Conservation of mural paintings

S. Subbaraman

Vrindaban Research Institute, Raman Reti, Vrindaban 281 121, India

The role of different branches of science such as physics, chemistry and biology in the conservation of antiquities and art objects through in-depth studies for a proper understanding of the deterioration process as well as the evolving of effective conservation techniques, is being increasingly recognized in the past few decades. This article deals with the application of scientific techniques in the conservation of mural paintings.

THE conservation of art objects, restoration as it used to be popularly known, has a long tradition. Its practioners used to be professional restorers using empirical methods. In the recent past, however, there is a growing recognition that, for really successful conservation, the techniques of science need to be employed. To begin with, the mechanism of the deterioration process undergone by an object over a period of time due to various factors, external as well as inherent, has to be clearly understood because, without correct diagnosis, an effective and lasting treatment is not possible. For this study, many modern analytical techniques have been used in the past forty or fifty years. Secondly the actual treatment techniques have to be carefully tested and their effects observed over a sufficient period of time so that we could develop constantly improved techniques. A continuing search for better materials for the conservation treatment becomes important in this context. For instance, many synthetic polymers have found application in this work recently in the place of natural products used earlier, because of superior properties. Thus research plays a vital role in conservation.

It is also being realized that a multidisciplinary approach is necessary because of the rather complex nature and composition of art objects and also because many different types of agencies are known to be at work in causing their deterioration. The study needs the help of chemists, physicists, biologists, etc., working in collaboration with archaeologists and art specialists. Environmental studies, receiving much attention these days, are of great importance in conservation science also because environmental pollution is one of the most potent causes of decay of art objects.

While this subject has engaged the attention of scientists in the West, the former Soviet Union and Japan in recent years, with some of the latest analytical tools being employed and a sizeable literature becoming available on the work, there have not been many research inputs in this field in our country. With our rich cultural heritage, comprising monuments, sculpture, painting, illustrated manuscripts on paper and palm-leaf, metal objects, wood and ivory and many other types of material in great profusion and variety, the task of conservation is indeed a challenging one. As already seen, research is the only basis for good conservation and this is a fascinating new field for research, comparatively little work having been done in it so far. It is to hoped that more and more active scientists will turn their attention to it in the future.

Conservation, in the modern sense, is a composite term applied to a set of scientific procedures aimed at stabilizing an object and prolonging its life to the maximum extent possible. Broadly speaking, it involves (i) the elimination of the causes of deterioration, (ii) reversing the adverse alterations in the object (caused by the deterioration process) as much as possible and, (iii) steps to prevent future deterioration.

Additions or reconstruction of missing parts of an object are normally not permitted in this country and, where considered absolutely essential for aesthetic reasons, such additions are kept to the minimum and done in such a way as to be clearly distinguishable from the original portions. Hence the term restoration, commonly used earlier, no longer appears to be valid except in a very limited sense as in conservation procedures under (ii) above, which frequently involve cleaning for the removal of disfiguring accretions and for bringing back the surface of the object to as near its original condition as possible. (Of course, cleaning may also be relevant under (i) above because the accretions could be chemically reacting with the surface and causing deterioration.)

The setting up of the chemistry branch of the Archaeological Survey of India at Dehradun in 1917 marks the beginning of Scientific Conservation in our country. In the beginning the ASI scientists were wholly engaged in the treatment and analyses of excavated objects and it was only in the forties that the conservation of monuments could be started. With the appointment in 1946 of S. Paramasivan, who had in the thirties done pioneering work on the scientific examination of Indian mural paintings, the conservation of mural paintings could also be taken up. However, the credit for the first attempt to conserve mural paintings in India should go to the government of the former Nizam of Hyderabad, who invited two Italian restorers,

L. Cecconi and Count Orsini in 1920–21 to treat the famous Ajanta paintings. While the Italian experts did a very good job of consolidating and fixing all loose and peeling paintings, the surface coating of shellac that they applied has since caused serious problems. Its removal has become a major task for present conservators.

