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TREATMENTS OVER TWENTY YEARS: A CRITICAL ASSESSMENT OF FOUR INTERVENTIONS UNDERTAKEN SINCE 1991

INTRODUCTION: THE PROBLEMS OF DAMP ENVIRONMENTS

As is well known, the treatment of plasters in damp environments is complicated. This is not just because the works themselves are subject to extreme conditions and may display exceptionally severe degradation, but also because treatment methods which function perfectly well under normal environmental conditions may prove to be ineffective or even have unforeseen or damaging consequences when applied in extremely damp places.

There may be several reasons for such negative results. One is that in damp environments, degradation may occur at a much faster rate than normal, so that standard treatment methods may not be effective. Further, the restoration materials used may themselves be subject to accelerated degradation, and thus become ineffective or even contribute to further decay.

Another reason might be that the conditions are so extreme that a conservation material will behave significantly differently from how it behaves under more normal conditions; for example what is a minor incompatibility under normal conditions, such as a grouting mortar with relatively low porosity, may create significant problems in more extreme conditions.

A third reason is that if the works to be treated and their environment have a achieved a situation of relative equilibrium, such an equilibrium is often highly unstable and even limited interventions may radically destabilise the situation and provoke a rapid acceleration in the decay process acting on the work. The most obvious example of this is the archaeological excavation of objects, but at times even the erection of a scaffolding may trigger significant decay processes, as we shall see below.

In such difficult situations, an obvious criteria to employ is that of using the least invasive treatments possible, employing materials which are the most compatible chemically and physically with the original materials to be conserved.

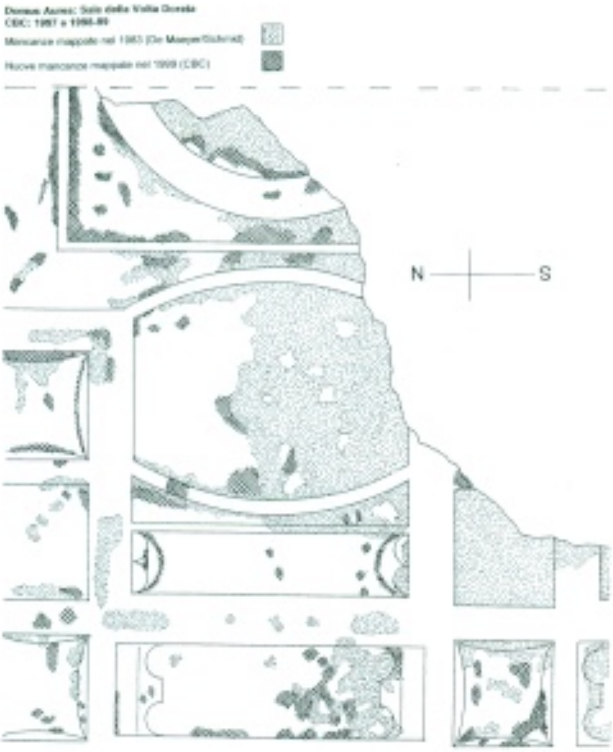
However, in the cases discussed below, it can be seen that the concept of least invasive can at times be wider in meaning than usually understood, and at times the criteria for chemical and physical compatibility may have to be overridden by more pressing concerns.

CASE STUDIES AND SELECTION CRITERIA EMPLOYED

The examples we have chosen were drawn from four interventions carried out by the author's company[1] over the last twenty years. These sites were selected not only for the extreme conditions they contain (the first three locations have relative humidities of around 90%, while the sanctuary at Paganica has problems of constant water seepage and condensation on the plastered cliff faces) but more importantly because in the years following the principal treatment they have all been subject to inspection and/or maintenance programs, thus enabling us to evaluate the effectiveness of the methods employed after a significant period of time.

