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Journal of Cultural Heritage 6 (2005) 269–275
Journal of Cultural Heritage
http://france.elsevier.com/direct/CULHER/

Original article

Salt damage at Cleeve Abbey, England. Part II: seasonal variability of salt distribution and implications for sampling strategies

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Received 2 November 2004; accepted 18 February 2005

Abstract

It is increasingly the case that assessments of large salt deteriorated objects, such as wall paintings, involve sampling and analysis to determine the object's salt content. However, the usefulness of this is somewhat compromised by the fact that the salt distribution within the object is apt to change. This paper presents a new approach to salt sampling, using statistical and experimental design techniques to determine the degree to which analytical results are potentially affected by factors such as the sampling location and prevailing environmental conditions.

A series of site investigations were undertaken to assess the spatial and temporal variability of the salt distribution within the thirteenth century wall paintings in the Sacristy at Cleeve Abbey, Somerset, UK. Analysis of variance (ANOVA) techniques were applied to the sampling data, and conclusively demonstrated that the salt content of the wall paintings varied significantly, not only with location, but also with depth, and over time. This has important implications for site assessment methodology, since analytical results can be strongly affected by factors such as the type of object under investigation, the sampling strategy, and the season during which the investigation is carried out.

Keywords: Salts; Wall paintings; Stone; Sampling strategies; ANOVA

1. Introduction and research aims

Recent advances in the thermodynamic prediction of 'safe' environmental ranges for controlling salt deterioration have resulted in a growing demand for accurate analytical information of salt content and distribution [1]. However, it is abundantly clear from the pattern of deterioration phenomena that the salt content of monuments is not uniform. Also the distribution of the salts is apt to change, as evidenced by the seasonal appearance and disappearance of salt efflorescences [2]. A better awareness of the extent to which the salt content can vary both spatially and temporally is vital for the design of sampling strategies, and selecting an optimum period for undertaking site assessments. We need to know the extent to which analytical data are affected by factors such as the type of samples taken; the location of sampling; and the prevailing environmental conditions at the time of sampling.

A series of site investigations, funded by English Heritage, were undertaken in the Sacristy at Cleeve Abbey, Somerset, during the period May 1998 through to September 1999. The aims of this study were two-fold: firstly, to gauge the spatial and temporal variability of the salt distribution within the thirteenth century wall paintings in the Sacristy in relation to climatic conditions, and secondly, to optimise site investigation methods to clearly identify the manner in which salt damage to the wall paintings was taking place in order and devise a possible solution for its mitigation.

This paper is primarily concerned with the first of these aims. The investigation of the damage mechanisms, optimisation of site investigation methods and other findings of the study are discussed in [3], which focuses on the practical application of a new thermodynamic modelling programme to predict environmental conditions under which there is less risk of salt damage.

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doi:10.1016/j.culher.2005.02.004

Table 1
Sampling strategy

Factor	Levels	Description
Location	Area 1	N wall, W of N door, 1.9 m above ground
	Area 2	N wall, W of N door, 2.3 m above ground
Depth within object	0–1 mm	All samples from: areas 1 and 2
	1–2 mm	" "
	2–3 mm	" "
	3–4 mm	All samples from: area 1 only
	4–5 mm	" "
	5–6 mm	" "
Time (sampling period)	May 1998	3 replicate samples taken from each sampling area
	September 1998	" "
	December 1998	" "
	April 1999	" "
	July 1999	" "

2. Investigation methodology

The investigations undertaken at Cleeve comprised graphic documentation of condition phenomena; sampling and analysis; and environmental monitoring. This paper is primarily concerned with the results of sampling and analysis to assess the salt distribution variability, the methods and findings of the other components of the study are discussed in more detail in [3], which also gives information of the equipment used for the environmental monitoring.

2.1. Sampling strategy

To determine the degree of salt mobility within the wall paintings at Cleeve, it was decided to assess the salt content of the wall paintings in relation to the sampling location, sampling depth, and time of sampling. The multi-factorial nature of the problem renders this a complex situation to interpret. Therefore, statistical methods were needed to determine to what extent the factors under assessment (i.e. sampling location, depth and time) affected the sample data. In order to undertake statistical analysis, the sampling strategy was designed so that these factors were incorporated within a balanced design, the rationale and methods by which this was achieved are discussed below. The overall sampling strategy is summarised in Table 1.

2.1.1. Sample type

For this study, accurate quantitative information of the salt distribution within the object was required, however this necessitates the taking of drilled profile samples. For ethical reasons the sample size was kept to a minimum (less than 0.05 g material was extracted from a bore hole of 1.5 mm maximum width) and sampling was restricted to areas of plaster that retained the support and ground layers, but lacked the final paint layer. Efflorescence samples were also taken, to determine the mineralogical identity of the crystalline salts present on the surface of the plaster and wall paintings.

2.1.2. Sample depth

The depth at which samples are taken needs to be related to where the salt damage is taking place. The salt damage in the Sacristy at Cleeve is primarily located within the top few millimetres of the painting's stratigraphy. Consequently, the sampling depth interval was set at 1 mm increments to a maximum depth of 6 mm, dependent on the thickness of the plaster layer.

2.1.3. Sample location

Two sampling areas were selected on the north wall of the Sacristy, situated on the same section of the wall (within the same island of painted plaster) to the west of the north door. Both areas were located above the current height of rising damp, which was previously determined by the Courtauld Institute to be above 0.57 m, but below 1.42 m [4]. Area 1 was approximately 1.9 m above floor level, and area 2 was 0.4 m above this. These locations were specifically chosen in order to assess the vertical distribution of salts over close range. See Fig. 1.

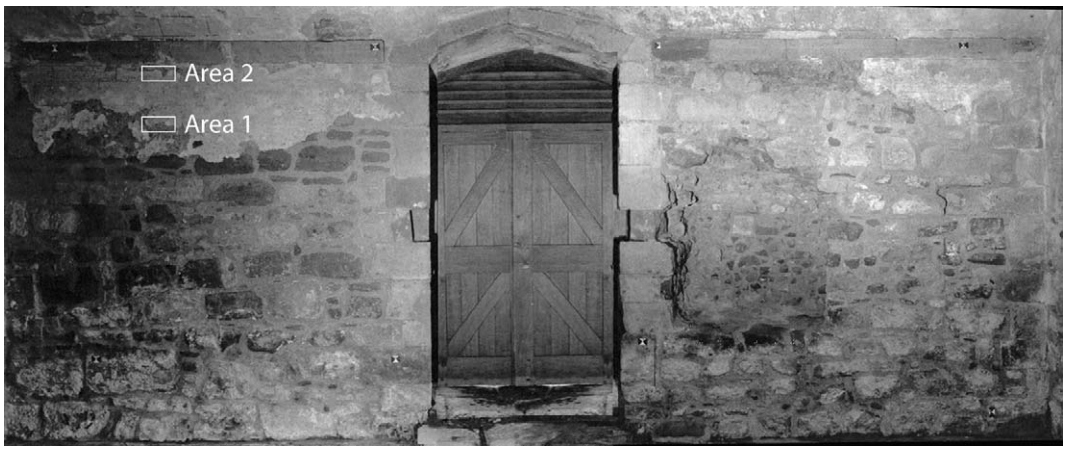

Fig. 1. Cleeve Abbey, Somerset. Sacristy North wall, showing sampling areas 1 and 2.