1,70 | E, N |
| mayo | 15,39 | 70,64 | 1,64 | E, N |
| junio | 14,86 | 65,20 | 1,89 | N |
| julio | 14,44 | 61,79 | 1,98 | N |
| agosto | 14,87 | 60,31 | 1,97 | N |
| septiembre | 15,13 | 59,86 | 1,92 | E, N |
| octubre | 15,39 | 62,30 | 1,93 | S, N |
| noviembre | 15,27 | 58,82 | 2,06 | S, N |
| diciembre | 15,62 | 66,48 | 1,96 | N |

**E=este, N=norte, S=sur*

mensuales como la temperatura, humedad relativa y del viento (Tabla 1). Esta última variable caracteriza el estudio de la morfología porque las direcciones predominantes siguen orientaciones de la trama de estudio tanto en sentido norte-sur como en este-oeste.

Debido a que la variación mensual en la temperatura no supera los 2 °C y el viento no modifica su intensidad, se requiere una caracterización climática horaria que puede centrarse en el mes de noviembre con mayor intensidad de viento. Para ello sé gráfica los valores horarios de las variables: temperatura, humedad relativa, velocidad y dirección de viento (Figura 3). Estos datos horarios muestran variación

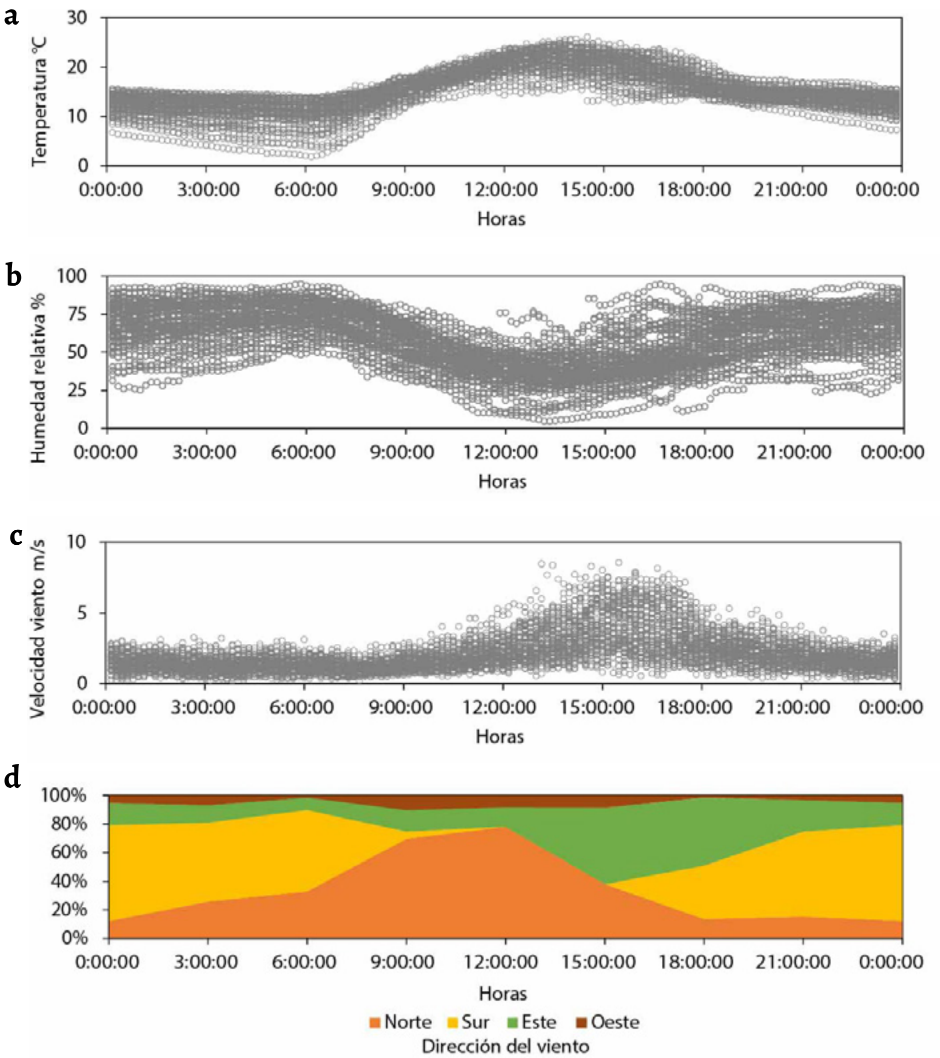


**Figura 3.** Variables climáticas promedio horarias (2015-2018) para el mes de noviembre: *a)* Temperatura; *b)* Humedad relativa; *c)* Velocidad del viento; *d)* Dirección del viento. Fuente: elaboración a partir de datos de la EMOV EP.

térmica superior a los 10 °C, y variación de la intensidad de viento en 5 m/s.

Por otra parte, el estudio puede delimitar el periodo de análisis en relación con horas de mayor actividad humana e ingreso y salida de sol, que significa ganancias térmicas. Entonces se aborda el periodo de 6 h a 18 h, mediante horas de análisis en: la mínima temperatura registrada a las 6 h con viento proveniente del sur; la máxima temperatura registrada a las 15 h con viento desde el este; y se evalúa a las 12 h con mayor porcentaje de viento desde el norte (Figura 3*d*).

**Análisis del viento y cálculo de la temperatura aparente**

La carga de viento que actúa sobre un edificio depende de la velocidad del viento, densidad de masa de aire, ubicación geográfica, forma y altura de los edificios y rigidez estructural. El tamaño, perfil y orientación del edificio hacia la dirección del flujo de viento tienen un impacto en la fuerza de arrastre. Es decir, la energía cinética del viento se convertirá en energía potencial, que tiene la forma de presión o succión en el edificio. Según el tipo de edificio se puede determinar el valor de resistencia a un objeto mediante el coeficiente de arrastre [20, 29], como se menciona en la expresión (1).

$$C_d = \frac{2F_d}{\rho v^2 A} \tag{1}$$

Donde,
$C_d$ = Coeficiente de arrastre
$F_d$ = Fuerza de arrastre que actúa en la dirección de flujo del fluido (N)
ρ = La densidad del aire para condiciones de agua a temperatura normal (1.2 kg/m$^3$)
$v^2$ = velocidad del fluido (m/s)
A = Area del objeto que se atraviesa (m$^2$)

El modelo matemático anterior es empleado en CFD, que nos permite visualizar el efecto del viento basándose en la velocidad actuante del sitio, geometría y orientación del edificio estudiado. Primero, se usa el *software* Flow Design que simula el túnel de viento. Tal sistema aplica situaciones de régimen incomprensible de baja velocidad, mediante métodos numéricos y modelos de turbulencia. En cuanto al uso de la interfaz, se siguen recomendaciones como el correcto uso de las unidades, y dimensionamiento del túnel del viento, para la obtención de resultados confiables [30].

En segundo lugar, los valores obtenidos en las simulaciones sirven para definir la temperatura aparente para un clima templado [31]. En este sentido se pueden utilizar dos expresiones, en donde la primera define una situación de sombra, mientras la segunda define una situación con sol (radiación).

La expresión (2) evalúa el efecto del viento en la temperatura aparente para situación en sombra (Tpv).

$$Tpv = -2{,}7 + 1{,}04\,T + 2{,}0\,P - 0{,}65\,v \tag{2}$$

Donde,
T = Temperatura de bulbo seco (°C)
v = Velocidad del viento (m/s) en una elevación de 10 m
p = Presión del vapor de agua (kPa) (humedad)

P se calculó por medio de la fórmula (3)

$$P = \left(\frac{rh}{100} * 6{,}105 * e^{\frac{17{,}27*T}{237{,}7+T}}\right)/10 \tag{3}$$

Donde,
rh = Humedad relativa (%)

Por otro lado, la expresión (4) evalúa el efecto del viento en la temperatura aparente para sol, (Tpvg), es decir con ganancias solares.

$$Tpvg = -1{,}8 + 1{,}07\,T + 2{,}4\,P - 0{,}92\,v + 0{,}044\,Qg \tag{4}$$

Donde,
Las variables T, P y v son las señaladas anteriormente.
Qg = Radiación neta absorbida por unidad de área de superficie corporal (W/m$^2$)

En las situaciones de la presente investigación, se consideró la radiación para las horas próximas al medio día entre 12 y 15 h que pueden penetrar con facilidad los cañones urbanos. Se usa un valor referencial Qg de 91 W/m$^2$ [31], debido que las ganancias por la superficie de piel son mediante el rostro y extremidades descubiertas y que depende también del albedo de la vestimenta y su capacidad para ganar calor.

**Definición de las morfologías y periodos de evaluación**

Basándose en las consideraciones anteriores se recrean modelos mediante ordenador con datos de mediciones in situ que definen la vía y las fachadas, y cuya proyección de los edificios permita la evaluación del viento. Los modelos pueden definir diferentes valores del ratio H/W y el ingreso solar según hora de simulación (Figura 4).

En el escenario local, Ochoa de la Torre [32] señala que la trama urbana puede entenderse como un complejo sistema que puede sintetizarse a partir de entender subsistemas como calle, plaza y vegetación. Esta última clasificación puede ayudar a la selección de casos de estudio.

A partir de las consideraciones anteriores se plantea casos de estudio por orientaciones norte-sur (Figura 5) y este-oeste (Figura 6) con longitudes igual al lado de una manzana de acuerdo con ratios H/W de valores inferiores a 0,25 (predominio de lo horizontal) hasta valores de 1,5 (predominio de lo vertical). Las Figura 5 y Figura 6 también consideran la hora de simulación y empleo de Tpv y Tpvg. Además, en la Figura 7 se muestran todos los casos estudiados dentro del tejido urbano, los cuales son agrupados por hora de simulación, dirección y velocidad de viento.

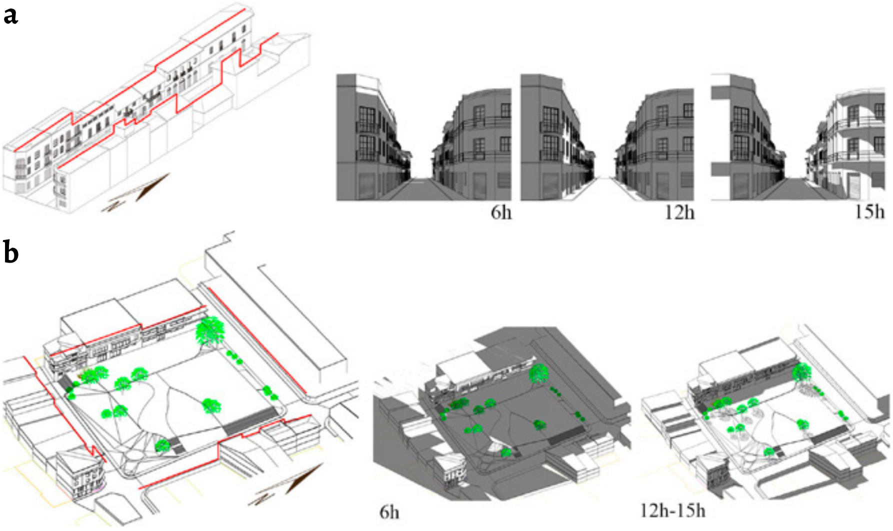


**Figura 4.** Tipologías de cañón y horas de estudio: *a)* Cañón tipo calle: a la izquierda variación de morfología por altura y derecha incidencia de radiación por horas; *b)* cañón tipo Parque: a la izquierda variación de morfología por altura y derecha incidencia de radiación por horas.

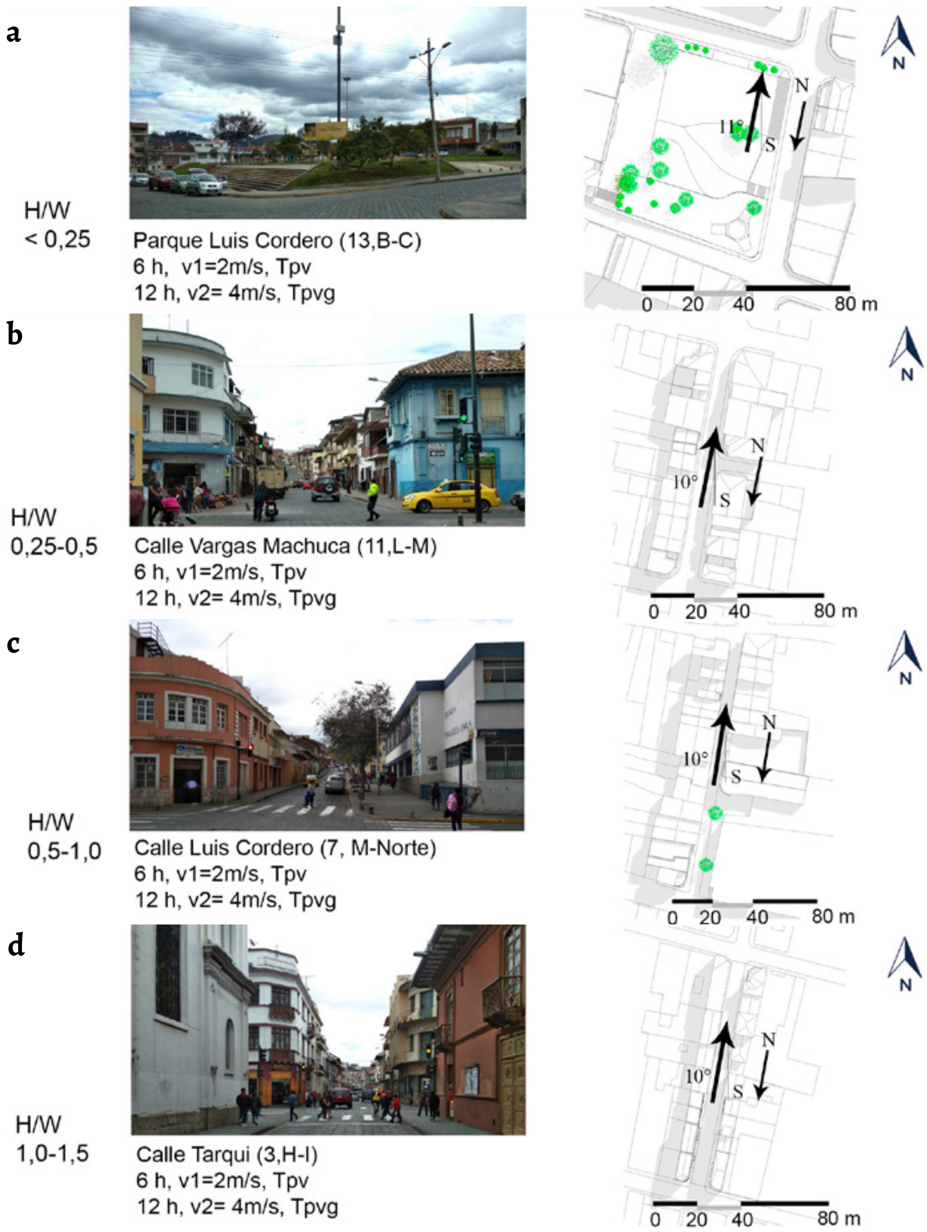


**Figura 5.** Casos de estudio en el sentido norte-sur. A la izquierda vista de la calle y a la derecha planta: *a)* Parque Luis Cordero; *b)* Vargas Machuca; *c)* Luis Cordero; y *d)* Tarqui.

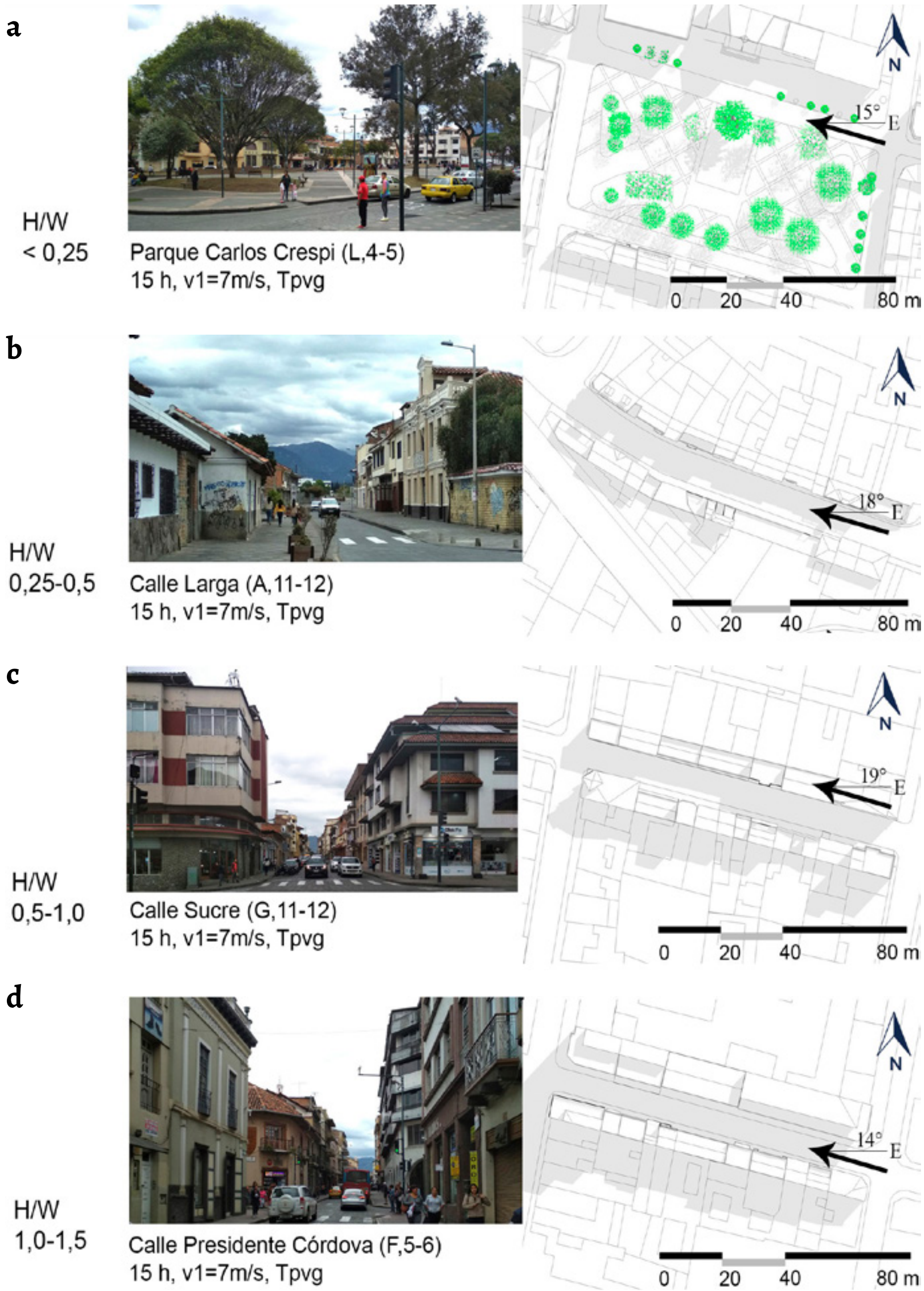


**Figura 6.** Casos de estudio en sentido este-oeste. A la izquierda vista de la calle y a la derecha planta: *a)* Parque Carlos Crespi; *b)* Larga; *c)* Sucre; y *d)* Presidente Córdova.