The four restorations discussed here, and the chronology of their treatments are as follows:

- *13th–14th Century wall paintings, Crypt of the Cathedral, Anagni, Italy*[2]
  1987–1995: Hygrometric studies (ICR)
  1991–1994: Restoration treatment (CBC)
  1997, 2001, 2008: Maintenance (CBC)
- *1st Century stucco and paintings, Sala della Volta Dorata, Domus Aurea, Rome*
  1997–1999: Hygrometric studies (Superintendency of Archaeology, Rome)
  1999: Trial waterproofing of terrain(Superintendency and Ippolito Massari)
  1997 and 1998–1999: Restoration treatment (CBC) (as part of a series of trial treatments)
  2004: Review of Volta dorata treatment (independent conservators)
- *Cave church of the Original Sin, near Matera, Italy*
  1994–2002: Geological and biological survey (ICR/Università di Rome Tre)
  Environmental/hygrometric survey (Ippolito Massari).
  2003: Mapping and test treatments (CBC)
  2004: Restoration (CBC)
  2010: Maintenance (CBC)



[1] Domus Aurea. A map of part of the Vault, the light grey showing losses in 1983 and the dark grey further losses occurring in just the 15 years to the treatment in 1998–99.

- *15th–18th Century wall paintings, Sanctuary of the Madonna dell'Appari, Paganica, L'Aquila*
  2011: Emergency treatment (CBC)
  2012: Maintenance (CBC)

Two of the sites are essentially underground (the Domus Aurea and the Crypt in Anagni cathedral), while two are cave churches, the Church of the Original Sin being inside a hill apart from one side of the nave, while two walls of the Sanctuary of the Madonna dell'Appari are part of a cliff face.

In the first three cases the restorations formed part of larger projects aimed at identifying major causes of deterioration and stabilising the environment in which the works were contained, and involved wider climatological studies. In the last case, the treatment was limited by funds to emergency stabilisation of the paintings.

DESTABILISATION OF EQUILIBRIA AND PROBLEMS CREATED BY TREATMENTS

1. Microbiological infestation

No other aspect of the conservation treatments examined so clearly demonstrated the potentially destabilising effects of restorations, leading to an acceleration of degradation of the original objects, so much as the problem of microbiological infestation.

[2] Church of the Original Sin, Matera. Carbonate efflorescence around the edges of the fills added during restoration.

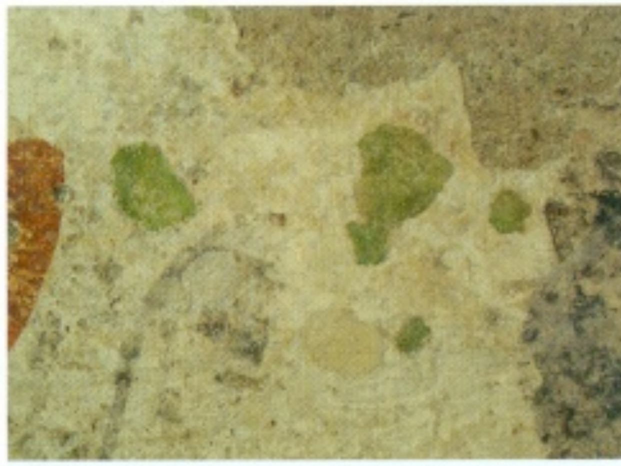
In three of the four sites under examination (Anagni, the Volta Dorata, Madonna dell'Appari), prior to the start of the treatment the sites displayed low level microbiological infestation, with limited traces of fungi and/or algae. Several weeks or months after the start of the restoration, in all three cases there was an explosive growth of micro-organisms, principally fungi.

There are several possible reasons for this phenomenon: changes in temperature, humidity and light levels due to the presence of conservators, their equipment and scaffoldings, the introduction of nutrients (principally organic materials: cotton wool, swabs, wood brushes etc.), the use of water in treatments, the distribution of spores by conservators (hand contact, brushing etc.), blocking of ventilation with scaffolds and other structures, etc.