Mural painting techniques

The origin of mural painting goes far back into man's prehistoric past. The earliest examples are just hand prints made with liquid colouring matter (red earth and even blood in some cases) on cave walls in the Aurignacian period of the Upper Palaeolithic of Europe, around 30,000 BC. The most outstanding examples of prehistoric painting are found in Altamira in Spain and Lascaux in the south of France. They depict animal life and hunting scenes with remarkable liveliness and vigour and have been dated to as early as the Magdalenian period (15,000 BC).

In the sand-stone regions of central India, comprising the states of Madhya Pradesh, parts of Uttar Pradesh and Rajasthan, more than a thousand rock-shelters with paintings have been explored and studied by archaeologists. It is interesting to note that prehistoric paintings in India were first noticed 12 years earlier to the famous discovery of the cave paintings of Altamira. This was done by Archibald Carllyle, a superintendent of the Archaeological Survey of India in 1867, in the Mirzapur area of the then United provinces. Like Marcelino de Santuola, the discoverer of Altamira in 1879, Carllyle was the first scholar to attribute these paintings to the stone-age tool maker.

Some of the prominent sites with shelters carrying prehistoric paintings are Pachmari in the Mahadeo Hills of Madhya Pradesh, Adamgarh, Raisen, Mirzapur, etc. The most extensively explored and documented site is perhaps Bhimbetka in the Bhopal region.

Besides these sand-stone shelters, there are a few granite shelters in the Raichur and Bellary regions of Karnataka and in Kerala, with prehistoric paintings (see Figure 1).

Like the cave paintings of Europe, the prehistoric paintings of India also depict various types of animals, including the rhinoceros, and hunting scenes (Figure 2).

Prehistoric rock paintings

In the prehistoric period, the painting was done

Regions

A Ahiraura
B Bhainsaur
C Rajpur
D Banda
E Pachmari
F Sagar
G Bhanpura Chambal
H Kota
I Bhopal
J Bhimbetka
K Raisen
L Hoshangabad
M Sivani Malwa
O Fatepur Sikri
P Narsinghgarh
Q Raichur Karnatak
R Tekkalkota
S Kishkindha
T Badami
U Keral
V Raigarh