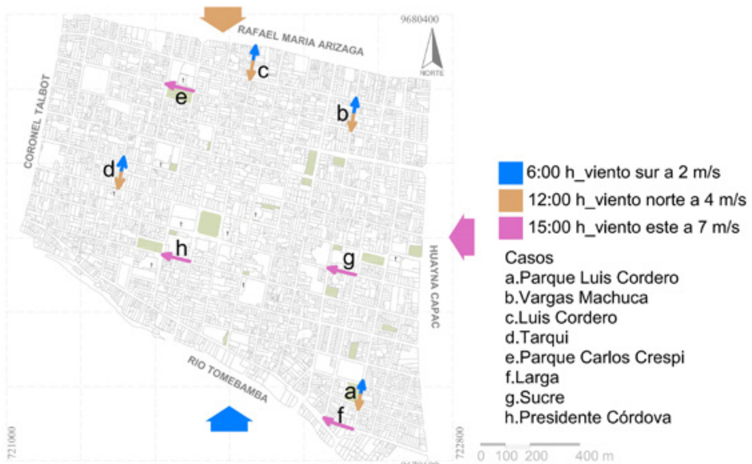


**Figura 7.** Planta del tejido urbano y casos de estudio según incidencia de viento por horas.

## Resultados y Discusión

En el primer grupo de cañones de las 6 h, con orientación norte-sur, velocidades de 2 m/s y viento proveniente del sur (Figura 8) se obtienen los siguientes comportamientos. El parque Luis Cordero (Figura 8*a*) no mostró el ingreso homogéneo del viento debido a las obstrucciones de edificios y también a la presencia de vegetación que puede alcanzar alturas de hasta 15 m. Además, el parque presenta un desnivel respecto a las vías de la parte sur que dificulta el paso del viento.

Los cañones tipo calle (6 h) al coincidir su orientación con la dirección del viento, permiten su fácil acceso debido a la homogeneidad en la sección de las calles: Vargas Machuca, Luis Cordero y Tarqui, mostradas respectivamente a la izquierda de las Figura 8*b-d*. Este encauzamiento del viento se rompe parcialmente cuando existe una circulación lateral o espacio abierto que ocasiona la pérdida de velocidad de

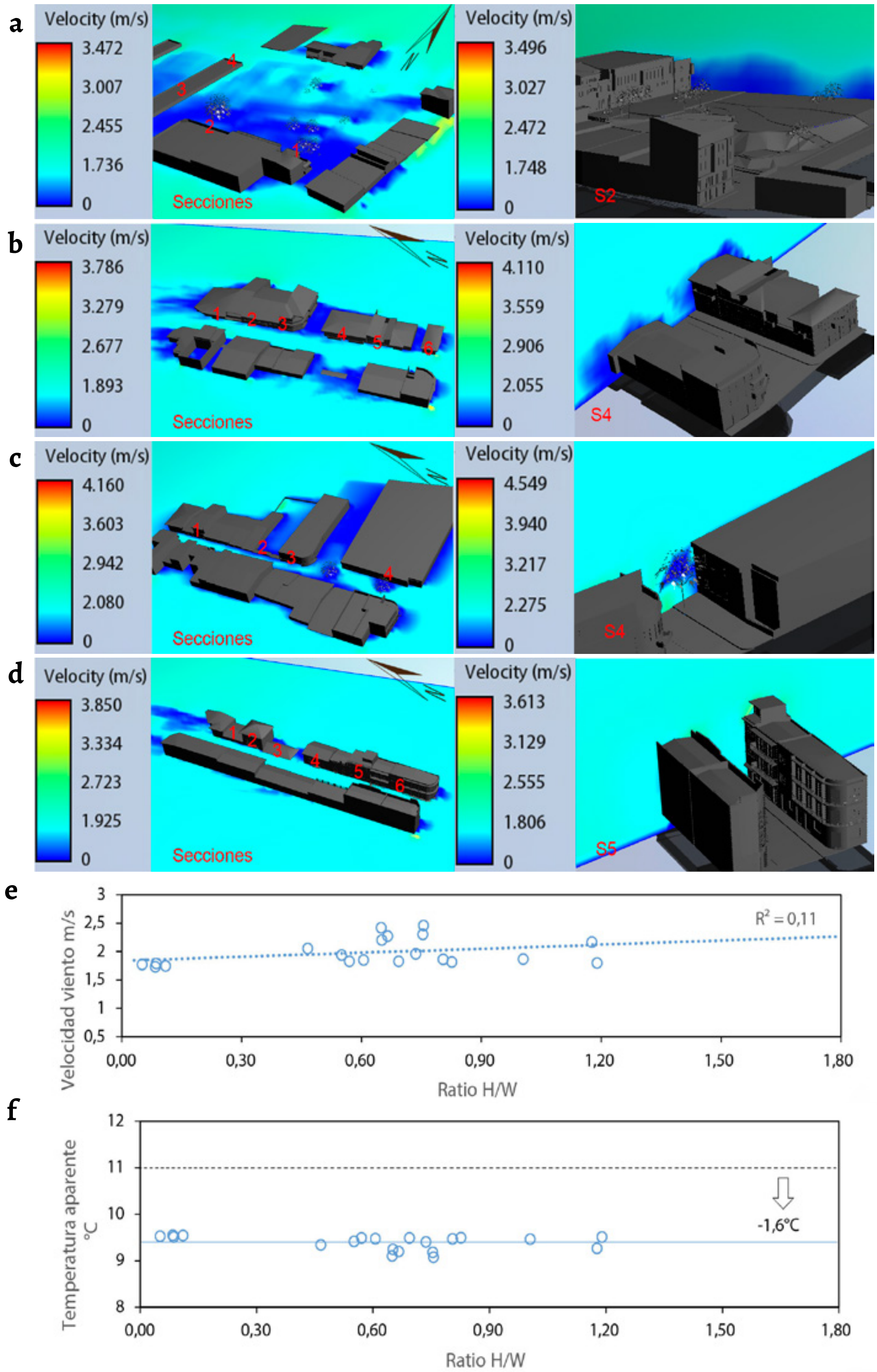


**Figura 8.** Simulaciones de los cañones urbanos a las 6 h en el sentido norte-sur con viento a 2 m/s desde la dirección sur. A la izquierda corte horizontal y a la derecha un ejemplo de sección vertical respectivamente: *a)* Parque Luis Cordero; *b)* Vargas Machuca; *c)* Luis Cordero; *d)* Tarqui. *e)* Velocidad de viento vs H/W; y *f)* Temperatura aparente vs ratio.

viento hacia el mismo. Tal acción se puede observar en la calle Luis Cordero (Figura 8*c*).

Las secciones verticales mostradas a la derecha de la Figura 8 ayudan a distinguir el efecto del viento por incrementos o decrementos de la velocidad cuando varía la altura (ratio H/W). Este último comportamiento se ejemplifica para el tramo de la calle Tarqui (Figura 8*d*) cuya sección en la parte superior y sur de los edificios (3 pisos) supera la intensidad de simulación (2 m/s). También, se observa en general que cuando el viento fluye perpendicular a los edificios o a sus elementos, este adquiere un valor próximo a cero (color azul oscuro según gráficas). Adicionalmente, el caso Luis Cordero presenta vegetación hacia el lado sur-oeste del mismo, cuya obstrucción delimita una menor sección de paso del viento que modifica su velocidad (Figura 8*c*).

Finalmente, la Figura 8*e* muestra que el primer grupo de casos estudiados tiene en promedio un $R^2$ de 0,11, mientras la Figura 8*f* muestra que el promedio de temperatura aparente desciende en 1,6 °C respecto a la temperatura en dicha hora (11 °C). Es decir a esta hora el efecto del viento genera enfriamiento.

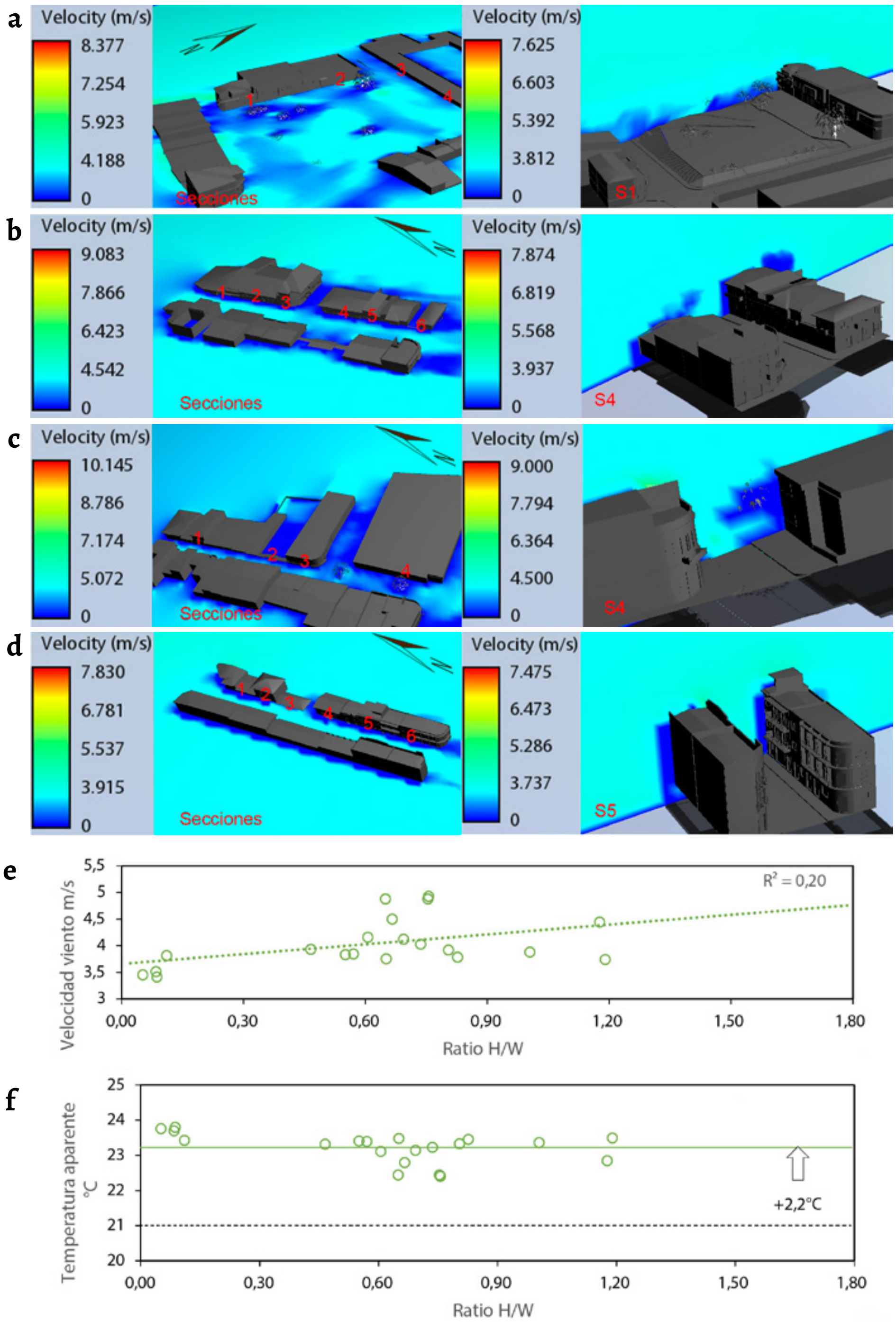


**Figura 9.** Simulaciones de viento en los cañones urbanos estudiados a las 12 h en el sentido norte-sur con viento a 4 m/s desde la dirección norte. A la izquierda el corte horizontal y a la derecha un ejemplo de sección vertical respectivamente: *a)* Parque Luis Cordero; *b)* Vargas Machuca; *c)* Luis Cordero; *d)* Tarqui; *e)* Velocidad de viento vs H/W; y *f)* Temperatura aparente vs ratio.

El segundo grupo de cañones de las 12 h, con orientación norte-sur, velocidades de 4 m/s y con viento proveniente del norte (Figura 9), señala los siguientes resultados.

En el caso del parque Luis Cordero la vegetación sigue aportando una obstrucción importante, mientras que el acceso del viento al interior del parque fluye con menos dificultad (Figura 9*a*), ya que ahora proviene desde el norte cuyo desnivel es menor respecto al sur.

Por su parte en las calles: Vargas Machuca, Luis Cordero y Tarqui, el viento penetra sin dificultad el interior del mismo, como se muestra respectivamente a la izquierda de las Figura 9*b-d*. Conjuntamente, en las secciones verticales mostradas a la derecha de las Figura 9*b-d*, se encuentra un comportamiento similar al descrito en el primer grupo de 6 h, pero con la característica de que se obtiene velocidades mayores al medio día.

La Figura 9*e* muestra que el segundo grupo de análisis (12 h) obtiene en promedio un $R^2$ de 0,20, en tanto que en la Figura 9*f* muestra que el promedio de temperatura aparente aumenta en 2,2 °C, respecto a la temperatura en dicha hora (21 °C). Esta segunda tendencia señala que el efecto del viento es inferior frente a las ganancias térmicas por radiación.

El último grupo de cañones (15 h) simuló casos en la segunda dirección característica de la zona de estudio (este-oeste) con velocidad de viento de 7 m/s y procedencia este. El cañón tipo parque (Carlos Crespi) mostrado en la Figura 10*a*, destaca la vegetación cuyos elementos alcanzan alturas de hasta 20 m, y al estar distribuidos en la superficie del parque provocan dificultad en el acceso del viento al interior. Además, en este caso la presencia de desniveles es mínima hacia el lado de la vía principal este-oeste.

Los casos tipo calle (este-oeste): Larga, Sucre y Presidente Córdoba, (izquierda de las Figura 10*b-d*) mostraron un flujo de viento constante en el cañón, mientras que las secciones verticales presentaron intensidades de viento superiores a mayor altura, como en la calle Presidente Córdova (Figura 10*d*).

Finalmente, la Figura 10*e* muestra que el tercer grupo de estudio (15 h) tienen en promedio un $R^2$ de 0,44, mientras que la Figura 10*f* muestra que el promedio de temperatura puede ascender (4,6 °C) y descender (4,3 °C) respecto a la temperatura en dicha hora (21 °C). Este último grupo muestra las tendencias de los grupos anteriores para enfriamiento y ganancia térmica.

Después de haber descrito las gráficas de simulación de viento, se resume un primer análisis de la relación entre la geometría e intensidad del viento. En general, se muestra una tendencia en los tres grupos de estudio que el viento puede intensificarse cuando la geometría tiene mayor verticalidad (mayor ratio H/W). Además, no se muestra una correlación fuerte entre la velocidad del viento y el ratio H/W, pero la correlación tiende a incrementarse a medida que aumenta la velocidad de viento (a 2 m/s tiene un $R^2$ de 0,11, a 4 m/s un $R^2$ de 0,2 y a la velocidad de 7 m/s adquiere un $R^2$ de 0,44).

Por otra parte, la caracterización del microclima del entorno histórico de Cuenca empleó la temperatura aparente a partir del efecto del viento. Esta expresión consideró: temperatura ambiente, velocidad de viento, humedad relativa y ganancias térmicas por radiación según horas de estudio. Los resultados de temperatura aparente se resumen en enfriamientos o calentamientos.

El primer comportamiento, muestra a cañones que se enfrían por el efecto del viento, pero sin ganancias por radiación. Este fenómeno se da en los casos simulados a las 6 h y 15 h, en donde los primeros disminuyen la temperatura en promedio de 1,6 °C, mientras el grupo de las 15 h con una mayor velocidad de simulación alcanza un decremento de hasta 4,3 °C para los casos tipo calle (H/W > 0,25). Así, la primera tendencia mostró que una mayor intensidad de viento disminuye la temperatura (sensación térmica).

El segundo comportamiento, muestra el incremento de calor cuando las ganancias por radiación son mayores, o porque la intensidad de viento no es suficiente para disminuir tal sensación. Esto se observó en los casos evaluados de 12 h y 15 h con temperaturas similares. El grupo de las 12 h mostró una menor intensidad de viento, pero facilita el ingreso solar de forma que se produce un incremento en la sensación térmica en promedio de 2,2 °C. Por su parte, en el caso de las 15 h, en el cañón tipo parque con ratio H/W menor a 0,25 también facilita las ganancias de radiación provocando un incremento térmico de 4,6 °C en la sensación térmica.

Los comportamientos anteriores sugieren que las obstrucciones por morfología en cañones tipo calle pueden tener un mejor control térmico que también dependerá de la orientación, mientras que los espacios abiertos como plazas pueden tener menor control en horas próximas al medio día. De forma seguida, la presente investigación de Cuenca se puede comparar con otros estudios señalando similitudes y diferencias en la metodología y resultados.

Tumini [11] utiliza el *software* ENVI-met y el software Ecotect y gráfica los resultados de perfiles de viento y temperatura para casos de Madrid tanto en condiciones de verano como invierno. Este primer estudio destaca el periodo más crítico en verano y en horas cercanas a las 15 h en donde los cañones con bloques de edificaciones con menor paso libre impiden el fluir del viento, y por lo tanto la disipación del calor acumulado. En el caso de Cuenca las horas de mayor temperatura también coinciden en este periodo, aunque este comportamiento de clima con incrementos térmicos al medio día puede ser similar en todo el año.

Colomer [14], mediante el uso CFD Flow Vector de Ecotect evalúa el viento en tipologías morfológicas. Para ello considera una velocidad de viento de 3 m/s con dirección este, que muestra un fácil acceso de viento cuando el cañón sigue la dirección de procedencia del fluido. Pero cuando el viento entra perpendicular a los cañones disminuye de velocidad. El anterior estudio también muestra que la velocidad del viento es superior en perfiles de simulación a 20 m del suelo. En el caso de Cuenca, se tiene cuidado de evaluar solo casos que sigan la dirección del viento,

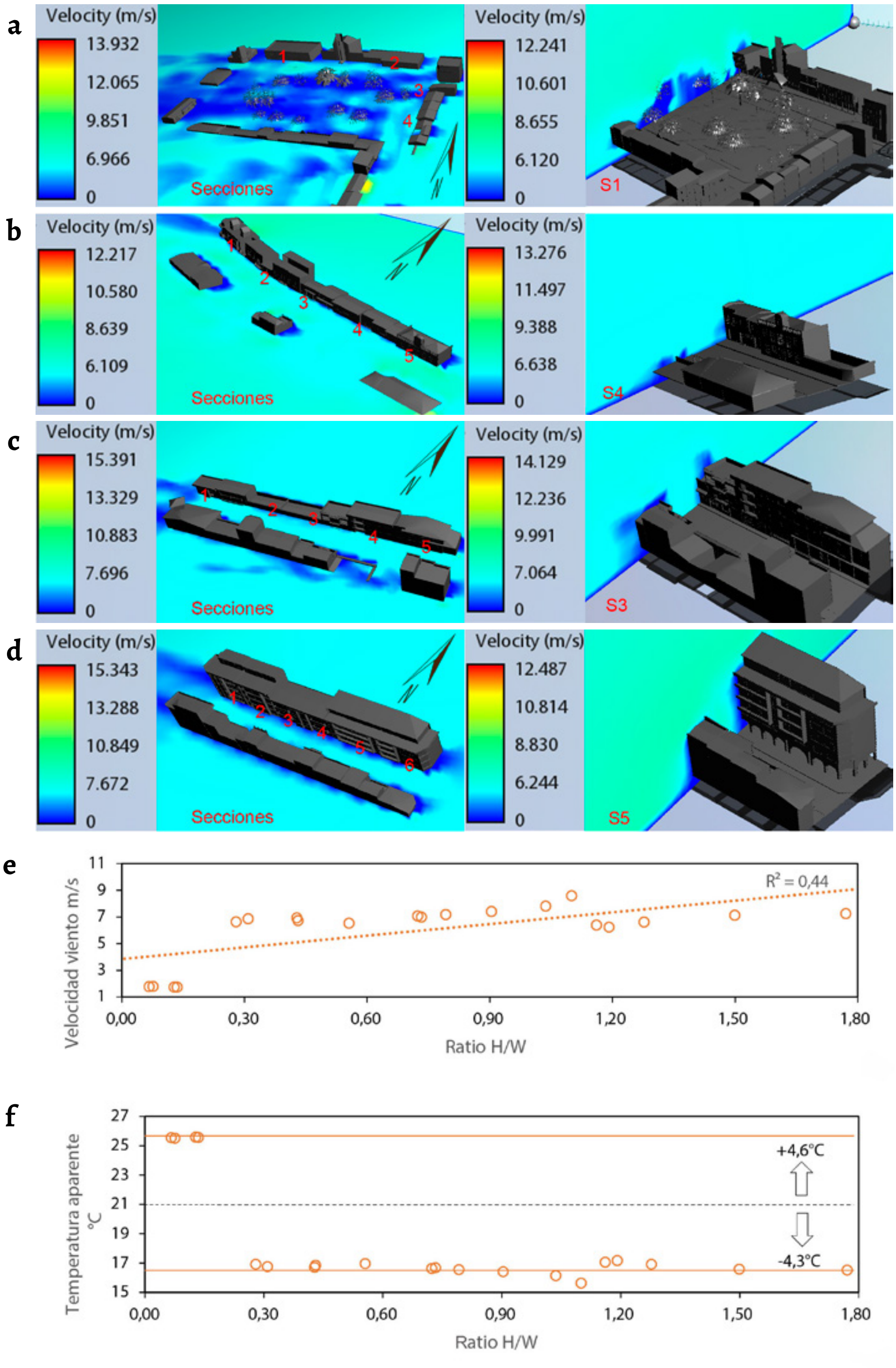


**Figura 10.** Simulaciones de viento en los cañones urbanos estudiados a las 15 h en el sentido este-oeste con viento a 7 m/s desde la dirección este. A la izquierda el corte horizontal y a la derecha un ejemplo de sección vertical respectivamente: *a)* Parque Carlos Crespi; *b)* Larga; *c)* Sucre; *d)* Presidente Córdova; *e)* Velocidad de viento vs H/W; y *f)* Temperatura aparente vs ratio.

ya que resulta limitado la evaluación del efecto desde una dirección opuesta a los cañones urbanos. Además, se encuentra una similar tendencia de que el viento puede incrementarse mientras esté a mayor altura del suelo (perfil de simulación).