Particularly in the case of the Sala della Volta Dorata serious measures had been taken to prevent such an occurrence: all natural organic materials were removed from the scaffolding or placed in airtight containers when not

[3] Church of the Original Sin, Matera. Carbonate efflorescence around the edges of the fills added during restoration.

[4] Church of the Original Sin, Matera. Water colour retouching has faded extensively on lime/sand fills added during restoration.



[5] Church of the Original Sin, Matera. The fills added during restoration have stimulated growth of green microrganisms.

[6] Church of the Original Sin, Matera. End wall of church prior to maintenance treatment in 2010.

in use (within 24 hours all cellulose-based materials [paper, swabs, cotton wool] left on the scaffolding would have fungi growing on them); water usage was minimised, only low temperature light bulbs were used, equipment was disinfected after every use etc. Nevertheless, during a suspension in work, the plasters of the vault became covered in vigorous fungal growth.

Scrupulous environment records kept in the Anagni crypt by technicians of the Istituto Centrale di Restauro of Rome showed that, despite the outbreak, in the zones being treated there was very little change in RH and temperature, indeed rather less than that later detected when visits by the public recommenced without any notable increase in microbiological activity.[3] Further, the micro-

[7] Sanctuary of the Madonna, Paganica. Severe powdering of plaster and detachment of paint film. The paint layer here is heavily contaminated with synthetic resin.

[8] Sanctuary of the Madonna, Paganica. A detail showing the severe powdering of plaster. The surviving paint layer here is so totally impregnated with synthetic resins that is has been completely denatured.

[9] Sanctuary of the Madonna, Paganica. A detail showing fungi growing on the paint layer.

biological outbreak in the Sala della Volta Dorata occurred when there were no conservators regularly working on site. These factors suggest that possibly a principal if not the only cause of such attacks may have been the blockage of air circulation caused by the erection of scaffoldings, though also likely assisted by the distribution of quiescent spores all over the surfaces by conservators.

The only remedial solution to such attacks was unfortunately the periodic treatment of the surfaces with biocide agents,[4] forced ventilation being potentially dangerous as it could lead to salt crystallisation.

However, the Sala della Volta Dorata provided yet another example of restorations creating further opportunities for deterioration. In this case, as biocide it was decided to use a volatile antifungal agent OPP (orthophenylphenol) dissolved in alcohol, partly to reduce the quantity of water introduced to the environment and partly to reduce the problem of residues. OPP treatment was effective, but the removal of the microfungal infestation, together with an increase in alkalinity in the substrate following desulphatation treatment using ammonium carbonate, seemed to provide suitable conditions for yet another microbiological infestation, this time an opportunistic attack by bacteria.[5]

In all cases, the removal of scaffoldings and conservators after the treatments also eliminated the problem of chronic microbiological attacks.

2. Problems created by fillings

In the case of the decoration in the Cave church of the Original Sin, near Matera in Italy, part of the final aesthetic treatment of the paintings was what was considered to be a minimally invasive intervention: only small losses in the plaster support were to be filled, and they would be retouched only using neutral tones in order that the somewhat optically fragmented images became a series of more easily perceivable images.

The materials chosen were for this part of the treatment were uncontroversial: a lime-sand mixture, fully chemically compatible with the original materials and

[10] Domus Aurea, Rome. A general view showing the catastrophic environmental conditions which prevailed in the 1990s.

[11] Domus Aurea, Rome. General view of the vault after treatment

both mechanically weaker and more porous, thus ensuring it could cause no damage to the original materials, while the pigments selected for the retouching were earth pigments and black, as these had proved to be stable in previous treatments

When the first maintenance programme was implemented, these choices were shown to have been incorrect.

Despite the fact the pigments should have been stable, in many cases they had faded significantly.

The fillings themselves presented more significant problems. In some cases, probably due to their greater porosity compare to the surrounding plaster, they had been subject to localised colonisation by microorganisms, being covered with a green bio-film, with the potential risk of these microorganisms spreading to the surrounding original painted surfaces. In other cases, and more dangerously, an impermeable lime film had formed over the surface of the fillings and the surrounding original plaster was being put at risk by carbonate efflorescence around the edges of the fills.