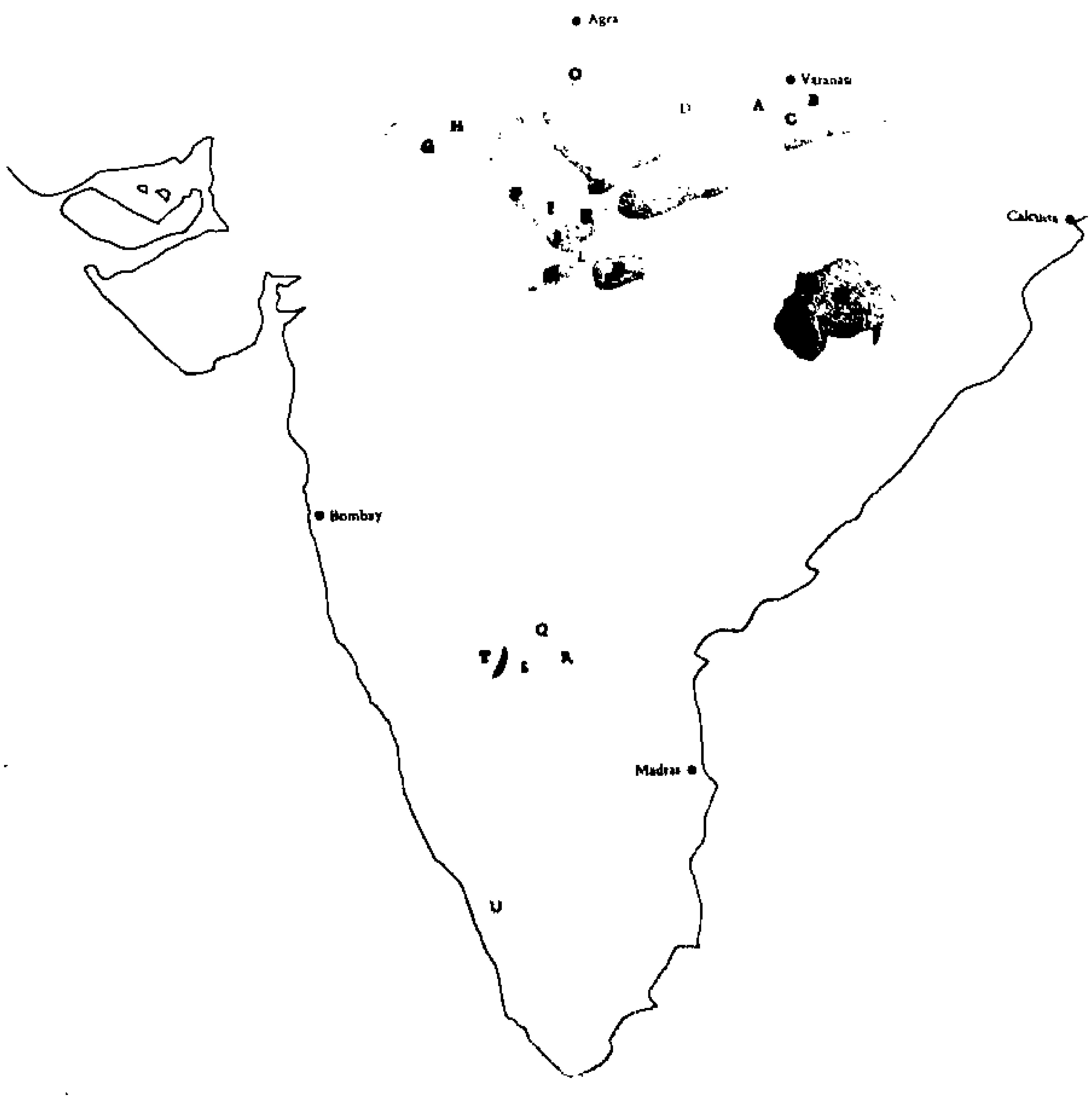

Figure 1. Painted rock shelter regions in India. [Courtesy: M/s D. B. Taraporewala & Sons, Bombay]

Figure 2. Prehistoric rock painting, Bhimbetka; Late Mesolithic. [Courtesy: M/s D. B. Taraporevala & Sons Pvt. Ltd, Bombay]

directly on the rock, making use of the roughness of the natural rock surface to bind the colours. Even the contours of the uneven rock surface were sometimes deliberately made use of to give a three-dimensional effect to the figures. The pigments most commonly used were the naturally occurring oxides of iron, haematite and limonite to produce shades of red, yellow, orange and brown. For white, kaolin or lime-stone was used. Charcoal or manganese dioxide provided the black colour. In Bhimbetka, instances of copper compounds being used for producing a bright green colour are found[1].

The pigments were probably ground to a powder with a mortar and pestle or in the natural hollow of a rock, mixed with water and applied with brushes made with twigs. One end of the twig is beaten to remove the pulp and expose the fibres. It has been suggested that most probably palmetto twigs were used since they were found to be the best after trying different materials[2].

No evidence of any binding medium such as resin or animal fat was found on analysis, though their possible use had been suggested by some scholars[3]. (In European rock paintings, however, animal fat has been made use of. It has been suggested that the rock surface was smeared with it evenly and dry powdered pigment was blown on to it through a blow pipe.)

In the sand-stone shelters, once the pigment seeps into the porous rock surface and is firmly ingrained with it, it cannot be removed even by washing. It is only the natural weathering of the rock surface that may cause deterioration of the painting.

Tempera technique

When the venue of painting activity first shifted from natural rock shelters to man-made structures of mud-brick in the neolithic period around 6000 BC, the need for specially preparing the surface for painting (by laying on a smooth layer of fine mud over the brick wall) was felt for the first time. Simultaneously, the need for using a binding medium, such as gum or glue, for fixing the colours onto the smooth ground of mud, was also realized. This technique in which the pigments are used with an organic-binding medium (like gum or glue or egg white or yolk in much later periods) is called the tempera. It is thus seen that tempera is the earliest technique employed when the practice of painting on a prepared surface came to be adopted.

The tempera technique, first practised in the neolithic period, was later developed and perfected in the great river-valley civilizations of Egypt and Mesopotamia, with the rich alluvial deposits from the rivers providing ample material for preparing the ground for the painting. In Egypt, a thin layer of gypsum was laid on the mud plaster and the painting done on it with the help of a gum or gelatine-based binding medium. In Mesopotomia, a layer of lime was laid on the clay surface, and the painting done.