Por su parte Ambrosini [2], emplea el *software* ENVI-met, para simulaciones con viento promedio de 3 m/s y dirección norte que coincide con la dirección de morfología norte-sur. Este estudio muestra que la distribución del viento es menor cerca de los obstáculos en área pequeñas, mientras que en los espacios abiertos adquiere mayor velocidad que varía entre 0,2 m/s y 4,3 m/s. Esta tendencia de incrementos de la velocidad en espacios abiertos es similar para el caso de Cuenca, aunque el incremento de velocidad al interior de las morfologías es evidente cuando se aumenta la velocidad de simulación.

El estudio de Salvo [19], destaca un aspecto puntual para el estudio de Cuenca de que a mayor velocidad existe un mayor desprendimiento de viento. Esto puede observarse en el efecto de las primeras edificaciones cuyas fachadas laterales están perpendiculares al sentido del viento y que al entrar en contacto modifican el flujo que incide sobre las siguientes edificaciones.

Para el estudio de Christen realizado en Basel [15], los resultados de los perfiles individuales de viento muestran una fuerte dependencia con la dirección del viento y estructuras de los edificios cuya forma del techo juega un papel importante en la incidencia del viento. Así los techos planos muestran un vórtice primario claro que se caracteriza por una mayor velocidad de viento en calle en comparación con el flujo de los techos inclinados. El centro histórico de Cuenca se caracteriza por la presencia de cubiertas inclinadas, sin embargo gran parte de las edificaciones evitan el efecto del mismo por los remates superiores, además de que no se puede apreciar cubiertas de inclinaciones pronunciadas. Por otra parte esta situación sugiere un mayor análisis para el caso de Cuenca, ya que básicamente se evalúa el efecto del viento al interior del cañón.

El estudio de Echave [16] para la ciudad de Madrid menciona que el tránsito peatonal junto a la fachada sur mejora la condición de confort, aunque el efecto de la vegetación mejora las condiciones de habitabilidad. En Cuenca la mayor variación térmica se da en los casos orientados este-oeste y cuyas fachadas de circulación son norte y sur. De esta forma el tránsito por las fachadas norte o sur son solo convenientes en horas de suficiente ventilación. Sin embargo, para evitar la radiación directa se deberá transitar por las fachadas este u oeste considerando la incidencia solar. Por otra parte, no se puede evaluar el efecto de habitabilidad a partir de la vegetación, pero se observa que esta última puede ser importante para limitar la acción del viento.

El estudio de Rajagopalan, Lim y Jamei [17], destaca que una mayor altura en las edificaciones obstruye el efecto del viento, que puede mermar la ventilación y ocasionar incrementos térmicos como islas de calor. A diferencia, de este estudio el centro histórico de Cuenca no dificulta el paso del viento porque esta zona se sigue caracterizando por su baja altura en edificación. Sin embargo, al interior de los cañones se puede identificar un efecto menor del viento para ventilar los mismos, lo que podría provocar incrementos térmicos o islas de calor.

La presente investigación de Cuenca con información de la estación principal del área de estudio permite estudiar intensidades máximas y direcciones de viento por horas para simular los modelos simplificados. Esta información referida al viento sigue la tendencia que la mayor hora de intensidad del mismo está próxima a las 15 h [9]. Además, se destaca el estudio de Rosas-Lusett [21] que advierte que entre las 12 h y 15 h se puede provocar un malestar ocasionado por el fácil acceso solar (situación a cuidar en las zonas cercanas al trópico).

Si bien el presente estudio de Cuenca se enfocó en las obstrucciones por edificaciones, también destaca a través de los limitados casos la importancia de la vegetación como elementos de obstrucción similar a edificios. El estudio de Rodríguez Potes destaca esta última idea [18]. Por otra parte, Ochoa de la Torre [32] sugiere que el control del viento paralelo a las calles es limitado, mientras que el control del viento en las plazas se maneja con vegetación. También, señala que el viento al seguir la misma dirección del cañón produce un "encauzamiento" que puede provocar un efecto de ventilación. Este último comportamiento se observa en los casos de Cuenca, aunque este efecto puede ser mayor, si se incrementa la intensidad de viento.

Todo lo anterior muestra que las simulaciones (CFD) tanto en los cañones tipo calle como parque tienen similitud en correlaciones y tendencias, a pesar de que las conciones de morfología difieran por entrantes y salientes definidas por las alturas de los edificios. También, se recrea a escala la morfología inmediata de cada cañón evaluando el ratio H/W. Además, los casos de parque con situaciones de desnivel y presencia de vegetación pueden complicar el estudio.

Finalmente en la Figura 11, se muestra una gráfica resumen de los casos de estudio en los que se destaca la sección evaluada en relación con la hora de simulación, dirección de viento e incidencia solar; elementos que sirven para obtener el promedio de la temperatura aparente en cada situación.

## Conclusión

El presente estudio analizó un aspecto del microclima del centro histórico a través del viento, como un elemento poco abordado en esta zona sensible de la ciudad. Por otro parte, se estudia la geometría implícita en los cañones urbanos que contribuyen la modificación de la intensidad del viento y por tanto la variación de la temperatura aparente.

El estudio del cañón urbano constituye la unidad básica de análisis para escala peatonal que definido por sus obstrucciones morfológicas explicitas en sus dimensiones geométricas y junto a su disposición (orientación), son aspectos básicos para valorar criterios de diseño urbano, que deben delimitarse para cada contexto climático.

El esquema metodológico empleado ha mostrado ser adaptable a los casos estudiados, es decir ofrece la ventaja de evaluar simultáneamente la geometría de cañones urbanos mediante el uso de CFD, que básicamente exige datos de la intensidad y dirección predominante de viento. Además, se guarda un mismo nivel de altitud dentro del área de estudio para que los datos de la estación local puedan ser representativos en las simulaciones.

Basándose en los resultados cuantitativos se puede señalar que: los cañones norte-sur de las 6 horas muestran una disminución térmica no menor a 2 °C, mientras que los cañones de 12 horas muestran un incremento mayor de 2 °C. Así estos dos primeros casos muestran una oscilación térmica en 2 °C. Por otro lado, los cañones este-oeste de las

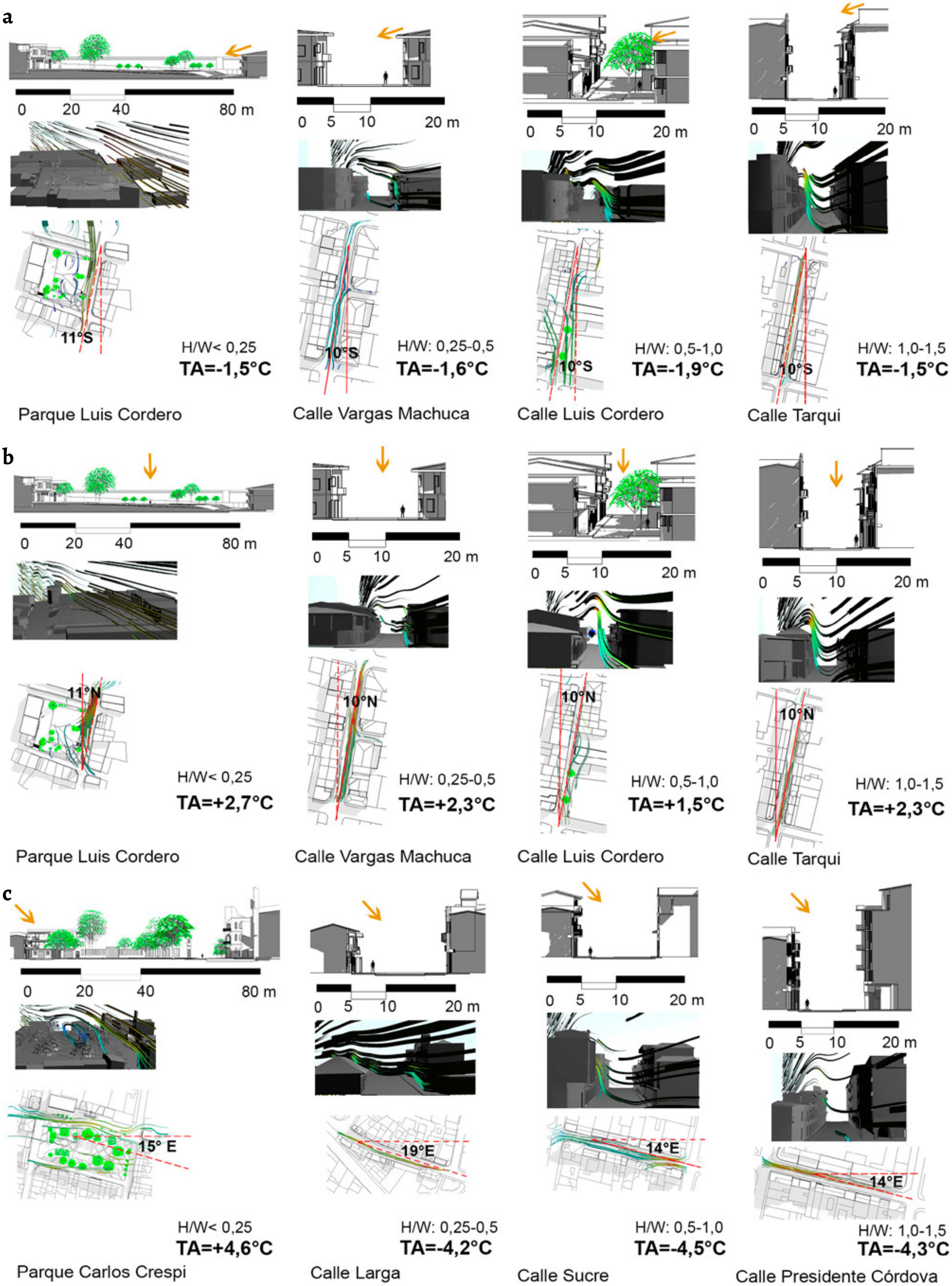


**Figura 11.** Temperatura aparente promedio según ratio H/W y orientación: *a)* Cañones de las 6 h con viendo desde sur a 2 m/s; *b)* Cañones de las 12 h con viento desde norte a 4 m/s; y *c)* Cañones de las 15 h con viento desde este a 7 m/s.

15 h muestran la mayor oscilación térmica con incrementos y disminuciones de hasta 4 °C respecto a la temperatura promedio.

La modificación micro climática varia secuencialmente a lo largo del día, cuya velocidad del viento está relacionada con la capacidad de ventilación. En Cuenca las velocidades de viento por horas seleccionadas se incrementan de casi dos veces respecto a la hora anterior de análisis, es decir: a las 6 h (2 m/s), a las 12 h (4 m/s) y a las 15 h (7 m/s). Esta última proporción se muestra similar en la modificación de la temperatura aparente: 6 h (-2 °C), 12 h (+-2 °C) y 15 h (+-4 °C). Es decir por cada vez que se duplica la velocidad, se duplica la capacidad para modificar la temperatura aparente.

De esta consideración se deriva una pauta de diseño a partir de la priorización de la dirección del viento por horas, en donde la menor oscilación térmica en sentido norte-sur sugiere espacios de menor control, mientras que la mayor oscilación térmica en los casos de sentido este-oeste sugieren mayor cuidado. Entonces la variabilidad diaria del viento por horas tanto en intensidad como dirección es fundamental para el estudio de asentamientos similares (sierra ecuatoriana) que con el esquema metodológico propuesto, valora la situación bioclimática de la ciudad.

Adicionalmente, la modificación del microclima del centro histórico de Cuenca puede sugerir dos afectaciones inmediatas. Primero, el malestar del peatón, efecto que puede verse intensificado si se considera al centro histórico como: la zona más densamente poblada de la ciudad, zona con menor superficie permeable o área verde, y como zona que presenta mayor conflicto vehicular. Segundo, estas modificaciones inciden en el balance térmico general que puede afectar el aspecto físico de los entornos patrimoniales, y por lo tanto generar vulnerabilidad en las fachadas y cubiertas por su exposición directa. Finalmente, los centros patrimoniales además de su valor histórico y estético también deben ser estimados por su valor ambiental.

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# Meteorites as a scientific heritage

# Os meteoritos como património científico

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**Abstract**

This paper investigates the importance of meteorites as a scientific heritage. While the significance of meteorites as natural heritage is relatively easy to establish, the implication of their meaning as scientific heritage may be more difficult to define. With this aim in mind, in this paper, we present the catalogue standards for meteorite specimens, preserved either in natural history museums or in private collections, proposed by the Italian Istituto Centrale per il Catalogo e la Documentazione – ICCD (Central Institute for Catalogue and Documentation). This work outlines the structure of the catalogue card that describes the meteorite specimen along with other information related to the sample (e.g., archival documentation on collectors and traders, museum catalogues and inventories, general bibliography). This paper concludes discussing the cataloguing, according to ICCD standards, of two Renazzo meteorite specimens, which fell in the eponymous Italian village in 1824 and are now preserved at the Natural History Museum of the University of Firenze.

**KEYWORDS**
Natural heritage
Scientific heritage
Cultural heritage
Meteorites
Preservation policies
Catalogue

**Resumo**

O presente artigo investiga a importância dos meteoritos como património científico. Enquanto a relevância dos meteoritos como património natural é relativamente fácil de estabelecer, a implicação do seu significado como património científico poderá ser mais difícil de definir. Com esse objectivo em mente, no presente artigo apresentam-se as normas de catálogo para espécimes de meteoritos preservados, quer em museus de história natural, quer em coleções privadas, propostos pelo Istituto Centrale per il Catalogo e la Documentazione – ICCD (Instituto Central para o Catálogo e Documentação). A estrutura do cartão de catálogo que descreve o espécime de meteorito, juntamente com outras informações relacionadas com a amostra (e.g. documentação de arquivo sobre colectores e comerciantes, catálogos de museus e inventários, bibliografia geral), é aqui delineada. Conclui-se com a discussão da catalogação de acordo com os padrões do ICCD, de dois espécimes de meteorito Renazzo, que caíram na aldeia italiana homónima em 1824 e que estão agora preservados no Museu de História Natural da Universidade de Florença.

**PALAVRAS-CHAVE**
Património natural
Património científico
Património cultural
Meteoritos
Políticas de preservação
Catálogo

## Introduction

More than 50 tons of extraterrestrial material hit the Earth every year [1]. Meteorites are natural objects that have survived passage through the atmosphere and have reached the ground. An important difference exists between meteorite falls and meteorite finds: the former are meteorites collected after their fall was witnessed by observers or camera networks designed for monitoring fireballs; the latter are meteorites that were recovered by people but whose fall was not seen [3]. Each meteorite found is given a name by the Nomenclature Committee of the Meteoritical Society, usually that of the closest geographical landmark where it fell or was recovered. All known meteorites recognized by the Meteoritical Society are then included in the Meteoritical Bulletin Database (https://www.lpi.usra.edu/meteor/metbull.php) a digital repository for basic information such as meteorite classification, place and year of discovery, whether it was observed to fall and references to catalogues (i.e., *Catalogue of Meteorites* from the Natural History Museum in London, *MetBase*, *Antarctic Meteorite Newsletter*) in which the meteorite is described.

Meteorites have been falling from the sky for aeons and have been investigated by scientists from a number of various disciplines. In 1858, Karl Ludwig Reichenbach (1788-1869) defined meteorites as cosmological, astronomical, physical, geological, chemical, mineralogical, and meteorological objects, highlighting the fact that they can be studied from different perspectives [4]. Even the term 'meteor' did not have the meaning it has got at the present. In his *Lexicon Technicum*, John Harris (1666-1719) described meteors as "various impressions made upon the Elements, exhibiting them in different forms (...) for the most part, they appear up in the Air, and they are either Fiery, Airy, or Watery" [5]. This description stemmed directly from Aristotle's *Meteorologica* (about 340 B.C.). The meteorological tradition, as stated by Jankovic (2006), remained entrenched in the Aristotelian view until the early nineteenth century when naturalists such as Ernst Chladni (1756-1827), Edward Howard (1774-1816) and Jean-Baptiste Biot (1774-1862) established the extraterrestrial origin of meteorites [6]. It is beyond the scope of this article to attempt a comprehensive reconstruction of the history of the meteoritics [9], nonetheless, even before scholars were convinced of the reality of meteorite falls from the outer space, meteorites were preserved in naturalistic museums and private collections throughout the world. In this regard, Burke [10] noted that the development of mineralogical collecting in the eighteenth century aided the recovery of meteorite specimens to the point that, after the mid-nineteenth century, meteorites collection became a symbol of a nation's scientific prestige and political power [11]. Burke [10] further pointed out how, between the late nineteenth and early twentieth century, the major European and American meteorite collections were established and opened to the public. From then on, the specimens in these collections have become an important source of extraterrestrial material for research purposes [14]. Hartmann's and Golia's [19] studies emphasize how meteorites have a social and cultural history, being surrounded by a significant corpus of myths, legends and folklore. In this regard, there have been numerous studies to investigate recorded accounts of meteoritic events in the oral traditions of Native Americans and Indigenous Australians [21]. For instance, the following studies were conducted using first-hand ethnographic records, literature, and field trip data to locate possible new impact structures or meteorites in Australia [23]. A number of authors have also recognized the use of meteorites in ancient human artefacts [27]. In short, as rightly remarked by Dorfman [33], the literature pertaining to meteorites in history strongly suggests that meteorites hold many levels of intangible heritage [34]. On this subject, a recent study by Wilson [35] concluded that the way in which planetary science is represented in natural history museums contributes to demonstrating the role of natural heritage as a means of moral and social witnessing. The author argued that in temporary or permanent exhibitions focusing on the formation of galaxies, stars and planets (e.g., the temporary exhibition 'The Evolving Universe' in The Arthur Ross Hall of Meteorites at the American Natural History Museum in New York, and the permanent exhibition 'Kosmos & Sonnensystem' in the Museum für Naturkunde in Berlin), visitors observe, through the display of meteorites, not only the cosmic processes that have shaped the Solar System, but also how humans have interacted with this aspect of the environment thanks to the recovery and the analysis of meteorite fragments. Wilson [35] further points out that meteorite exhibitions demonstrated "how humanity is not the measure but a component in a wider system that is dependent upon the relationships that are built within it".