These problems were resolved by an even more minimal intervention: the fills and retouching were removed.

MINIMALLY INVASIVE TREATMENTS AND COMPATIBLE MATERIALS – CONSOLIDATION OF POWDERING PAINT AND PLASTERS

One of the major problems faced in all these treatments – as in most conservation treatments – was consolidation of the paint layer, particularly in cases where the paint layer was severely powdering. I will discuss the methods adopted here in chronological order as the results of previous treatments influenced later treatments.

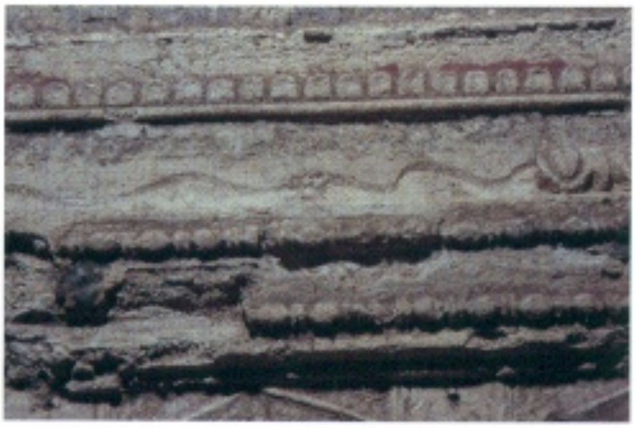
Obviously here we must distinguish between consolidation as treatment of decohesion and powdering in paint and plasters, and consolidations to treat detachment of paint and plasters flakes and layers.[6]

Decohesion clearly requires adhesive agents with good penetration of the decohesed material, but only relatively weaker and shorter range adhesive links to adhere small particles together. Adhesives with poor penetration of decohesed layers risk creating a hard crust over a powdery substrate, while excessively film forming agents may also provide barriers to water vapour and salts. Typically, the materials used in these cases are highly dispersed agents or composed of small particles. Examples are inorganic materials such as barium hydroxide, ethyl-silicate, ammonium oxalate, nano-lime suspensions, lime water etc. or dilute solutions of organic materials such

[12] Domus Aurea, Rome. General view of the vault before treatment. The white areas are sulphate incrustations of up to 5 mm in thickness.

[13] Domus Aurea, Rome. Detail showing extent of losses in the stucco decoration and the thin, painted intonachino layer.

[14] Domus Aurea, Rome. Raked light, showing salts and the detachment and cupping of the thin, painted intonachino layer.



[15] Domus Aurea, Rome. Detail showing losses and powdering in the stucco decoration.

as acrylic resins, vegetable gums, glues, ammonium caseinate, etc.

Detachment and flaking, on the other hand, requires good fluid flow of the adhesive or filling agent between detached plates or flakes, but relatively poor penetration into the underlying substrate, and also relatively stronger and longer range adhesive bonds. Typically, larger particle or denser or thickened agents have been used in these cases: lime or mortar grouts, gelled ethyl silicate, higher concentrated mixtures of the organic materials listed above.

Generally speaking, when decohesion is limited in extent, the above mentioned materials are perfectly adequate, and generally speaking inorganic methods are preferred to maintain physical/chemical compatibility with the substrates.

However when there is very severe decohesion and powdering of the substrate, up to depths of several millimetres or more, in our experience it is difficult to obtain satisfactory consolidation due to problems of inadequate penetration.[7] Further, the desirable use of inorganic consolidants is further complicated by their relatively poor adhesive properties, their slow curing times and the risk of mechanical damage in their application.