Besides the earth colours that were in use from prehistoric times, the painters of the early historical period started using several mineral pigments like lead white, orpiment, realgar, litharge, cinnabar, Egyptian blue, malachite, verdigris, etc. as well as dyes like madder, dragon's blood and indigo. At a later stage, pigments such as Indian yellow, lead and tin yellows, lapis lazuli, azurite etc. came into use[4]. The use of synthetic pigments like cadmium and chrome yellows, artificial ultramarine, Prussian blue, cobalt blue, Scheeles green, etc. is, of course, comparatively recent.

Fresco technique

With the development of painting technique, it was at some stage realized that, when painting is done on lime plaster, lime by itself could serve as a good binding medium under certain circumstances (rendering the use of a separate organic binding medium unnecessary).

In the fresco technique (also known as fresco buono or true fresco), first a rough lime plaster, consisting of a mixture of lime and sand, is laid on the wall and over it is applied a fine lime plaster, consisting mostly of lime, called intonaco. Painting is done on the intonaco when it is still wet, using pigments ground only with water or a little lime water. As the painting dries, the slaked lime, viz. calcium hydroxide is gradually converted to limestone, viz. calcium carbonate, through reaction with atmospheric carbon dioxide. This carbonatization process firmly integrates the paint layer with the ground and the thin film of crystalline calcium carbonate that forms on the surface renders the colours practically insoluble[5]. Secondly, since the painting is done on a wet ground, the colours partially seep into the ground so that later it is found that, even if the top most layer of the painting is scraped, there is another layer present underneath.

In this technique, the lime not only serves as a binding medium but is the only white pigment present. The choice of the other pigments has to be somewhat limited because only pigments that are compatible with lime can be used. For instance, it is found that, if indigo is used in the fresco technique, it fades quickly because it reacts with lime.

The fresco technique is believed to have been first practised by the Cretans and Myceneans in the early first millennium BC and later developed and refined in ancient Greece and Rome. Samples from several sites have been analysed by scientists but the results are not always conclusive[6]. The Etruscan paintings in the Catacombs of the Tarquinian region of Italy, which are of the 4th and 5th centuries BC have been clearly shown to be true frescoes. In the middle ages, in the Byzantine, Gothic and Romanesque styles of painting, the techniques were of a rather mixed nature. It was from the renaissance period onwards that the fresco technique came to be universally practised in Italy and other parts of Europe. Sometimes, after executing the painting in the fresco process, certain portions of it were finished in the tempera or secco process in order to produce certain specific desired effects.

Secco technique

In the third process, known as secco, the painting is done on dry lime plaster. The pigments are ground with lime water sometimes with the addition of a little skimmed milk. While the binding of the colours with the ground cannot be as strong in this case as in the fresco process because of a very limited carbonatization, there is a greater freedom of operation. In the fresco technique, the area that can be painted in one day has to be clearly conceived in advance and the intonaco laid accordingly. Any portion that remains unpainted and dries overnight has to be removed and fresh intonaco laid the next day. In the secco process, on the other hand, the entire wall surface is available for painting at the artist's convenience allowing greater freedom in planning the entire composition.

Indian mural paintings

The earliest mural paintings of the historical period in India are in the Jogimara Caves in Madhya Pradesh and are datable back to 2nd century BC closely followed by the paintings at Ajanta, which range from 2nd century BC to the 6th century AD. The ground used was mud plaster in all these early paintings. At Ajanta, a rough plaster of ferruginous earth admixed with clay and reinforced with vegetable fibres and paddy husk was first laid on the rock surface. Over this was laid a fine thin plaster of clay. A coat of lime was applied over the fine plaster. The pigments used were yellow ochre, red ochre, carbon, lime and gypsum, terreverte and lapis lazuli. The painting was done in the tempera technique, the binding medium being an animal glue[7].