As stated before, meteorite collections are the subjects of studies looking into the evolution of both the universe and our planets [36]. Within these research projects, the analysis of historical documents, museum catalogues and inventories can lead both scientists and historians to the potential discovery of meteorite specimens previously unknown [41]. Meteorite collections in natural history museums are therefore representative of scientific as well as historical and cultural meanings that add extra value to a specimen. The issue that then naturally arises is how best to define museum meteorite collections in the heritage context. Revisiting the questions posed by De Chadervian [44], we can ask why meteorite collections in natural history museums are an issue we are invited to think about? Has the way in which meteorite specimens are valued and collected changed? Is the access to the samples an issue? Are science historians, museum curators and planetary scientists raising the issue?

These questions are especially true for the meteorites that have been recovered in Italy over the centuries. Due to physiographic factors, Italian meteorites are extremely rare and to date only 42 meteorites – both falls and finds – have been officially approved by the Meteoritical Society. In spite of their small number and their belonging to a rather common typology (among these, 25 are ordinary chondrites) the study of Italian meteorites has long been the subject of intense historiographic and theoretical debates [45] such as the lively controversy that arose after the shower of stones that fell on Siena on 17 June 1794 [52]. Furthermore, Italian meteorites, such as those of other Western countries, are particularly sought out in the collector market due to their rarity. This can sometimes lead to false 'discoveries' designed to meet this market demand, e.g. the compelling case of the Castenaso meteorite in 2003 [54]. Some authors have also suggested that increased commerce in meteorites raises legal and ethical questions for museum curators, considering that international law about meteorite acquisition is non-uniform [55]. Natural history museums preserve the majority of the Italian meteorites known, as well as archival sources regarding the history of their discovery. These collections are repositories of specimens, documents and artefacts that allow reconstructing the processes by which they were assembled, beginning from the late seventeenth century, as the result of diverse cultural practices that involved different persons, places and things [57].

Starting from the methodological approach presented by Alberti [63], this work revisits the metaphor of "unpacking museum collections", proposed by Byrne et al. [64], in the light of the establishment of cataloguing standards for meteorite specimens. The creation of a standardized cataloguing card, elaborated by the Italian Central Institute for Catalogue and Documentation (Istituto Centrale per il Catalogo e la Documentazione – ICCD) together with museologists and academics, describes meteorite collections as a scientific heritage, problematising the specimens as both naturalistic and cultural objects through the compendium of data about their minerochemical classification, the roles they had over the times and in contemporary planetary science, the social relations they formed and the interactions they continue to have with varied persons and groups (i.e., collectors, scholars, museum curators and visitors) within a complex network of agency. As Godsden et al. [65] and Bennett [66] have noticed, this agency does not end with the specimen acquisition, but it continues in the procedures of display as well as in the social and cultural practices or researching and learning which arise from the study of the single meteorite sample [67] (Figure 1).

The management of the catalogue cards through the SIGECweb digital database then shows how meteorite collections have not only a documentary value, but they represent a scientific heritage, the study of which helps to increase and improve our understanding of the cosmos, through the sharing of data otherwise unknown to the scientific community [68].

## The standardized cataloguing of meteorite collections

Much has been said about the concept of heritage in museum studies [69]. Quoting the expression proposed by Boundia and Soubiran [71], the "heritage fever" – and thus the notion of heritage – has been the subject of countless studies since the 1980s. De Chadarevian [44] underlined how the term 'heritage' usually indicates "something preserved from the past" – from artefacts to buildings, from cities to landscapes – but also living cultures and intangible heritage (i.e., gestures, feasts, ceremonials) according to the definition proposed by the UNESCO [72]. Policies for safeguarding and management both material and intangible heritage have been developed by the International Council of Museums (ICOM), which established a new international committee dedicated to the cultural heritage of museum universities (UMAC) in 2002 [73]. In 2005, the Committee of Ministers of the Council of Europe adopted the Convention on the Value of Cultural Heritage for Society (also known as the

**Figure 1.** Ordinary chondrite meteorite with fusion crust (weight 2236 g). Museum of Planetary Sciences – Prato, Italy, Inv. No. 1413/1.

**Figure 2.** Acfer 371 oriented meteorite showing well visible regmaglypts (weight 9608 g). Museum of Planetary Sciences – Prato, Italy, Inv. No. 2282/1.

Faro Convention), which emphasizes the concept of heritage and its relationships to communities and society [75].

Lourenço and Wilson [77] advocate the view that, while natural or industrial heritage are concepts of immediate understanding, the notion of scientific heritage is "diverse, complex, multi-layered, and more difficult to define." The authors then underline how the concept of scientific heritage lies "at the intersection of two distinct and complex worlds – the world of science and the world of (cultural) heritage." In this context, the term 'heritage' refers not only to buildings and landscapes of historical value (e.g., astronomical observatories and botanical gardens) but also – and among many others – to anatomical preparations, scientific instruments, herbaria, fossils, archives and documents, ethical issues in conducting research and teaching practices, meteorite specimens. This material is often dispersed in scientific museums or institutions and university collections [78].

Scientific heritage, due to the variety of the material and immaterial media that it encompasses, raises broad-spectrum issues related to its preservation, conservation and dissemination. The problems related to the preservation of meteorite collections concern, for instance, the transfer of the specimens into research and teaching laboratories making the samples more exposed to the risk of damage or loss. This is especially true when samples are involved in inter-institutional loans under international research agreements. In this section, we, therefore, discuss how the standardized cataloguing of meteorites preserved in natural history museums – whether historical or newly acquired specimens – can prove to be a useful tool to safeguard their roles and identities as well as to promote their scientific heritage preservation and use (Figure 2). The case study research has been conducted on the legislation and regulations promoted in Italy regarding the standardized cataloguing of the planetological heritage (*beni planetologici*).

The decree 22 January 2004, n. 42 (*Codice per i Beni Culturali e del Paesaggio*, Code for Cultural Heritage and Landscape) acknowledged as cultural heritage all the collections preserved in public museums and institutions in Italy regardless the typology of the objects that are part of it (art. 10, part 2, letter a). In Attachment A (n. 13), the Code directly mentions as cultural heritage "collections and/or specimens belonging to zoological, botanical, mineralogical and anatomical collections". In 2007, the Ministry of Cultural Heritage and Activities (*Ministero per i Beni e le Culturali e per il Turismo* – MiBACT) in collaboration with the Conference of the Rectors of the Italian Universities (*Conferenza dei Rettori delle Università Italiane* – CRUI), ENEA (*Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile*), ICCD, the National Association of Scientific Museums (*Associazione Nazionale Musei Scientifici*ANMS) scholars and museum practitioners, established a standardized procedure to catalogue objects identified as natural heritage. The ICCD realised six different catalogue cards for: botanical specimens (*Beni Naturalistici, Botanica* – BNB), paleontological specimens (*Beni Naturalistici, Paleontologia* – BNP), zoological specimens (*Beni Naturalistici, Zoologia* – BNZ), mineralogical specimens (*Beni Naturalistici, Mineralogia* – BNM), petrological specimens (*Beni Naturalistici, Petrologia* – BNPE), planetological specimens (*Beni Naturalistici, Planetologia* – BNPL). The last type of catalogue card has been defined for the study of meteorite samples.

Tucci [85] noted that all the catalogue cards, generally speaking, contain: (a) both descriptive and more detailed data, which highlights the cultural value of the catalogued specimen; (b) geographical information (i.e., the place of recovery, the place where the specimen is actually preserved and/or previous institutions where it was stored); (c) information about other data possibly related to the specimens (i.e., archival documents, museum catalogues and inventories); (d) administrative data such as economic evaluations. The structure of the data is then organized in a series of sections, which are dedicated to a specific topic (e.g., identification of the specimen, location, scientific and historical background, technical data, archival or general documentation). Each catalogue card presents a set of guidelines for the standardized filling of the sections (i.e., which sections must be completed, which can be repeated for additional information, which need the use of a predefined vocabulary) as well as for management of the catalogue card on the digital database (SIGECweb). About filling some sections according to a predefined terminology, the ICCD guidelines provide for the use of an 'open' vocabulary or a 'closed' vocabulary. Open vocabularies consist of lists of terms that can be increased during the editing of a catalogue card, with the insertion of new headwords by the cataloguer. The proposals for updating the vocabularies are subsequently submitted to a scientific verification committee and, in case of acceptance, they are officially published on the ICCD website. Closed vocabularies consist of a series of predefined terms that cannot be updated by the cataloguer. Open and closed vocabularies may be formed by a list of terms, definitions, references to primary sources or general bibliography, thesauri. The cataloguing activity can be conducted at a (1) inventory level (i.e. the level of minimum information required for the correct preservation of the specimen as well as for the planning of conservation and valorisation activities); (2) pre-catalogue level that provides additional information deduced from the direct observation of the specimen; (3) catalogue level, which corresponds to a more in-depth study of the specimen (e.g., bibliographical and archival research). It is noteworthy to mention that the cataloguing system here described can be arranged from (1) to (3) depending on the type of sample to be catalogued. However, the main objective of any cataloguing level remains the precise identification of the specimen and its historical, cultural and geographical background, in order to emphasize the network of relations between the natural heritage and the territory [86].

## How to catalogue a meteorite? The cataloguing card BN-PL

The catalogue card BN-PL consists of more than 400 sections. It is therefore not possible to describe all the individual sections, so this study discusses the most significant paragraphs of the card for the correct preservation, conservation and valorisation of a meteorite specimen [90].

After having established which institution is carrying out the cataloguing activities, the Object Section (OS) contains the essential information for the identification of the catalogued specimen. The name of the collection to which the specimen belongs must then be indicated in full. The Meteorite Systematics Section (MSS) provides for information about the classification of the specimen based on its mineralogical and petrographic characteristics as well as on its whole-rock chemical and O-isotopic compositions [3] (Figure 3). As Weisberg et al. [92] rightly pointed out meteorite classification is the basic framework from which planetary scientists and cosmochemists work and communicate. The process of classification evolves with both the collection of new data and the discovery of unknown meteorite types. Therefore, it is also very important to reanalyse the historical meteorites in order to confirm their extra-terrestrial origin and to revise their classification. This is the reason why the catalogue card must provide accurate information about the meteorite analytical data.

The MSS section then contains information if the specimen was a fall or a find. This is an important distinction because finds are more prone to contamination with the terrestrial environment, depending on the time they spent on the ground [3, 92]. Most of the meteorites actually preserved in Italian natural history museums are falls. Nonetheless, in the last two decades, diverse institutions have increased their meteorite collections with finds recovered in hot and cold deserts [60, 93]. It is important to note that the date of the meteorite fall could not be the same as of the meteorite recovery. For instance, fragments of the Sikhote-Alin meteorite (Figure 4), which fell on the eponymous Russian mountains on 12 February 1947, are still being found today. The MSS then contains information about where the holotype is preserved and who holds the biggest meteorite specimen (i.e., naturalistic museum or private collector). Within this section, the cataloguer can

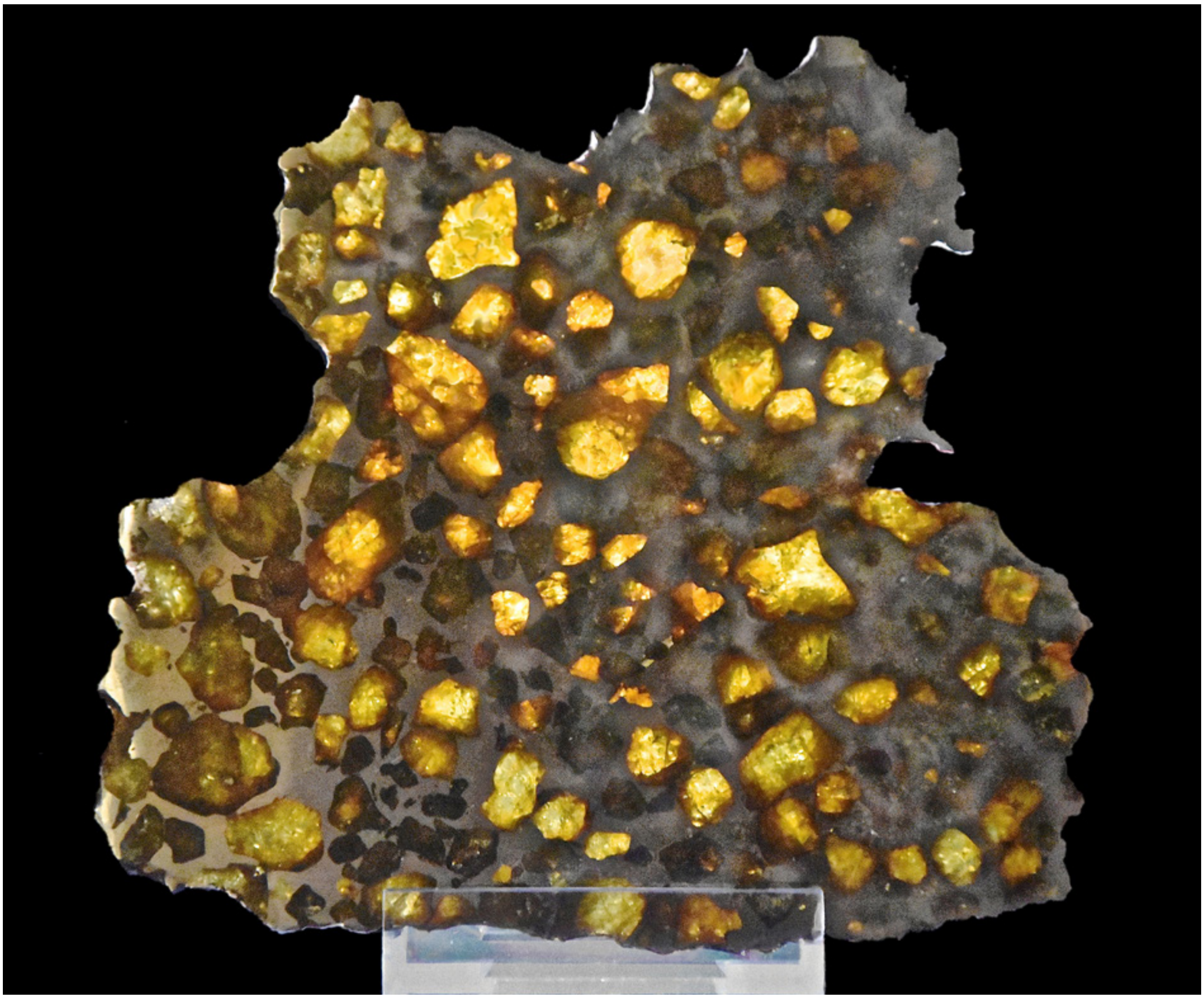


**Figure 3.** Slice of Imilac pallasite with olivine crystals embedded in metal (weight 199 g). Museum of Planetary Sciences – Prato, Italy, Inv. No. 1394/1.

**Figure 4.** Sikhote Alin meteorite (weight 290 g). On the upper side of the specimen, it can be noted a fragment of wood that remained attached on the hot meteorite surface following the impact with a tree. Museum of Planetary Sciences – Prato, Italy, Inv. No. 2241/1.

also enter data about the presence of meteorite fragments, thin sections and powder available for loan as well as general bibliography and any information taken from museum catalogues, inventories or original exhibition labels.

The subsequent section is dedicated to Meteorite Collection Data (MCD). In these paragraphs shall be included data about the year and the place where the meteorite specimen was found and any information concerning the scientific expedition that led to its discovery. As stated before, meteorites are given names based on the location in which they were recovered. Fragments from cold or hot desert areas are given names and numbers. For instance, Istifane 005 is a meteorite find that was collected in the Moroccan ridge of Istifane in 2017, and it is now preserved at the Florentine Natural History Museum. The cataloguer can specify all this information in MCD as well as other data about the mineralogical and petrographic characteristics of the collected meteorite. A specific sub-section is then devoted to the description (about 2000 characters) of the paper labels attributed to the specimen during the meteorite-hunting expedition.

After providing detailed information on the scientific institution or the natural history museum preserving the specimen, the BN-PL catalogue card provides an economic evaluation of the meteorite fragment along with information about the collector and the collection in which the specimen is included. The economic evaluation of the single meteorite sample is a very important data that the cataloguing process returns to the community and stakeholders. In recent years there has been a growing interest in the processes for determining the economic value of naturalistic collections. This is an indicator useful for establishing the costs of protection, conservation, valorisation and insurance cover against theft, fire, and damage to be used even in the case of loans for temporary exhibitions or study purposes [91, 94]. As pointed out by Burke [10], museum curators complained from the 1840s about the prices of meteorites in what seemed to be a chaotic market. An element that seemed to influence this chaotic market was, as Burke [10] further asserted, the total weight of the recovered specimen. In this regard, Buchner [102] made the first attempt to standardize meteorite pricing, listing 263 specimens held in various private and public collections and their total weight. A few decades later, Wülfing [103] brought Buchner's survey up to date, considering eight factors as determining meteorite exchange values: (1) the amount of preserved material, (2) the total weight of the petrographic group in which the meteorite was classified, (3) the number of owners, (4) the addition of a new fall or find to a group of limited weight, (5) the cost of acquisition, (6) the state of preservation, (7) the historical interest, and (8) whether the meteorite was a fall or a find. The factors 1-3 were then used in a mathematical formula to determine the correct exchange value of a meteorite specimen.

All the criteria listed in Wülfing's essay are still valid today and considered within the BN-PL catalogue card. Furthermore, as rightly pointed out by Moggi Cecchi et al. [104] the classification of newfound meteorites according to their mineralogical and petrographic characteristics (Figure 5), carried out by natural history museums on behalf of third parties, is a useful instrument in terms

**Figure 5.** Slice of Nantan iron meteorite showing Widmanstätten figures (weight 3100 g). Museum of Planetary Sciences – Prato, Italy, Inv. No. 1364/2.

of both economic enhancement of naturalistic heritage and improvement of museum's image in the scientific community. The next paragraph of the BN-PL catalogue card reports the coordinates X, Y where the meteorite fragment was recovered. These parameters are very important because failure to report precise locality information makes it difficult for scientists to pair up recent finds with previous ones [105]. The last paragraphs describe technical and analytical data relative to the meteorite specimens including size, colour, shape, surface, interior features (Figure 6), weight, and magnetic properties. Information about meteorite care, preservation, previous restoration works, and laboratory analysis is also given within these sections.

The BN-PL catalogue card ends with bibliographical data on essays and scientific articles about the specimen as well as references to archival material. In this section, the cataloguer can also upload a high-resolution image relative to the sample along with the photo credits.