3. Anagni (1991–1994)

The decohesion and powdering of the paintings in the crypt of Anagni was fortunately not very severe, and was

[16] Anagni Cathedral, Crypt. Part of the vault during cleaning

treated using a material commonly employed at the time (early 1990s) and in the Rome area the acrylic resin in emulsion Primal AC33. However, due to obvious concerns over the creation of barrier films which would block water vapour, the adhesive was applied at very low concentrations (1,5% vol/vol in water/alcohol), left to cure, then reapplied only where the previous treatment had been insufficient.[8] Several follow up maintenance treatments (1997, 2001, 2008) verified that the treatment was effective and had not created problems.

4. Sala della Volta Dorata – Domus Áurea (1997, 1999)

The treatment of the Sala della Volta Dorata was one of several test worksites aimed at stabilising decay processes as part of an overall programme of microclimatic stabilisation of the Domus Aurea.

The decorated plasters and underlying intonacos of the Sala della Volta Dorata were in critical condition at the time of the treatment: there were sections of plaster detached by centimetres from the underlying arriccio, large areas of the vault were covered in sulphate efflorescence and much of the final intonachino was partially or totally detached – indeed thanks to a detailed documentation of part of the vault carried out in 1983[9] we were able to determine 15% of the surviving intonachino had been lost in just 16 years.

Given the extent of the deterioration, it was clearly necessary to intervene in depth, but at the same time due to the extreme conditions it determined to attempt the least invasive and most compatible treatments possible. These criteria meant either using minimal quantities of materials which were similar to materials already present or alternatively using methods and materials which had been used previously successfully in the Domus Aurea or indeed the Sala della Volta Dorata, thus showing themselves to be compatible.

It was observed in this room and others of the Domus Aurea that since the beginning of the 20th century bronze pins had been used to stabilise detached areas of plaster; in many cases these were still effective, and where they were not effective, this seemed to be due to the use of non-porous cement mortars to hold them in place. Consequently, the most detached areas of plaster (voids of 4–15 cm) were anchored to the masonry of the vault using 40 cm bronze pins held in place with injections of hydraulic grouting mortar.

Lesser detachments (up to 3 cm) were consolidated instead with limited quantities of grouting mortar, spaced every 30 cm so as not to increase the weight of the vault too much.

Small detachments of the intonaco and intonachino were filled with micro-injections of diluted hydraulic

[17] Anagni Cathedral, Crypt. Flaking paint on a figure in raked light

[18] Anagni Cathedral, Crypt. Salt efflorescence, fortunately limited and flaking paint

grouts, and where the intonachino was in danger of detaching, its borders were lined and reinforced with fine lime putty/sand mortars.

Another problem to be faced was the widespread and highly visible sulphate efflorescence on the vaults. However, detailed examination and analyses of cross-sections established that the salt crystallization was principally located on the surface of the plaster with limited subflorescence within the intonaco, and consequently, the plasters were suffering from only mild decohesion. It was decided to try the ammonium carbonate/barium hydroxide method for sulphate removal and passivation, and plaster/paint consolidation.

In order to provide an evaluation of the method, a series of analytical tests were devised: some areas were treated with only ammonium carbonate poultices, and others with both ammonium carbonate and follow-up barium hydroxide poulitices. Samples of intonaco were taken from areas before treatment, after ammonium carbonate treatment, and after both ammonium carbonate and barium hydroxide treatment. These samples were compared to samples taken at the same time from test areas treated with barium hydroxide by the ICR (Istituto Centrale per il Restauro) some 10 years earlier in two other rooms of the Domus Aurea nearby.[10] The samples were subject to micro-chemical salt analysis and SEM-EDS.

Unexpectedly, the analyses showed in all the samples essentially total elimination of the sulphates during the phase of ammonium carbonate treatment and very limited uptake of barium during the second phase of treatment, perhaps due to the dampness of the plasters and/or due the fact the sulphates were almost entirely located on the surface of the plasters. The ammonium carbonate treatment also provided a limited but adequate consolidation of the decohesed plaster in most areas, with no significant difference being detected in the areas also treated with barium hydroxide.[11]

Following the criterion of minimally invasive treatment it was therefore decided to procede soley with ammonium carbonate poulticing of the sulphated areas and not to employ the barium hydroxide treatment.

Successively, in some areas the stucco decoration was found to be still slightly decohesed. Rather than subjecting the fragile material to further treatment of wetting and poulticing and rinsing, it was decided to once again implement a treatment previously employed in the Sala della Volta Dorata. In the late 1970s a part of the surface of the vault had been treated with Paraloid B72 as part of a test consolidation. In the intervening 20 years this treatment had provoked no discernible side effects. Consequently, on the principal of not introducing new materials, but rather re-employing successful methods, and reluctant to subject fragile stuccos to the cycles of poulticing, the stuccos were treated with low concentrations of Paraloid B72 dissolved in acetone (4%) and applied, as in the previous case study in the crypt of the cathedral in Anagni, only where necessary and only reapplied if the first treatment was not adequate.

[19] Anagni Cathedral, Crypt. Microbiological infestation of fungi on the paint layer

5. The Sanctuary of the Madonna dell'Appari, Paganica, L'Aquila (2011)

This treatment was carried out as part of an emergency stabilisation treatment carried out on the chapel which had been slightly damaged in the earthquake of 2009. As mentioned previously, the chapel is built against a rock cliff, and on the plaster covering the rock face is an eighteenth century Madonna and Child painted over fragments of an earlier work now lost. The current painting had suffered severe damage from sulphate salt efflorescence in several areas, areas which were also in part heavily contaminated with films of an unknown synthetic resin applied in a treatment carried out in 1991.

In the damaged areas was a mixture of powdered pigment and intonaco with tiny fragments of paint flakes in a layer several millimetres in thickness. Here the large quantities of synthetic resin precluded a treatment using barium hydroxide. Attempts to treat the massive decohesion with nanoparticles of lime applied through Japanese paper were hindered by the low surface tension of the alcohol vehicle for the lime nanoparticles, and the lack of immediate adhesion of the lime: no matter how carefully the materials were applied and removed, the powdered paint and plaster would either preferentially adhere to the Japanese paper or simply fall off the wall.

Given the extreme state of degradation of the paint and plasters, and given the limited and slow acting adhesive characteristics of the inorganic consolidants available, it was decided to firstly remove the sulphate salts using anionic ion-exchange resins and then apply an organic adhesive in low concentrations until the paint layer was stabilised.[12] In this case, to ensure the survival of the degraded materials, the aspect of physical and chemical compatibility of the consolidant had to be subordinated to other characteristics of the adhesives being considered – the ability to provide temporary stability

[20] Anagni Cathedral, Crypt. Detail of microbiological infestation of fungi on the paint layer

with Japanese paper, and the ability to provide a minimum of adhesive stability in a relatively short time-span.

It is perhaps also worth considering that here we were no longer treating a purely inorganic system either, as the use of synthetic resins in the past had created a complex inorganic-organic system (inorganic paint and plaster inextricably mixed with synthetic resin contaminants), and thus the problem of physical and chemical compatibility becomes indeed complicated.

CONCLUSIONS

In all conservation treatments, the concept of minimally invasive treatment is always elusive, and this especially so in the case of plasters in damp environments, as we have seen above: in some cases even the mere presence of conservators and their equipment is enough to compromise the objects being conserved, and what in any other context may be universally considered a non-invasive treatment may in fact risk damage to works in extreme conditions.

Further, the extremes of conditions and the extremes of damage found in these contexts, should also prepare us to approach more carefully and flexibly these key concepts, including perhaps the dogmatic prioritising of certain characteristics of methods or materials over others; as ever, the needs of the work and the influence of its context should always be our priority.

NOTES

1 CBC Conservazione Beni Culturali of Rome is a private co-operative of 18 conservators and support staff. The group, founded in 1977, works principally for the Italian State and Local Government bodies, and frequently collaborates with research bodies such as Centro Nazionale di Ricerca, Istituto Superiore per Conservazione e Restauro (ex ICR) and various Universities. See www.cbccoop.it. For help with this article I am indebted to all my colleagues at CBC and particularly Giovanna Martellotti, Rosanna Coppola, Doretta Mazzeschi and Sibylle Nerger (†).