## The Renazzo meteorite (1824): cataloguing a meteorite specimen through the BN-PL card

According to the chronicle written by Francesco Lenzi (dates uncertain) and now preserved at the Historical Archive of Cento [106], on 15 January 1824, a stone fell on the small village of Renazzo, in the current province of Ferrara (Italy). Three fragments of the meteorite were found, one of which was 5 kg, for a total mass of 10 kg. Two weeks later, Camillo Ranzani (1775-1841), the director of the Natural History Museum of Bologna from 1803 to 1841 [107], went to Renazzo to recover as many samples as possible. In 1827, he sent one of these specimens to the French chemist André Laugier (1770-1832) for analysis. The mineralogical and petrographic description of the fragments was then provided by Pierre Louise Antoine Cordier (1777-1861), who was a naturalist and a founder of the French Geological Society [108]. Cordier noted that the sample was not similar to other known meteorites, except for the black and glassy crust which partly covered its surface. On this basis, he classified the specimen as a *meteorite vitreuse* (vitreous meteorite) [109]. Contemporary petrological, geochemical and oxygen isotopic studies have identified the Renazzo meteorite as the holotype of the CR (Renazzo-type) carbonaceous chondrite group because of a set of properties that distinguishes it from other chondrite groups [110]. For this reason, the meteorite Renazzo is still today one of the most studied meteorites by the scientific community as well as one of the most sought-after on the collectors' market.

The Natural History Museum of the University of Firenze preserves two specimens of the Renazzo meteorite that have been catalogued through the BN-PL card. The first is a

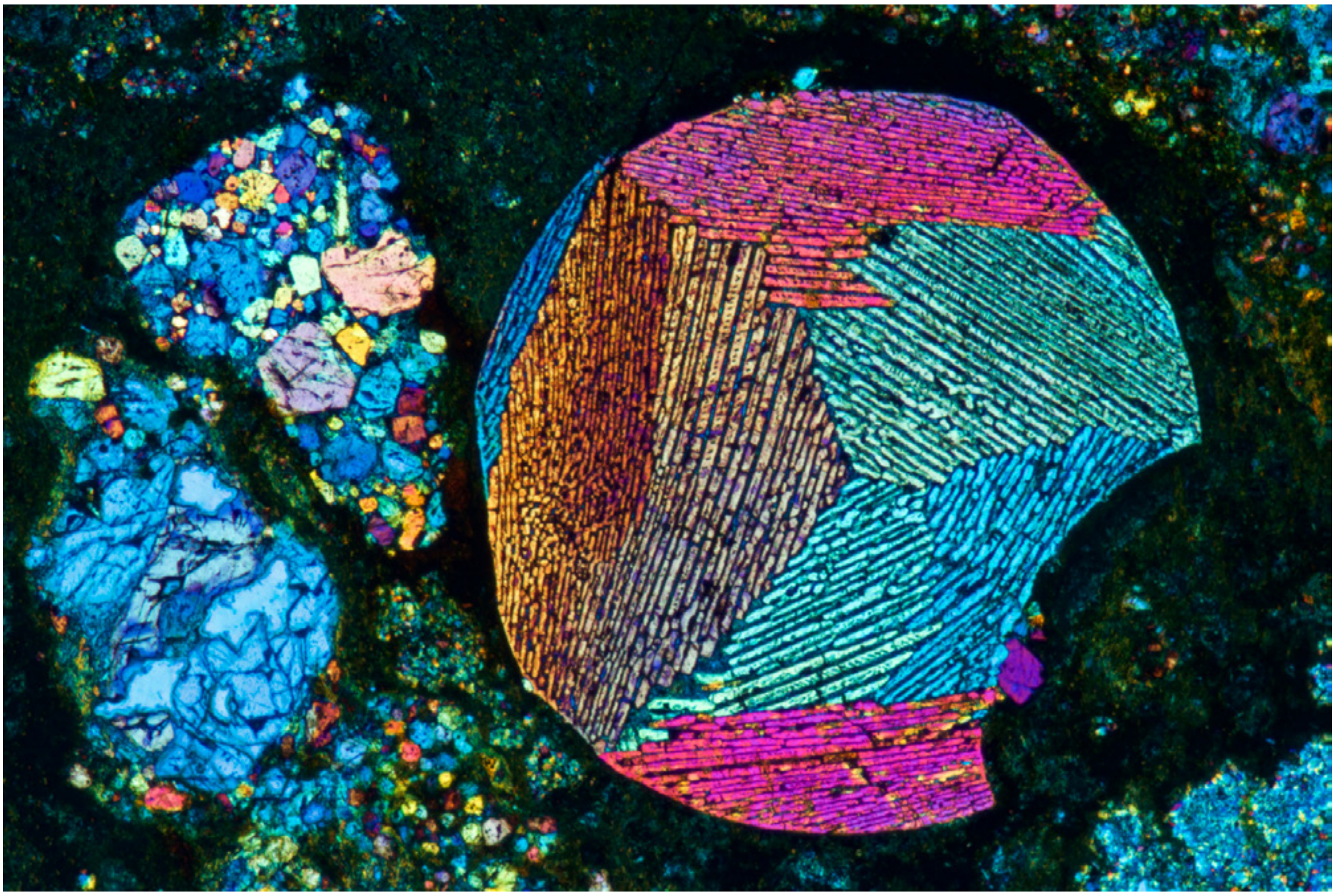


**Figure 6.** Cross polarized nicols image of a chondrite meteorite. It is to be noted the barred olivine chondrule on the right-middle of the image. Museum of Planetary Sciences – Prato, Italy. Photo credit Prof. Bernardo Cesare (University of Padova).

**Table 1.** Extract of the BN-PL catalogue card for the Renazzo meteorite specimen (ICCD Cat. No. 01142167) preserved at the Natural History Museum (Collection of Mineralogy and Lithology) of the University of Firenze.

| | |
|---|---|
| **ICCD catalogue number** | 01142167 |
| **Name** | Renazzo |
| **Genre** | Chondrite |
| **Class** | Carbonaceous Chondrite |
| **Group** | CR |
| **Fall/Find** | Fall |
| **Date** | 1824 |
| **Definition** | Renazzo Carbonaceous Chondrite |
| **Locality** | Renazzo, Province of Ferrara, Italy |
| **Type of localization** | Recovery location – historical data |
| **Valuation** | 2.500 € |
| **Weight** | 70 g |
| **State of conservation** | Good |
| **Laboratory analysis** | Minerochemical analysis |
| **Date of analysis** | 1998 |
| **Type of acquisition** | Donation |
| **Name of the donor** | Camillo Ranzani |
| **Date of the donation** | 1824 |
| **Sources and documents** | Archivio Storico, Collezione di Mineralogia e Litologia, *Appendice di Aumenti al Catalogo della Mineralogia del 1824*, n. 00525.<br>Archivio Storico, Collezione di Mineralogia e Litologia, *Catalogo della Mineralogia e Orittologia 1843-1845*, n. 7148.<br>Archivio Storico, Collezione di Mineralogia e Litologia, *Catalogo della Collezione di Meteoriti*, 1947, n. 13770.<br>Archivio Storico, Museo Galileo, ARMU Affari 038, Carteggio della Direzione, gennaio-dicembre 1824, c. 37. |

specimen of 70 g acquired by the Museum in 1824 (Figure 7, Table 1).

Table 1 illustrates data regarding the cataloguing of the Renazzo meteorite specimen using the BN-PL catalogue standard. The information shows the date of the fall, where the meteorite was recovered, and its minerochemical classification. Furthermore, the table indicates the state of conservation of the specimen, its economic valuation, and how it was acquired by the Florentine Natural History Museum. In this regard, it is interesting to note the information that stands out from the Sources and Documents (SD) field. This field is repeatable within the BN-PL card and contains all the references relative to the catalogued specimen. In this case, the SD reports the historical documentation about the Renazzo meteorite preserved both at the Historical Archive of the Natural History Museum (HA-NHM) of the University of Firenze and at the Historical Archive of the Galileo Museum (HA-GM). The archival documents kept in HA-NHM reconstructs the trajectories of the Renazzo meteorite specimen within the Natural History Museum through catalogues and museum inventories. Thanks to the study of this material, it is possible to trace the "career" of the specimen from its acquisition in 1824 to 1947, and to analyse the different scientific contexts and the changes of value incurred by these shifts [111]. In this regard, the specimen was described in the *Catalogue of the Mineralogical Collection* (1843-1845) as a "meteoritic iron fallen on 15 January 1824 [112]". It will be necessary to wait until 1947, when the meteorite collection was first inventoried, to see the sample described as a meteorite whose economic value was 130 lire [113].

As stated by Alberti [63], collectors, curators, and scientists encountered museum objects in very different ways. For instance, things collected in the field, as meteorite specimens, can be connected to institutions and scientific practices, providing insights into the role of museums in scientific and civic culture. Of this, the HA-GM preserves the *Archivio del Reale Museo di Fisica e Storia Naturale di Firenze* (Archive of the Royal Museum of Physics and Natural History of Florence), a fund of more than 5700 documents covering a period of almost a century (1780-1872), and representing one of the most important sources to reconstruct the history of the Florentine Natural History Museum and its relationships with the main European


**Figure 7.** The largest sample (70 g) of the Renazzo meteorite preserved at the Natural History Museum of the University of Firenze, Collection of Mineralogy and Lithology, ICCD Cat. No. 1142167.

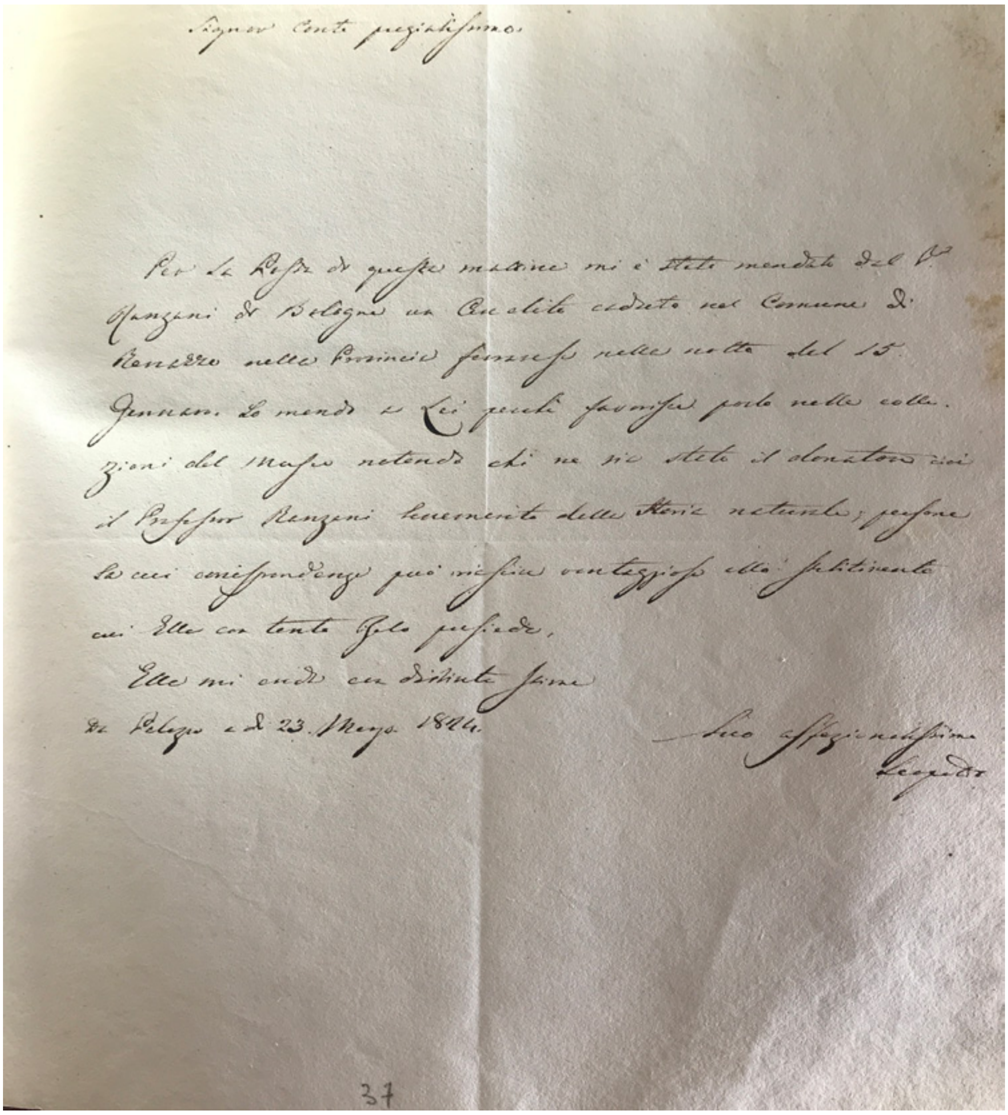
scientific institutions. Within these funds, we can trace a letter from the Grand Duke of Tuscany Leopold II (1797-1870) to Girolamo Bardi (1777-1829), Director of Natural History Museum of Firenze from 1806 to 1829 [114]. On 23 March 1824, Leopold II sent to Bardi an "aerolite that fell in the village of Renazzo on the night of 15 January", which he had received from Camillo Ranzani. The Grand Duke stated that the meteorite was sent to Bardi as Director of the Natural History Museum of Firenze so that he could display it in the mineralogical collections, specifying the name of the donor on the specimen label [114] (Figure 8).

This important document (Figure 8), which represents the deed of donation of the Renazzo meteorite to the Museum, was found thanks to the cataloguing of the specimen through the BN-PL card. It reveals not only the scientific importance attributed to the meteorite Renazzo since its discovery, but also the primary role played by the meteorite exchange within naturalistic collections [10]. Furthermore, it is interesting to note how Ranzani did not send the meteorite specimen directly to Bardi, but to Leopold II, thus confirming the importance of the House of the Habsburg in the mineralogical collecting in the nineteenth century [116].

The Natural History Museum of the University of Firenze preserved a second fragment of the Renazzo meteorite, i.e. a small specimen of about 7 g that was acquired by the Museum in 1840 (Table 2, Figure 9).

As noted earlier, the museum catalogues provide information for the second Renazzo meteorite fragment since its acquisition by the Natural History Museum in 1840 onwards. The *Catalogue of the Mineralogical Collection* (1843-1845) described the specimen as an "aerolite, year 1824", while the inventory of the meteorite collection (1947) gave the sample a 10 lire value [120]. Even if the museum catalogues do not provide further data about the sample except for the year of acquisition, this information is crucial to trace the object's career through archival sources kept in other Florentine research institutions.

In this regard, the National Library of Firenze preserved the Targioni-Tozzetti Fonds', which includes more than 2500 documents belonging to the Targioni Tozzetti family,


Signor Conte pregiatissimo.

Per la Posta di questa mattina mi è stato mandato dal P. Ranzani di Bologna un Aerolito caduto nel Comune di Renazzo nella Provincia ferrarese nella notte del 15 Gennaro. Lo mando a Lei perchè facendone posto nelle collezioni del Museo notando chi ne sia stato il donatore cioè il Professor Ranzani benemerito della Storia naturale, persona la cui corrispondenza può riuscire vantaggiosa allo stabilimento cui Ella con tanto zelo presiede.

Ella mi creda con distinta stima

di Palazzo li 23. Marzo 1824.

Suo affezionatissimo
Leopoldo

37

**Figure 8.** Letter of donation to the Florentine Imperial and Royal Museum of Physics and Natural History, by the Grand Duke Leopold II, of an aerolite fallen in the village of Renazzo and sent to him by Camillo Ranzani, 23 March 1824. Historical Archive, Galileo Museum, Firenze.

and therefore of great interest for the history of physics and natural sciences between the eighteenth and the nineteenth centuries [123]. In this fonds is also preserved the correspondence of Ottaviano Targioni Tozzetti (1755-1826), a naturalist and an expert in mineralogy, who maintained scientific relationships with the Natural History Museum of Firenze. The analysis of Ottaviano Targioni Tozzetti's scientific correspondence showed how his studies on meteorites were well known to the scientific community of the time, to the point that he had a close exchange of letters with Ambrogio Soldani (1733-1808) about the mineralogical analyses carried out on the Siena meteorite (1794) [52, 126]. On 13 July 1824, Ottaviano Targioni Tozzetti received from Camillo Ranzani "a very small fragment of the aerolite that fell on Renazzo" in exchange for "fossil bones from Valdarno, in particular hippopotamus and rhinoceros' bones" [129] (Figure 10). On 18 December 1824, Ranzani wrote a second letter to Targioni Tozzetti to thank him for the historical notes he sent about the "aerolites fallen on Italy" that Ranzani will use as a preface to his "book on the aerolites that fell on the Cento area this year." Ranzani was, therefore, preparing to write an essay on the meteorite of Renazzo (Cento is the largest city near the place of fall). The book was never published, as Ranzani had predicted in his letter to Targioni "but when will I be able to write this book? God only knows" [130].

No further information about the Renazzo meteorite fragment sent by Ranzani to Targioni was available before the specimen was catalogued thanks to the BN-PL card. As already been said, this meteoritic sample was recorded for the first time in the museum inventory in 1840. One year before, although the negotiations had begun in 1836, the mineralogical collection belonging to the Targioni Tozzetti family was

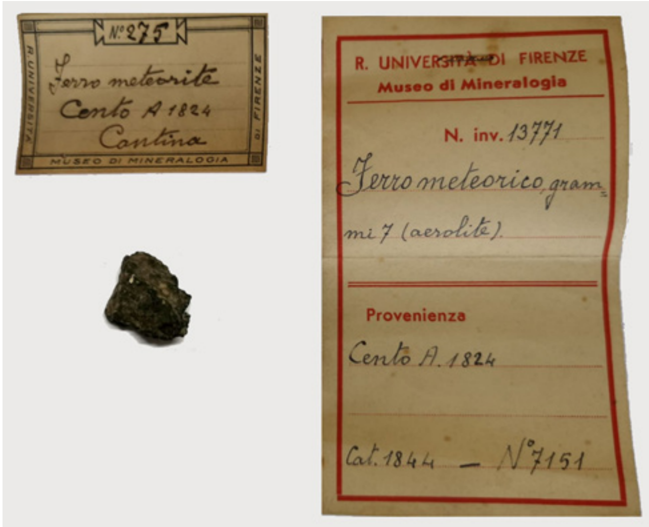
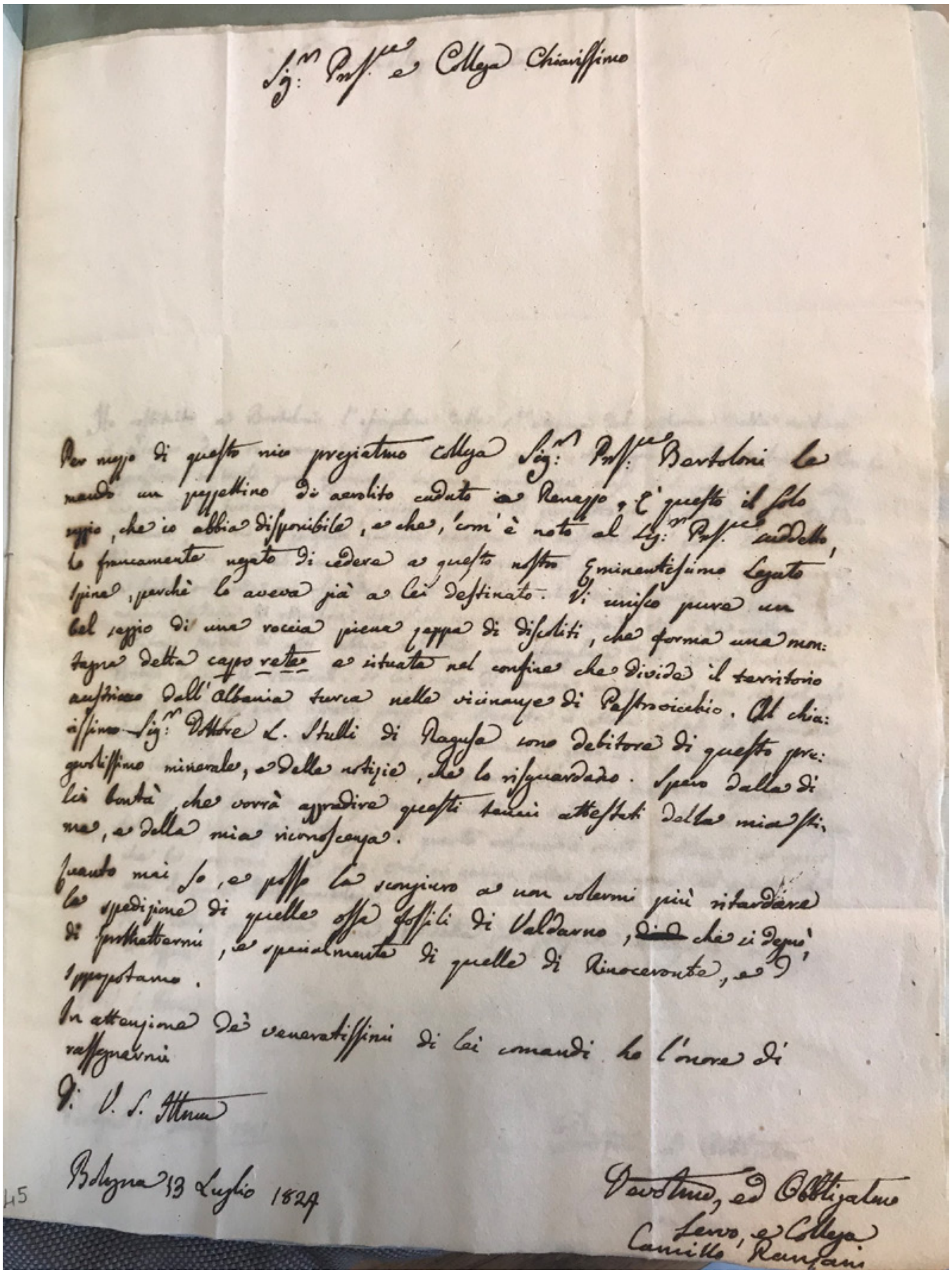



**Figure 9.** The smallest sample (7 g) of the Renazzo meteorite specimen. Natural History Museum of the University of Firenze, ICCD Cat. No. 1142168.

acquired by the Natural History Museum of Firenze for a price of 12.000 lire [131]. This mineralogical collection was initiated by the naturalist Pier Antonio Micheli (1679-1737), acquired by his pupil Giovanni Targioni Tozzetti (1712-1783) that enriched it and accompanied it with a catalogue in 12 volumes, and at last inherited from Targioni's son, Ottaviano, who added his own collection of minerals [133]. A first survey of the samples was made by the chemist Andrea Cozzi (dates uncertain) at the end of February 1839. Afterwards, the Court Secretariat of the Grand Duchy of Tuscany approved the project presented by the geologist Filippo Nesti (1780-1849) for the arrangement of the Targioni Tozzetti mineralogical collection [134]. From this standpoint, the second Renazzo meteorite specimen

**Table 2.** Extract of the BN-PL catalogue card for the second Renazzo meteorite specimen (ICCD Cat. No. 01142168) preserved at the Natural History Museum (Collection of Mineralogy and Lithology) of the University of Firenze.

| | |
|---|---|
| **ICCD catalogue number** | 01142168 |
| **Name** | Renazzo |
| **Genre** | Chondrite |
| **Class** | Carbonaceous Chondrite |
| **Group** | CR |
| **Fall/Find** | Fall |
| **Date** | 1824 |
| **Definition** | Renazzo Carbonaceous Chondrite |
| **Locality** | Renazzo, Province of Ferrara, Italy |
| **Type of localization** | Recovery location – historical data |
| **Valuation** | 2.000 € |
| **Weight** | 7 g |
| **State of conservation** | Good |
| **Laboratory analysis** | Minerochemical analysis |
| **Date of analysis** | 1998 |
| **Type of acquisition** | Unknown |
| **Date of the acquisition** | 1840 |
| **Sources and documents** | Archivio Storico, Collezione di Mineralogia e Litologia, *Appendice di Aumenti al Catalogo della Mineralogia del 1820-1844*, n. 02378.<br>Archivio Storico, Collezione di Mineralogia e Litologia, *Catalogo della Mineralogia e Orittologia 1843-1845*, n. 7151.<br>Archivio Storico, Collezione di Mineralogia e Litologia, *Catalogo della Collezione di Meteoriti*, 1947, n. 13771. |


Sig.r Prof.re e Collega Chiarissimo

Per mezzo di questo mio pregiatmo Collega Sig.r Prof.re Bartoloni le mando un pezzettino di aerolito caduto a Renazzo, è questo il solo saggio, che io abbia disponibile, e che, com'è noto al Sig.r Prof.re suddetto, ho francamente negato di cedere a questo nostro Eminentissimo Legato Spina, perchè lo aveva già a lei destinato. Vi unisco pure un bel saggio di una roccia piena zeppa di [illegible], che forma una montagna detta capo [illegible] e situata nel confine che divide il territorio austriaco dall'Albania turca nelle vicinanze di Pastrovicchio. Al chiarissimo Sig.r Dottore L. Stulli di Ragusa sono debitore di questo prezioso minerale, e delle notizie, che lo risguardano. Spero dalla di lei bontà che vorrà aggradire questi tenui attestati della mia stima, e della mia riconoscenza.

Quanto mai so, e posso la scongiuro a non volermi più ritardare la spedizione di quelle ossa fossili di Valdarno, [illegible] che ci [illegible], e specialmente di quelle di Rinoceronte, e d'Ippopotamo.

In attenzione de' veneratissimi di lei comandi ho l'onore di rassegnarmi

Di V. S. Ill.ma

Bologna 13 Luglio 1824

Dev.mo, ed Obbligat.mo
Servo, e Collega
Camillo Ranzani

**Figure 10.** Letter sent to Ottaviano Targioni Tozzetti by Camillo Ranzani, which deals with the small fragment of the Renazzo meteorite, 13 July 1824. National Library of Firenze.

preserved at the Natural History Museum of Firenze can be considered as the small fragment that was sent by Camillo Ranzani to Ottaviano Targioni Tozzetti in 1824. It is important to highlight the fact that this result would not have been achieved without the cataloguing of the sample with the BN-PL card, which identified the year of the specimen's acquisition and therefore linked the archival material about the Renazzo meteorite stored in other Florentine research institutions, with the fragment preserved at the Natural History Museum of Firenze.

## Conclusions

Since the early 1800s, naturalists began to collect meteorites systematically. As might be expected, Chladni was among the first to join this activity (he possessed about 33 specimens in 1820), along with Martin Klaproth (1743-1817), Johann Blumenbach (1752-1840) and Johann Kaspar Lavater (1741-1801) (10, 135). The first catalogue that collected all the meteorite specimens belonging to a museum was published in 1847 by the Natural History Museum of London. Since then the catalogue has been kept up to date and its last and fifth edition was issued in 2001 [136].

Despite the fact that there is still no international standardized regulation for the cataloguing of meteorites, the BN-PL catalogue card proposed by the ICCD proves to be an efficient and scientifically valid instrument for the cataloguing of meteorite collections preserved in Italian naturalistic museums and could represent a useful guideline for an international standard. The use of the BN-PL catalogue standard within the meteorite collection of the Natural History Museum of Firenze has allowed not only the cataloguing of the Renazzo meteorite specimens, but also to trace correctly their historical and scientific background.

In conclusion, cataloguing is an essential part of managing a natural history museum on which are based important museum activities such as research, conservation, risk management, exhibition development and publications. The standardized cataloguing of meteorite collection discussed in this paper proves how meteorite specimens are part of a scientific heritage, which is important to preserve at the highest possible level of care and stewardship.

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# Modelo de regeneración y conservación del espacio cultural urbano como estrategia de capitalización de barrios singulares. Caso de Barrio Italia, Chile

# Modelo de regeneração e conservação do espaço cultural urbano como estratégia de capitalização de bairros únicos. O caso do Bairro Itália, Chile

# Regeneration and conservation model of urban and cultural spaces as a capitalization strategy for unique districts. The case of Italy District, Chile

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**Resumen**

El turismo urbano está transformando las ciudades, que están dejando de ser lugares donde vivir para convertirse en paisajes donde disfrutar. Por ello, es necesaria la construcción de nuevos modelos urbanos donde lo local, la preservación del patrimonio y las experiencias innovadoras cobren fuerza. Se ha seleccionado Barrio Italia, en Santiago de Chile, para realizar el estudio porque posee un espacio urbano delimitado, emprendimientos peculiares y un modelo organizativo y de gestión de barrio. Su oferta cultural, comercial y de ocio supone una adaptación y remodelación de un casco histórico que, gracias al asociacionismo y las redes de colaboración de pequeños emprendedores, ofrece nuevas experiencias a los visitantes. Se concluye que este barrio posee características ideales para el desarrollo de turismo cultural, ya que vincula los diversos grupos de interés en un espacio urbano, junto el desarrollo de una oferta cultural, comercial y de servicios bajo la marca Barrio Italia.

**PALAVRAS-CLAVE**
Barrios históricos
Barrios singulares
Regeneración urbana
Imagen de destino turístico
Emprendimiento

**Resumo**

O turismo urbano está a transformar as cidades, que estão a deixar de ser lugares para se viver, convertendo-se em paisagens para se disfrutar. Assim, é necessário o desenvolvimento de novos modelos urbanos onde o local, a preservação do património e as experiências inovadoras, ganhem maior força. Neste estudo, foi selecionado o Bairro Itália, em Santiago do Chile, uma vez que possui um espaço urbano delimitado, empreendimentos peculiares e um modelo organizativo de gestão do bairro. A sua oferta cultural, comercial e de atividades lúdicas e recreativas pressupõe uma remodelação de um centro histórico que, graças ao associativismo e às redes colaborativas entre empreendedores locais, oferece experiências inovadoras aos seus visitantes. Conclui-se que este bairro tem as características ideais para o desenvolvimento de turismo cultural, uma vez que reúne diversos grupos de interesse num espaço urbano, juntamente com o desenvolvimento de uma oferta cultural, comercial e de serviços sob a marca Bairro Itália.

**PALAVRAS-CHAVE**
Bairros culturais
Bairros únicos
Regeneração urbana
Imagem de marca de destino turístico
Empreendedorismo

**Abstract**

Urban tourism is transforming cities, which are no longer places to live in because they are becoming landscapes to enjoy. Therefore, it is necessary to build new urban models, where the local, the heritage preservation and the innovative experiences can gain strength. Italy District was selected, in Santiago, Chile, to carry out the study because it has a delimited urban space, peculiar stores and an organizational and management model of the district. Its cultural, commercial and leisure time offer is an adaptation and remodeling of a historic center that, thanks to association and collaborative networks of small entrepreneurs, promote new experiences to visitors. It is concluded that this district has ideal characteristics for the development of cultural tourism, since it links the various interest groups in an urban space, together with the development of a cultural, commercial and service offer under the Italy District brand.

**KEYWORDS**
Cultural districts
Unique districts
Urban regeneration
Tourist destination brand image
Entrepreneurship

## Introducción

La masificación turística está provocando que muchos de los antiguos habitantes de los centros de las ciudades se trasladen a otros barrios menos céntricos. Esto es debido al aumento del precio de la vivienda y al cambio en el modelo de comercio de proximidad y la economía de servicios, que pasan a estar dedicados prácticamente en exclusiva a los visitantes. Los centros urbanos afectados pasan a ser una especie de decorado deshumanizado, por el cual desfilan hordas de turistas, perdiendo todo su valor cultural y patrimonial [1-2]. Así ocurre en ciudades como Londres, París y Barcelona que sufren desde hace años este fenómeno.

Pero, ante la tendencia a la globalización, gentrificación y turistificación urbana a todos los niveles, existen otras apuestas que reclaman la transformación de los espacios geográficos [3] manteniendo las características originales de los mismos: "predominio de la pequeña empresa, importancia de las relaciones locales y estructuras interempresariales basadas en la red frente a las estructuras jerárquicas" [4].

El sector turístico se ve afectado por la globalización debido a la expansión internacional del mismo, que ha provocado el surgimiento de nuevos destinos turísticos, nuevos mercados y una tendencia creciente hacia la homogeneización del planeta, que lleva a la perdida de la identidad cultural ya que hay un intercambio cultural grande y se van adoptando costumbres externas a la cultura nacional.

A partir de la globalización se intentan desarrollar pueblos o ciudades para atraer a más turistas, lo que provoca un fenómeno como la turistificación, entendida como el impacto que tiene la masificación turística en el tejido comercial y social de determinados barrios o ciudades. Surgen, así, espacios turistificados, espacios donde la economía turística es la más importante, la que genera la mayor parte de las rentas económicas y una parte destacada de los puestos de trabajo y donde hay una notable concentración de equipamientos y servicios turísticos.

Normalmente el término turistificación y gentrificación aparecen relacionados, si bien hay que considerar algunas diferencias entre los procesos de gentrificación y turistificación.

La gentrificación es el proceso de transformación de un espacio urbano deteriorado a partir de la reconstrucción o rehabilitación que provoca un aumento de los alquileres o del coste habitacional en estos espacios. En realidad, supone convertir un barrio degradado, socialmente obrero y económicamente empobrecido en una zona de moda, con comercios, bares y restaurantes de diseño, en la que la gente *cool* o de mayor poder adquisitivo acude a pasar el rato, o pasa a vivir en estas zonas, haciendo cada vez más difícil la convivencia a las clases populares.

La turistificación viene a ser una variante de la gentrificación, sólo que en vez de "repoblar" esas zonas degradadas con gente de mayor poder adquisitivo, esas zonas pasan a ser "repobladas" por turistas, haciendo que todos los comercios y servicios de la zona vayan cada vez más dirigidos al turismo de masas.

Gentrificación y turistificación afectan, claramente al patrimonio cultural de los espacios donde se dan dichos fenómenos, modificando el patrimonio cultural material (edificios, construcciones tradicionales, calles...) como inmaterial (formas de vida y usos de los barrios). Pero, aunque es evidente que, el turismo urbano genera impactos en la comunidad local, a su vez, puede ser un instrumento de conservación del valor patrimonial de las ciudades, aportando, además calidad de vida a sus habitantes y revalorizando los lugares visitados [5-6].

En este contexto, el marketing urbano hace referencia a la investigación, valorización y promoción del territorio basándose en aquello que lo hace único [7]. Al *marketing* urbano se suma el concepto de *city marketing*, entendido como la fidelización tanto de la población local, como de la temporal (turistas, empresas e inversores) y como forma de impulsar la ciudad hacia el exterior, pero focalizado en el centro de la ciudad, su comercio, su cultura y sus residentes.

Cada ciudad con herencia cultural centra sus esfuerzos en la atracción de turistas, por lo que planifica y gestiona su patrimonio cultural en función de unas estrategias y contextos específicos, por ello resulta imposible estudiar o analizar la gestión y planificación mediante un enfoque generalizado. Es indispensable el estudio de casos concretos con sus problemáticas e impactos [8]. Por ello, el presente artículo tiene como objetivo describir y analizar los componentes que definen lo que es un barrio singular, junto con el desarrollo de un modelo de regeneración del espacio cultural y de ocio urbano como estrategia de capitalización de barrios singulares.

La situación actual de las grandes urbes muestra cómo, a medida que los efectos del turismo de masas afectan cada vez más a los centros históricos de las ciudades, emerge un segmento minoritario de viajeros que prefiere zonas urbanas menos conocidas y explotadas turísticamente [7]. Este segmento se convierte en imprescindible para aquellas ciudades más expuestas al turismo masivo, que requieren descongestionar sus zonas históricas [9-11] y promocionar sus nuevos barrios singulares. Por esta razón, se ha seleccionado Barrio Italia, en Santiago de Chile, para la presente investigación, como un paradigma al límite de la gentrificación y posterior turistificación, en búsqueda de un modelo de desarrollo sostenible que sustente el turismo cultural y de ocio urbano, usando tres aristas fundamentales: la preservación del entorno cultural, la calidad de la experiencia cultural y de ocio del turista a través de la creación de una marca "barrio destino" y el mantenimiento y transformación del pequeño comercio en la zona como estrategia para salvaguardar el patrimonio inmaterial del barrio.

Los factores determinantes de la elección de Barrio Italia como caso de estudio son: (1) es un espacio urbano delimitado, (2) cuenta con oferta cultural, comercial y de servicios singular, (3) posee un modelo organizativo que gestiona dicha oferta, (4) es un barrio en fase de crecimiento en cuánto a desarrollo como barrio con valor patrimonial, (5) fue seleccionado como Barrio del Diseño el 2012 por el Consejo Nacional de la Cultura y las Artes del Ministerio de las Culturas las Artes y el Patrimonio.

Hasta la fecha, no existen metodologías sistemáticas para gestionar adecuadamente patrimonio cultural junto a desarrollo territorial y urbano sustentable [12], referenciado al posicionamiento de marca en los barrios históricos. Ello supone que hay un espacio aún no cubierto y que es necesario cubrir cuánto antes para no sobre explotar este tipo de lugares, llegando a perder su singularidad y, por tanto, su atracción. Se hace necesario, por tanto, actuar con rapidez en el desarrollo de mecanismos que aseguren la renovación del barrio a largo plazo [13].

La investigación se articula del siguiente modo: (1) en primer lugar, se inicia un recorrido teórico para comprender los modelos de gestión de espacios urbanos, junto con estudios de desarrollo de imagen de marca. Se revisan estudios de imagen de marca que consideran a la misma como un instrumento para salvaguardar la cultura y crear identidad común, en base al patrimonio material e inmaterial de los barrios singulares que se emplazan en las ciudades; (2) en segundo lugar, se desarrolla la metodología para comprender el asociacionismo actual en el barrio y el perfil de su oferta cultural; (3) seguidamente se muestran los resultados diseñando un modelo de regeneración y revitalización del espacio cultural urbano adaptado a la realidad de Barrio Italia y se analiza en detalle cada uno de los actores que lo componen y la creación de identidad de marca del barrio, yendo más allá de la "estética de lo patrimonial hecho moda" [14]. El modelo propuesto es un aporte, ya que puede ser adaptado como marco de referencia a otros barrios con características similares a Barrio Italia para su gestión y conservación.

## Revisión de la literatura: modelos de revitalización de espacios urbanos e imagen de marca de los destinos turísticos

El marco teórico del presente trabajo se centra en dos focos de revisión. Por un lado, se analizan los modelos de revitalización en espacios urbanos y por otro el desarrollo de la imagen de marca de los destinos turísticos como estrategia para posicionar los barrios singulares.

### Modelos de revitalización del espacio urbano

En muchas ciudades los centros urbanos han ido perdiendo progresivamente gran parte de su atractivo comercial, debido a cambios en el comportamiento del consumidor de ocio.

Ante este panorama se han impulsado, tanto desde el ámbito público como el privado, acciones para lograr una regeneración de estos núcleos urbanos, que redunden en beneficios para habitantes, visitantes y comerciantes [15]. En esta línea, surgieron los denominados modelos de regeneración urbana. Básicamente se distinguen dos modelos de gestión de centro de ciudad: el modelo americano y el europeo [16-18]:

- modelo americano, *Business Improvement Districts*, (BID). El modelo americano se focaliza en el desarrollo comercial de los distritos [19]. Este modelo grava a los dueños de la propiedad con un recargo adicional sobre el impuesto de bienes inmuebles con el propósito de mejorar (no de sustituir) los servicios proporcionados por las autoridades locales (limpieza y mantenimiento de las calles, alumbrado, seguridad, etc.), buscando mejorar la calidad de los servicios públicos en las zonas comerciales [20]. Sin embargo, el modelo americano sólo considera la actividad comercial enfocada en la ganancia y beneficio económico, pasando por alto los intereses de sus grupos de interés [21] y tiene una visión restringida al comercio tradicional, no incluyendo la generación de valor a través de turismo;
- el modelo europeo, *Town Centre Management*, (TCM). El modelo europeo, posee una perspectiva más amplia y de gestión integral, que implica la gestión del desarrollo y promoción de áreas públicas y privadas en los centros de las ciudades en beneficio de todos los interesados [22]. Se incorpora así, una visión tanto pública como privada del barrio junto con políticas que beneficien a todos los grupos de interés involucrados [23].