2 A comprehensive review of the studies undertaken, the conservation treatment and the historical back ground can be found in Bianchi, A. (ed.): Il Restauro della Cripta di Anagni Rome, Rome 2003.

3 The areas being treated consistently showed temperatures about 2°C higher and RH 5–6% lower than areas not being treated; however both areas followed exactly the same overall variations of T and RH over the months of the treatments. The heating effect was probably due to the presence of lights and human bodies while the reduction in RH may have been a local effect caused by the absorption of water by the wood parts of the scaffold and condensation on the metal parts. See Accardo, G./Cacace, C.: Indagini microclimatici, in: Bianchi, see note 2, pp. 213–216.

4 We use the word »unfortunately« as these treatments obviously involve applying extraneous materials (biocides) to the works with only limited means for removing residues without very invasive washing treatments, due to the fragility of the original materials. Volatile agents such as alcohol were not considered as they frequently provide nutrients and indeed stimulate microbiological growth.

5 The attacks may have also been provoked by the use of organic solvents – principally ethyl alcohol and acetones – during phases of the treatments. I am grateful to Dott.ssa Maria Pia Nugari, staff biologist of the ISCR for suggesting these causal chains. The bacteria were successfully treated using a wider-spectrum biocide Preventol R-80 (alkyl dimethyl benzyl ammonium chloride).

6 The discussion here is obviously highly generalised. More detailed accounts can be found in Horie, C. V.: Materials for conservation, London 1987, pp. 71–79 and Allen, K. W.: Adhesion and adhesives – some fundamentals, in: Brommelle, N. S./Pye, E. M./Smith, P./Thomson, G. (eds.): Adhesives and consolidants, London 1984, pp. 5–12.

7 Recent tests conducted by staff of CBC on very badly decohesed plasters using a variety of organic and inorganic consolidants resulted in poor penetration. In another paper in this conference by Breitenfeldt and Rieffel on the detachment of modern paintings in the basement of the Akademie der Künste in Berlin, the authors mention that Paraloid B-72 used to consolidate the rear of the plasters only penetrated 1–2 mm. Further, a recent paper reporting a series of tests carried out by U. Santamaria and the ISCR on the severely decohesed capitals of the Tower of Pisa confirmed the relatively poor penetration of most consolidants, in particular inorganics, with the notable exception of nano silicates, though these appeared to have problems with long term stability. Capponi, G./Vedovello S.: The Leaning Tower of Pisa: consolidation of the capitals on the 2nd and 3rd orders, NanotechItaly 2012. Venice, Italy. November 22, 2012. Obviously in these cases we must distinguish between the penetration of the vehicle carrying the consolidant (water, solvent etc.), which is often very deep, and the penetration of the consolidant itself, usually very limited.

8 Coppola, R./Martellotti, G.: Il Restauro, in: Bianchi, see note 2, pp. 232.

9 De Maeyer, A./Schmid, W.: La Sala della volta dorata, ICR Diploma thesis, 1983 (unpublished).

10 These tests were carried out with the consultancy of conservator Daniele Rossi, who had also carried out the earlier treatments in collaboration with the ICR.

11 Unpublished analyses carried out by R&C Scientific, Vicenza, Italy.

12 The powdered material is held in place by Japanese paper applied with water – the surface tension of the water acts as a temporary adhesive. Over this is applied a second piece of Japanese paper with the ion-exchange resin. Upon completion of the action of the ion-exchange resin, this is removed with the second piece of Japanese paper leaving the original piece of Japanese paper in situ, still protecting and holding the decohesed material in place. The water soluble consolidant is then applied through this piece of paper in the conventional way.

PICTURE CREDITS

1–20 C.B.C., Rome