El modelo europeo busca una mayor colaboración público-privada con los comerciantes, que suelen concretarse en la puesta en marcha de asociaciones de comerciantes que realizan ciertas actividades de *marketing*, principalmente de tipo promocional. En el modelo europeo, las asociaciones locales de pequeño comercio y empresarios tienen un papel importante como coordinador de comercio y como identificador de oportunidades de negocio [24]. Este papel es esencial en la revitalización producida en muchos centros históricos de ciudades, porque en Europa las asociaciones de comerciantes se implican en la gestión de los centros de las ciudades, cambiando las estructuras comerciales urbanas y mejorando el atractivo de determinadas áreas urbanas [25]. Por todo ello es necesario favorecer la interacción entre la administración y las asociaciones [24] para gestionar de manera conjunta aspectos comerciales y mejorar la actividad de determinadas zonas urbanas [26].

Si se pone el foco de atención en los núcleos urbanos que son núcleos turísticos, se hace aún más necesaria la planificación de un sistema de gobernanza urbana, ya que en los destinos turísticos patrimoniales existe una interacción entre aspectos sociales, culturales, económicos y políticos que se entremezclan generando un sistema complejo para gestionar [27]. Dicha gestión ha de alinear los valores de sus comunidades e incluir a todos los grupos de interés, generando actitudes positivas hacia la actividad turística, por lo que una comunicación efectiva resulta fundamental, tal como se observó en la ciudad de York [27-29].

Teniendo en cuenta los anteriores análisis, se considera que se hace necesario un modelo de gestión de centros histórico de las ciudades para desarrollar ecosistemas de turismo cultural.

Los modelos de ciudad como Centro Comercial Abierto se asientan sobre tres aspectos fundamentales: un espacio urbano delimitado, las características de la oferta comercial y el modelo organizativo [30-32].

El modelo presentado en la Figura 1, requiere una zona o espacio urbano delimitado, ya que en las ciudades dónde se crea y hace presente el turismo cultural, el turista visitará un espacio geográfico y dicho espacio está asociado una identidad histórico-cultural, patrimonial, comercial, etc., que dicho turista ha de percibir como única [33]. Por lo tanto, al referirse a patrimonio e historia es habitual no poder separarlo de la identidad y comunidad que se va conformando, consolidando y transformando con el paso del tiempo.

El turismo cultural se vive, crea y desarrolla en lugares, comprendidos como una construcción social, un fenómeno cultural o una narrativa [34] dónde se ha de contemplar todos los aspectos físicos que resultan evidentes como la infraestructura y atracciones de un espacio, pero también hay que considerar a los individuos que allí se mueven y las diversas experiencias que pueden generarse (oferta cultural, comercial y de servicios en el modelo de la Figura 1).

Se genera un énfasis especial de análisis hacia la calidad de la herencia cultural, intervenciones públicas y privadas, asociaciones culturales, configuración del mercado turístico y el gobierno local, lo que ayuda a generar el contexto en que se debe situar un centro histórico para poder desarrollar en éste un destino turístico que sea sostenible (modelo organizativo en el modelo que recoge la Figura 1). Entender y tener en cuenta lo anterior resulta fundamental, ya que para que un destino realmente se consolide, se debe tener una mirada integradora en que todas las partes colaboren y se comprometan al trabajo mancomunado.

## Desarrollo de la imagen de marca de los destinos turísticos como estrategia para posicionar los barrios singulares

Se entiende el marketing urbano como la investigación, valorización y promoción del territorio, con el fin de fomentar y sostener el desarrollo local, basándose en aquello que lo hace único desde una perspectiva global [35]. Es, por tanto, una herramienta que permite la creación de la imagen de una ciudad, imagen capaz de proporcionar a su vez una serie de beneficios a la misma, mediante el aprovechamiento de ventajas económicas, pero también sociales de dicha ciudad, como el mantenimiento de costumbres y oficios o mantenimiento del patrimonio y los servicios en los barrios debido a la habitabilidad permanente de los mismos.

La literatura sobre la gestión de marcas de ciudad y centros urbanos ha sido prolífica [23], [36]. Sin embargo, se hace necesario desarrollar y profundizar en la investigación relacionada con la construcción de marcas que sean algo más que una referencia a un centro comercial en un casco histórico ya que se ha de considerar no sólo al pequeño comercio, sino también a otras instituciones culturales e históricas que ofertan actividades de ocio cultural y experiencial.

La finalidad de la creación de marcas en turismo [37] es generar una imagen de calidad y diferenciación turística. Así, diversos autores desarrollan el concepto de imagen de destino y personalidad de destino como elementos altamente correlacionados [38-39] analizando si la percepción de

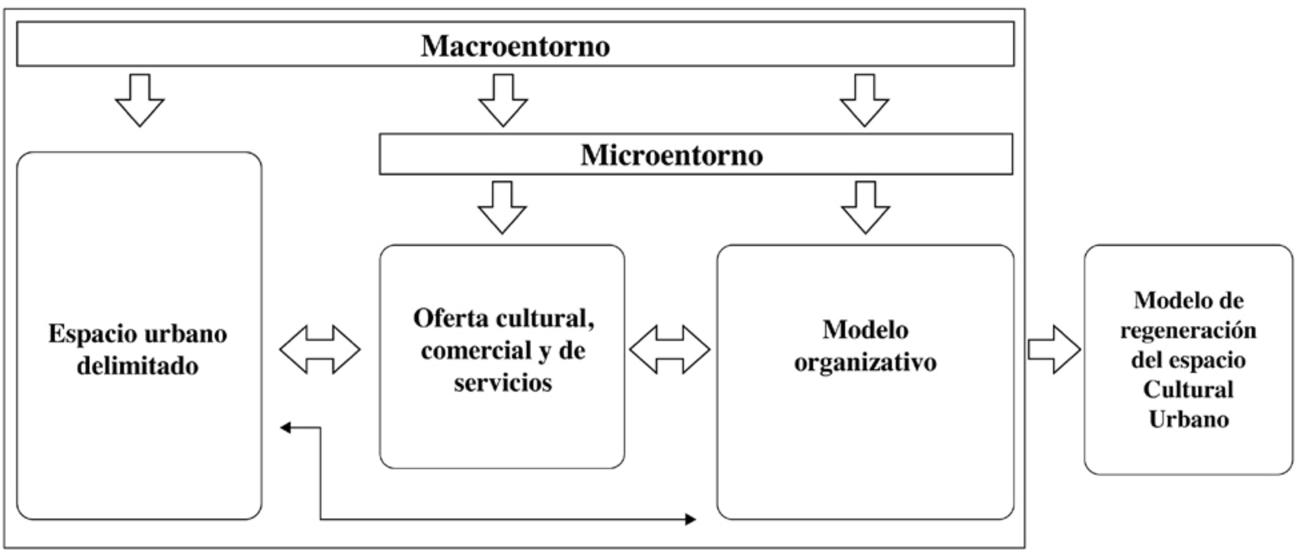


**Figura 1.** Modelo de regeneración del espacio cultural urbano genérico.

personalidad tiene una imagen positiva y favorece las visitas y recomendaciones de los destinos.

Como los destinos turísticos cada vez son más fácilmente sustituibles, debido a la creciente competencia en el mercado turístico global, los destinos con personalidad o singularidad han de trabajar en la creación de marcas identificativas de los mismos. Dichas marcas servirán para la elaboración de una identidad única cuyo fin será conseguir el posicionamiento y diferenciación de unos destinos frente a la competencia, reducir el riesgo de sustitución por productos similares [40] y usar la marca de lugar como un instrumento estratégico de planificación espacial [41]. Es, por tanto, necesario trabajar en la creación de una imagen de marca favorable y que diferencia claramente a cada destino [42].

Los lugares y destinos de turismo cultural son narrativas, esto significa que se han de entender los aspectos intangibles, como las experiencias y simbolismos que se puede llevar a cabo en ellos. Dichos aspectos intangibles, resultan fundamentales para consolidar e identificar los destinos y lograr estar dentro de las preferencias de visita [40].

Se alude a la importancia de potenciar una identidad común entre los grupos de interés para generar identidad de un lugar y crear una marca de destino, lo cual tiene alta lógica ya que quién visita un lugar recibe el destino como un todo, por lo que es necesario que sus partes estén alineadas para transmitir un mismo mensaje y así posicionar de un mismo modo al lugar [43]. Del punto de vista de marketing, se indica que un lugar es válido, principalmente, por sus aspectos intangibles, ya que elementos como los signos, los mitos y la imagen es lo que percibe el consumidor. Por ende, los aspectos de corte simbólico resultan fundamentales para la construcción y desarrollo de marca de destino [40].

En los destinos turísticos la orientación de las marcas se divide en cinco áreas: (1) cultura de la marca, (2) coordinación departamental, (3) comunicación de la marca, (4) asociación de partes interesadas y realidad de la marca [44]. Se complementa lo anterior con un modelo que incluye los grupos de interés, para implementar la responsabilidad social. En dicho modelo, el marketing pasa de una mirada reduccionista, con foco miope centrada en la captación de clientes, a una mirada amplia, que integra a todos los grupos de interés [45].

La ciudad es mucho más que una marca, es por ello que el consumo de cultura y la historia son transferencias semánticas que cobijan el verdadero patrimonio de los lugares y son los elementos que los diferencian a unos de otros y hacen auténticos. El consumo de la oferta que brinde un barrio se convierte en elemento dinamizador del espacio [46] por lo que resulta fundamental un trabajo asociacionista en la esfera tanto pública como privada para que exista salvaguarda a los enclaves con valor simbólico sin caer en la cosificación y banalización de un destino.

La turistificación del espacio en los barrios es compleja (influyen numerosos intereses económicos y sociales), ya que es un continuo devenir de interacciones entre diversos actores (habitantes, comerciantes, turistas, empresas del sector turístico, ayuntamientos, etc.) y sus respectivos intereses (intereses económicos de comerciantes y asociaciones de comerciantes y empresas del sector turístico, intereses económicos y sociales de los organismos públicos o intereses sociales de las asociaciones de vecinos).

Por lo tanto, el foco ha de estar puesto en un desarrollo formal de marca, que trascienda a la mera realización de eventos efímeros sin un beneficio claro [46] creando una imagen que consiga ser recordada y causar deleite [47]. Además, se ha tener siempre en cuenta los impactos que esto puede generar sobre los intereses y el bienestar de los residentes y habitantes locales.

Por todo ello, el diseño de una marca urbana en base a sus procesos de identidad y a su imagen tiene como finalidad: (1) ser el motor principal del desarrollo urbano, (2) atraer inversores y turistas y (3) lograr cautivar a numerosos artistas y emprendedores creativos absortos, justamente por su vida de barrio, ante todo los barrios histórico-culturales como Barrio Italia [13].

Se describe la imagen de lugar como una oportunidad de marketing para incorporar la multiplicidad de factores que existen en cada sitio y que son singulares [48], lo que requiere el desarrollo de gestión de marcas urbanas, bien sea de ciudad, de barrios o eventos [49].

Al hablar de marca de ciudad, se puede hacer referencia a los modelos de desarrollo de productos y servicios, como los estudios realizados en Birmingham en Reino Unido donde se comprobó que para hablar de desarrollo de marca de ciudad es necesario generar marca corporativa e incluir el impacto de las redes entre las organizaciones existentes [21]. En Turín [51] y en Copenhague [52] se explica cómo el desarrollo de marcas urbanas y la creatividad son motores para el desarrollo del turismo cultural en ciudades industriales.

Lo único cierto es que las ciudades no dejan nunca de mutar, pero cada ciudad posee su centro fundacional que posee y es fuente de la verdadera identidad e idiosincrasia del territorio. Por tanto, el concepto de imagen de destino y personalidad de destino están altamente correlacionados [39].

Así, la idea de lo auténtico, lo que es real y verdadero es un factor clave en el desarrollo de una ciudad (personajes, estilo de vida, carácter del comercio local, gastronomía, etc.), ya que esos elementos propios e irrepetibles atraen a visitantes ávidos de lo auténtico [53].

Las ciudades son *per sé* un devenir de contrastes dónde se une lo nuevo con lo antiguo, lo contemporáneo con lo tradicional que se plasma en sus construcciones, pero no sólo en eso sino también en aspectos intangibles que hacen que proliferen diversos barrios [54]. Por otro lado, mientras en Europa algunos cascos históricos son y han sido territorios de respeto y alto interés, en el caso de América Latina, en numerosas ocasiones, se produce un constante deterioro de los centros históricos, acompañado por la expulsión de sus habitantes hacia otras zonas de la ciudad creándose así nuevas formas de centralidad.

Los territorios con valor patrimonial han de generar diferenciación y, para ello, es importante que las personas se involucren de un modo u otro [11], [55]. Así, la transformación de los espacios geográficos con patrimonio y expresiones culturales se ha convertido en una oportunidad y ventaja competitiva para el desarrollo, no sólo económico sino también social.

El eje fundamental de la transformación de los barrios singulares anteriormente mencionados recae en la cultura, como símbolo de la identidad. Sobre la base de las tradiciones y el patrimonio cultural, las pequeñas empresas pueden, a través de la organización y la colaboración social, aprovechar de estos activos y transformar los espacios urbanos con un impacto directo en el rendimiento de las organizaciones que forman y transforman este espacio, creando marca de identidad identificativa de esos barrios.

Existen numerosos estudios de imagen de marca destino y su relación con la colaboración público-privada, como los llevados a cabo en Marque (Italia) [56], el caso del comercio minorista en la generación de imagen de la ciudad de Bilbao en 2005 [26] o las investigaciones realizadas en Viena y Barcelona en 2009 [57].

Se puede concluir, así, que las marcas turísticas (de destino, ciudad o barrio) creadas por asociaciones en torno al comercio y otros ítems relacionados con la cultura y el turismo posicionan a los barrios históricos como destinos singulares dentro producto turístico ofertado por una ciudad. En este sentido, la creación de la marca Barrio Italia concibe al barrio como un destino con personalidad, caracterizado por su oferta cultural, creativa y de ocio para satisfacer a los nuevos turistas en busca de experiencias turísticas.

## Metodología

En la presente investigación se han utilizado fuentes primarias (Tabla 1) y secundarias. En primera fase del proyecto, se realizó una revisión de la literatura y de fuentes secundarias.

Se ha recurrido a fuentes primarias de información, para así obtener de primera mano, datos sobre las características de la oferta cultural, comercial y turística del Barrio Italia, por medio de un modelo de entrevista estructurada a varios emprendedores y representantes de la Asociación de Comerciantes de Barrio Italia. Dichas entrevistas fueron relevantes para conocer las dinámicas y procesos sociales y cómo éstos impactan en el fenómeno que se está estudiando y se utilizaron para la elaboración de un cuestionario.

La investigación primaria cualitativa se basa en entrevistas estructuradas por medio de un cuestionario realizado a miembros del directorio de la Asociación de Comerciantes de Barrio Italia. El diseño y la aplicación de la encuesta personal a los emprendedores y comerciantes fue administrada en el período comprendido entre los meses de abril y mayo de 2017. Las unidades muéstrales consideradas para el análisis son emprendimientos, relacionados con el sector de la moda y textil, galerías de arte, librerías, antigüedades, decoración, hotelería, hostelería y restauración, entre otros.

## Resultados

Los resultados de la investigación se muestran desde dos prismas. Por un lado, se diseña un modelo de regeneración y revitalización urbana adaptado a Barrio Italia, analizando con detalle cada uno de los actores que lo componen y, por otra parte, se presenta la creación de la identidad a través de la marca "Somos Italia" como identificativa del barrio.

**Tabla 1.** Ficha técnica de la investigación primaria.

| | **Barrio Italia (Santiago de Chile)** |
|---|---|
| Universo | Unidades comerciales del Barrio Italia, Santiago de Chile. (antigüedades, comida, artes, belleza, comunicaciones, flores y plantas, fotografía, hogar y decoración, impresiones y artes gráficas, instrumentos musicales, tecnologías de la información o web, joyería, librería, moda y textil, salud, ocio, otras actividades comerciales, reparación y ventas de motocicletas y otros) |
| Área geográfica | Santiago, Chile |
| Muestra | 197 encuestas válidas |
| Procedimiento de muestreo | Muestreo de conveniencia |
| Error muestral | ± 4 % para un intervalo de confianza del 95 % bajo la hipótesis de p = q = 0,5 |
| Técnica de recogida de información | Encuesta personal administrada a los emprendedores y comerciantes del área comercial de Barrio Italia a través de un cuestionario estructurado |
| Período de recogida de información | Abril a mayo de 2017 |
| Tratamiento de la información | Análisis univariable y bivariable descriptivo |
| Procesamiento de la información | Dyane, Excel |

**Modelo de revitalización urbana en Barrio Italia**

Tras el análisis realizado en el estudio de la literatura es evidente que resulta imperativo el desarrollo de un modelo de regeneración del espacio cultural urbano como para poder salvaguardar el patrimonio de un barrio particular como es el caso de Barrio Italia, en Santiago de Chile.

La Figura 2 recoge como los tres componentes principales del modelo serían: el espacio urbano, que en este caso es el centros histórico de la ciudad (Barrio Italia en Santiago de Chile); las características la oferta comercial y cultural (comercio especializado, el patrimonio histórico y cultural y los servicios turísticos y culturales) y el modelo organizativo y de gestión que considera el pequeño comercio y empresarios la asociación y las redes de colaboración informal entre comerciantes y empresarios [58]. Estos componentes crean un ecosistema ideal para el turismo cultural.

El modelo presentado, en el caso de Barrio Italia se asienta sobre estos tres pilares fundamentales: un espacio urbano delimitado; emprendimientos con unas características peculiares y un modelo organizativo y de gestión del barrio.

***Un espacio urbano delimitado***

Barrio Italia pertenece a dos municipios, dentro de la ciudad de Santiago de Chile, al municipio de Ñuñoa y Providencia (entre Calle Seminario, Rancagua, Sucre y José Manuel Infante), por lo que debe adecuarse a la legislación y exigencias de ambos entes, tal como recoge el mapa del barrio [59].

Si bien el barrio no se encuentra oficialmente declarado como zona típica o de conservación histórica, la normativa y planos reguladores comunales, donde el ayuntamiento de las comunas de Ñuñoa y Providencia indica las pautas de gestión urbana, impone un gravamen indirecto de protección patrimonial a través de la limitación de la altura de edificación en Barrio Italia.

Por otra parte, Barrio Italia fue declarado en 2012 Barrio del Diseño, por la Corporación Nacional de la Cultura y las Artes. Esto ha generado un valor simbólico al uso de suelo, que ha frenado, en cierto modo, la demolición desmedida de edificaciones. Cabe destacar, además, que la normativa, al ser poco rígida, permite que el uso del suelo evolucione, fácilmente, de un uso residencial a un uso comercial. Esta situación está consolidando al barrio con la llegada de artistas y pequeños comercios [5].

Barrio Italia es un barrio histórico marcado por amplia llegada de población migrante desde inicios del siglo XX. El desarrollo económico y urbano, en ese entonces, comenzó con la llegada de la sombrerería *Girardi* que se instaló en una de las esquinas más icónicas del barrio para el comercio de sombreros en aquel entonces, logrando generar un amplio espacio para que mano de obra debiese trabajar en la fábrica y por ende transitar por el barrio, como también se dio espacio a que individuos de clases más acomodadas de la época visitaran la sombrerería conociendo el barrio.

Actualmente la sombrerería no existe como tal, pero sí su antiguo edificio que fue adquirido por la Fundación Mustakis para utilizarlo como un nuevo polo de

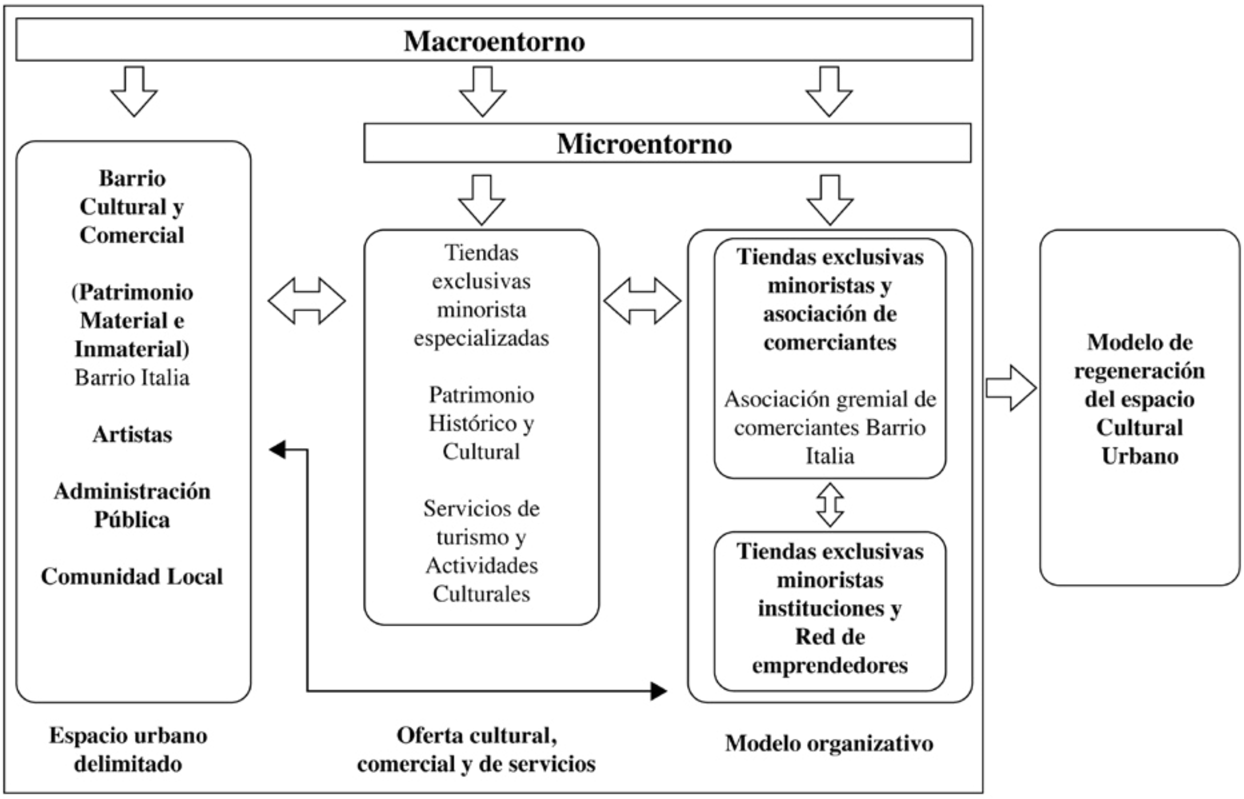


**Figura 2.** Modelo de regeneración del espacio cultural urbano para Barrio Italia.


**Figura 3.** Ejemplos de tipología de emprendimientos peculiares que capitalizan Barrio Italia (galerías comerciales, almacenes de alimentación y pequeño comercio): *a)* Almacén Caupolicán: almacén tradicional, además de la asociación Somos Italia, posee el distintivo de Boliches con Historia (Guía virtual sobre comercio de barrio tradicional, en Santiago de Chile); *b)* Almacén Caupolicán: comercio que busca simular cómo eran los almacenes de mediados de siglo XX dedicado a las frutas y las verduras; *c)* Galería Maison Italia: casona que alberga emprendimientos de moda en la primera planta y un hotel boutique y restaurante en la segunda planta; *d)* Galeria Porta Azul: Casona con diferentes emprendimientos de moda, diseño, muebles y restaurantes; *e)* Estación Caupolicán: calle repleta de comercios de anticuarios donde poseen tienda y talleres dichos anticuarios; *f)* Café Candelaria: café tradicional de Barrio Italia dentro del patio o galería Candelaria. Fotografías de las autoras.

emprendimiento, dónde albergan a diversos emprendedores para actividades de *coworking*, universidades tienen su despacho de emprendimiento en aquel sitio y además existe un *maker space*, para que emprendedores puedan desarrollar sus prototipos. Existe además el Teatro Italia, que es el mismo que existía en la antigüedad y que actualmente se utiliza para actividades culturales y de emprendimiento.

***Naturaleza de los locales comerciales***

Barrio Italia cuenta con valor patrimonial y atractivos culturales y de ocio adaptados al turismo urbano, capitalizado por emprendimientos peculiares (Figura 3).

La oferta cultural, comercial y de ocio de Barrio Italia, supone una adaptación y remodelación de un casco histórico que oferta nuevas experiencias a los turistas con nuevas necesidades y, a todo ello, ha contribuido el asociacionismo y las redes de colaboración del pequeño comercio emprendedor de la zona, junto con instituciones culturales ubicadas en el barrio. Dichos comercios son pequeños comercios con aproximadamente tres empleados, comercios de cercanía y marcas propias basadas en la creatividad (Tabla 2). Barrio Italia posee una amplia actividad de emprendimiento artístico-cultural y comercial, posicionándose en torno a tres ítems principales: comercio, cultura y turismo.

**Tabla 2.** Perfil del pequeño comercio en Barrio Italia, Santiago de Chile.

| Actividad del comercio | Número | Porcentaje |
|---|---|---|
| Comida | 49 | 24,9 % |
| Moda, textil y accesorios | 40 | 20,3 % |
| Hogar y decoración | 25 | 12,7 % |
| Antigüedades y arte | 23 | 12 % |
| Joyerías | 6 | 3 % |
| Belleza | 4 | 2 % |
| Reparación y venta de motocicletas | 4 | 2 % |
| Librerías | 3 | 1,5 % |
| Ocio | 3 | 1,5 % |
| Otros | 40 | 20,3 % |
| Total de comercios encuestados | 197 | 100 % |

El análisis descriptivo muestra que el tamaño de los negocios es, en general, pequeño (la media de trabajadores fluctúa entre uno y trés). Un dato destacable es que el 69 % de los negocios son gestionados por personas con estudios universitarios y un 31 % poseen estudios secundarios [60]. Según los datos extraídos de la Tabla 2, se observa que los establecimientos comerciales que crean la identidad del barrio en su mayoría se asocian con alimentación, moda, textil y accesorios junto con hogar, decoración y antigüedades.

La oferta comercial consiste, principalmente, en pequeñas tiendas comerciales de especialidad (197 respuestas), con 24 % dedicado a servicios gastronómicos (49 respuestas), 20 % a moda, textil y accesorios (40 respuestas), un 12,7 % a hogar y decoración (25 respuestas) y otro 12 % de los negocios están dedicados al comercio de antigüedades y arte (23 respuestas).

***Modelo de organización***

El comercio del Barrio Italia se organiza en torno a un gerente controlado por una asociación: Asociación Gremial de Comerciantes Barrio Italia [59] (de los 197 comercios entrevistados, 39 dicen pertenecer a la Asociación). La Asociación Barrio Italia oficialmente es fundada en diciembre 2011, pero surge como proyecto en año 2008 con el fin de potenciar el patrimonio cultural del barrio y promover su desarrollo. Parte de las acciones que han realizado han sido:

- crear el logo corporativo del barrio;
- desarrollar un mapa oficial;
- crear el sitio www.barrioitalia.com [59];
- generar cinco rutas caminables junto con la organización de una actividad cultural el último sábado de cada mes [61].

En el Barrio se encuentran además algunos otros entes organizacionales como la Asociación Gremial de Anticuarios de la Estación Caupolicán, residentes, vecinos y Junta de Vecinos nº 6 Santa Isabel, que corresponde a los vecinos del sector de calle Condell, Rancagua, Manuel Montt y Caupolicán. Las principales acciones de la Asociación son el asesoramiento y las tareas relacionadas con la promoción y publicidad del barrio. La Asociación Gremial de Comerciantes Barrio Italia promueve actividades de todo tipo (Figura 4) para darle dinamismo al barrio y hacerlo más interesante.


**Figura 4.** Actividades de dinamización del barrio organizadas por la Asociación Barrio Italia. Afiches desarrollados por la Asociación Gremial de Comerciantes Barrio Italia (http://www.barrioitalia.com): *a) Mercado Italia* (*food trucks*, *stands* gastronómicos, música, zona de juegos y actividades culturales); *b) Ruta del Café* (degustaciones, venta y charlas sobre café, té y chocolate, impartidas por los cafés del barrio); *c) Ruta del Vino y la Cerveza* (expositores de vino y cerveza del movimiento de viñateros independientes, *food trucks*, títeres, música y danza); *d) Poesía y Literatura* (es una feria literaria con cuentacuentos, firma de libros al aire libre); *e) Christmas Market* (Mercado navideño, dónde los pequeños comercios exponen sus productos en el barrio); *f) Vendimia Fest* (vendimia urbana, *stands* de degustación y venta de vinos en la avenida principal del barrio).

Las principales acciones comerciales y culturales de los últimos años son el *Mercado Italia*, la *Ruta del Café*, la *Ruta del Vino y la Cerveza*, *Poesía y Literatura*, *Christmas Market* y *Vendimia Fest* (Figura 4).

***La marca destino como identificativa de un territorio: Barrio Italia***

En el sector turístico una marca destino es el nombre del lugar y los destinos han de trabajar con el fin de crear una imagen de marca positiva e identificativa del lugar.

Diferentes estudios teóricos sobre las marcas turísticas muestran que estas consiguen: (1) la identificación de un territorio o barrio como "barrios históricos", (2) representan una expectativa de recursos a encontrar por parte de los posibles consumidores (recursos relacionados con la historia, el arte y el comercio tradicional) y (3) consiguen un valor de personalización del barrio [62].

En el caso de Barrio Italia, la marca se identifica con la historia del lugar. Es un barrio de antiguas edificaciones, donde vivieron artesanos inmigrantes de diferentes países, ante todo italianos, que generaron un activo comercio entre los mismos residentes. La construcción de la fábrica de sombreros *Girardi*, en 1905, fue uno de los hechos más relevantes en la historia del barrio, cuando una familia italiana del mismo nombre se instaló en el sector y dio empleo a cientos de trabajadores que decidieron vivir cerca de la planta, casas comunes en torno a patios de vecinos (conventillos), donde, actualmente, se encuentran ubicados anticuarios, restaurantes, comercios artesanos y galerías de arte.

Una de las principales acciones de la Asociación Gremial de Comerciantes de Barrio Italia es la creación del logo corporativo del barrio bajo el *slogan* "Somos Italia", tal como recoge la Figura 5.

Bajo la marca Barrio Italia, se crea una marca cuya finalidad es promocionar el atractivo de un barrio del centro de Santiago de Chile e impulsar la actividad cultural, comercial y de ocio del mismo.

En el mercado turístico, la comunicación es esencial para que los consumidores puedan identificar qué es lo que ofrece el destino o empresa. Por esta razón, se necesita un logotipo como identidad visual corporativa.

**Figura 5.** Generación de marca Barrio Italia (Chile), Somos Italia. Marca utilizada como nombre de marca del barrio y como distintivo de los comercios de dichos barrios. Logo desarrollado por Asociación Gremial de Comerciantes Barrio Italia (http://www.barrioitalia.com).

En el caso del Barrio Italia el nombre se puede atribuir a cuatro fases de desarrollo que han ido transformando y consolidando al barrio: (1) construcción de un barrio acomodado de uso principalmente residencial, (2) recepción de habitantes de un nivel socio-económico menor donde, además del espacio residencial, se desarrollan actividades productivas e industriales, (3) colonización de artistas por el atractivo en cuanto a precio y libertad de acción y (4) valorización por parte de los artistas junto a los demás grupos de interés, lo cual es atractivo a inversionistas [13].

La creación de la marca Barrio Italia concibe al barrio o destino como una marca, buscando la consecución de los siguientes objetivos [60], [62]:

- identificación de la zona o territorio o barrio de Santiago de Chile [59].
- utilidad de selección o elección por parte de los usuarios: su nombre se identifica con un barrio histórico relacionado con la tradición de la comunidad italiana ubicada en el mismo relacionada con el comercio (Barrio Italia).
- garantía: la marca representa una expectativa de recursos a encontrar por parte de los posibles consumidores. En el caso de Barrio Italia se trata de recursos relacionados con la historia, las antigüedades, el comercio tradicional, los patios antiguos donde se encuentran los negocios y la oferta gastronómica.
- valor de personalización: este valor se consigue gracias a la existencia de pequeños comercios, anticuarios, galerías de arte, pequeños restaurantes que ofrecen productos y servicios personalizados fuera de la estandarización de los servicios masivos y del comercio *main street*. Todos los comercios, además, cuentan con logos y señaléticas peculiares, en su mayoría realizadas a mano y hechas a la medida (Figura 6). Estos comercios no solo forman parte del patrimonio histórico y cultural de la ciudad, sino que además cada vez adquieren mayor reconocimiento por ser capaces de adaptarse a los nuevos tiempos, sin perder de vista la tradición que los sustenta. Partiendo de esa base y teniendo en cuenta que lo *vintage* y lo *retro* están más de moda que nunca, estos establecimientos tienen actualmente un gran potencial y no cesan en su propósito de ensalzar los valores los comercios con larga vida, esos que permiten hacer un viaje en el tiempo a través de productos, objetos, olores y sabores.
- valor lúdico: en el caso de Barrio Italia se generan experiencias relacionadas con eventos culturales, gastronómicos, artísticos y literarios (véase Figura 4, que recoge algunas de las actividades lúdicas generadas por ambas asociaciones de comerciantes).

La oferta cultural, comercial y de ocio del barrio, supone una adaptación y remodelación de un casco histórico que oferta nuevas experiencias a los turistas con nuevas necesidades y, a todo ello, ha contribuido el asociacionismo y las redes de colaboración del pequeño comercio emprendedor de la zona, junto con instituciones culturales.


**Figura 6.** Uso del logo Barrio Italia (Somos Italia) en los comercios generando imagen identificativa de este barrio singular: *a)* color dorado: gastronomía; *b)* color turquesa: diseño y comercio minorista; *c)* color rojo: comercios patrimoniales. Fotografías de las autoras.

## Conclusión y reflexiones finales

Una vez revisados modelos de gestión urbana y cambios en el sector turístico, se puede concluir que los barrios singulares necesitan fortalecer su sistema de organización urbana. Por ello, en el presente caso de estudio particular, se diseñó un modelo de regeneración y revitalización urbana, adaptando a la realidad y necesidades locales de un barrio histórico de una ciudad como Santiago de Chile.

Los factores determinantes de la elección de Barrio Italia como caso de estudio sobre otros barrios históricos-culturales han sido que ha desarrollado los factores que son necesarios para crear un modelo de revitalización urbana, tales como: (1) un espacio urbano delimitado, (2) cuenta con oferta cultural, comercial y de servicios singulares, (3) posee un modelo organizativo, (4) es un barrio en fase de crecimiento en cuánto a desarrollo como barrio con valor patrimonial, (5) fue seleccionado como Barrio del Diseño el 2012 por la Corporación Nacional de la Cultura y las Artes.

La idea de la ciudad ha cambiado a través de los años, si antes se pensaba que una urbe debía ser pragmática, eficiente y productiva, hoy se busca que también genere otro tipo de experiencias urbanas [63].

Barrio Italia supone un ejemplo de dinamización y revitalización de un barrio histórico que ha conseguido mantener la vida local y a los habitantes del mismo, consiguiendo poner en valor su patrimonio cultural a través de la colaboración entre pequeños emprendedores dinamizando el barrio y poniendo en valor el patrimonio histórico (material e inmaterial), cultural y social de la zona a través de la sinergia del comercio, el turismo y la cultura.

El presente caso de estudio ha explorado cómo el turismo urbano ha de ser salvaguardado, tanto tangible como intangiblemente, aportando la creación de metodologías sistemáticas para gestionar adecuadamente patrimonio cultural junto al desarrollo territorial y urbano sustentable.

Se ha conseguido describir y analizar los componentes que definen lo que es un barrio cultural junto con el desarrollo de un modelo de regeneración del espacio cultural urbano como estrategia de capitalización de barrios auténticos. Dentro del modelo de revitalización urbana, Barrio Italia hay tres pilares base: 1) posee un claro espacio urbano delimitado dentro de la ciudad de Santiago de Chile, el cual alberga al barrio cultural y comercial, junto a su patrimonio material e inmaterial respectivo, los artistas, la administración pública y la comunidad local 2) su oferta comercial, cultural y de servicios está enfocada en la conservación de oficios y pequeño comercio, 3) además cuentan con una Asociación Gremial de Comerciantes, para generar redes colaborativas, 4) poseen la marca "Barrio Italia", cuya denominación comercial es "Somos Italia", como una marca destino identificativa del territorio con diversas acciones para mantener viva la marca y por ende al barrio y ser una alternativa de visita para disfrutar una experiencia urbana y patrimonial diferente a lo que se puede encontrar en el comercio de tipo *main street*.

En base a los resultados extraídos de la presente investigación, a continuación, se exponen las principales dificultades, ventajas y retos que enfrenta Barrio Italia bajo este nuevo modelo de regeneración y conservación de su espacio cultural urbano como estrategia de capitalización del barrio en sí mismo.

Respecto a las principales dificultades que enfrenta Barrio Italia es el poder lograr y incorporar a los diversos grupos de interés dentro del modelo, con una mirada participativa, sin dejar voces no escuchadas, junto con alinear un objetivo común, lo cual en la práctica no es fácil de llevar a cabo. Por otro lado, un elemento que dificulta que el sistema se mantenga sinérgicos es la seguridad y limpieza, lo cual depende directamente del trabajo que desarrolle el ayuntamiento, por tratarse de bienes públicos.

Respecto a las ventajas que le aportan a Barrio Italia su carácter singular, la principal es el posicionamiento y reconocimiento de su marca como el "barrio de los anticuarios". Además de esta singularidad, Barrio Italia posee otras características que le hacen singular: Pero no sólo este reconocimiento, (1) alberga diversos tipos de emprendimientos, lo cual fortalece el intercambio comercial internamente en el barrio, (2) posee una asociación formal que salvaguarda el desarrollo del barrio, generando publicidad que influye positivamente a todos los emprendedores que forman parte del tejido comercial y (3), por último, se tiene además como ejemplo casos de éxito que se han desarrollado positivamente bajo el modelo de Centro Comercial Abierto (como el Barrio de Las Letras en Madrid o el centro histórico de Bilbao).

Los retos que enfrenta Barrio Italia es mantener su sello de “Somos Italia” bajo una mirada asociacionista de trabajo colaborativo, buscando representatividad y prácticas de cooperación entre sus grupos de interés. Además, se deberá conservar y salvaguardar el sello de su imagen de marca “Barrio Italia” como un barrio que se caracterice por pequeño comercio y lograr así una oferta diferenciada que no se vea reemplazada por el ingreso de tiendas de cadena.

Se puede concluir que el modelo propuesto supone, no solo un aporte para Barrio Italia, sino que puede ser adaptado como marco de referencia a otros barrios con características similares a Barrio Italia para su gestión, ya que es un modelo de salvaguarda y conservación urbana que puede ser un facilitador de ecosistemas ideales para el turismo cultural urbano.

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