The use of lime plaster first came into practice around 7th century AD and was noticed for the first time at Ellora. Following this, the Pallava paintings in the Kailasanatha Temple in Kancheepuram (7th century), the paintings of the early Pandian period at Sittannavasal (9th century) and the Chola paintings in the Brihadiswara Temple, Tanjavur (11th century) were all on lime plaster, not to mention the later paintings of the Vijayanagar, Nayaka and Maharatta periods

(16th to 18th centuries). It is seen that from the 7th century onwards, the use of lime plaster became the general practice. This is also true of the mural paintings of the Muslim era from the early dynasties to the Mughal period (Table 1).

It may be noted that the range of pigments used in Indian mural paintings is rather limited and has remained the same over a wide geographic region and over a time span of nearly two thousand years.

Investigation of the painting techniques has shown that while some of them have been executed in tempera technique, most of them are probably in the secco technique[8,9]. It was only in the case of the early 11th century Chola paintings in the Brihadisvara temple, Tanjavur, that Paramasivan found some grounds to believe that they were probably in the true fresco technique but he could not firmly establish this[10].

Very recently, the present author found some evidence to reinforce this belief. While examining 10 pigment samples of the Chola painting, by X-ray diffraction, it was found that in all the cases, the d lines of calcite were so strong that they masked the d lines of the actual compounds constituting the pigment, making the identification of the pigment almost impossible. This seems to indicate carbonatization having taken place and the pigment particles being completely surrounded by calcite[11].

A technique of mural painting very similar to the true

Table 1. Chronological development of Indian mural painting techniques

		Techniques			
Date	Location	Carrier	Ground	Pigments	Binding medium
2nd century BC	Jogimara Caves (M P)	Rock	Mud plaster	Data not available	Data not available
2nd century BC–6th century AD	Ajanta (Maharashtra)	Basaltic rock	1 Rough plaster: Ferruginous earth reinforced with veg fibre– 8–15 mm 2. Fine plaster. Clay–4 mm 3 Coat of lime	Red ochre, Yellow ochre, Carbon, lime, gypsum, Terreverte and lapis lazuli	Animal glue
7th Century AD	Ellora (Maharashtra)	Basaltic rock	Rough lime plaster with fine lime plaster– 6 mm	Red ochre, Yellow ochre, Carbon, lime, gypsum, Terreverte and lapis lazuli	Lime (Secco Technique)
7th century AD	Panamalai (Tamil Nadu)	Granite	Lime plaster– 4 mm	Data not available	Lime (Secco)
Late 7th century AD	Kanchipuram (Tamil Nadu)	Granite	Rough lime plaster & fine lime plaster– 4 mm	Yellow ochre, Red ochre, Carbon, Terreverte and Ultramarine	Lime (Secco)
9th century AD	Sittannavasal (Tamil Nadu)	Granite	Lime plaster– 6 mm	Yellow ochre, Red ochre, Carbon, Terreverte and Ultramarine	Lime (Secco)
11th century AD	Tanjavur (Tamil Nadu)	Granite	Lime plaster– 3 mm	Yellow ochre, Red ochre, Lamp black, Lime, Terreverte, Ultramarine	Lime (Fresco?)
16th century	Tanjavur (Tamil Nadu)	Earlier 11th century painting	Lime plaster– 4 mm	Yellow ochre, Red ochre, Lamp black, Lime, Terreverte, Ultramarine	Lime (Secco)
16th century	Lepaksi (A P.)	Granite	Lime plaster– 2.5 to 12.5 mm	Yellow ochre, Red ochre, Carbon, Lime	Lime (Secco)
17th–18th century AD	Kerala paintings	Stone or brick wall	Lime plaster– 4 to 8 mm	Yellow ochre, Red ochre, Carbon, Terreverte	Lime (Secco)
18th century AD	Tippu Sultan palaces at Bangalore and Srirangapatna	Brick wall and wooden ceiling (covered with cloth)	Lime plaster 6 to 10 mm	Data not available	Lime (Secco). Oil medium in some places

fresco process is in practice in Rajasthan from early times to the present day. The painted surface, when still partly wet, is polished with a smooth stone to give it a lustrous appearance.

It is of interest to note in this context that there are several old Indian texts from the 9th century AD onwards that deal with painting techniques. All of them mention binding media like gums and glues of different types. No mention of the lime medium has been made by any of them.

Paramsivan examined plaster and paint samples from several important sites and carried out detailed chemical analyses. Results of two representative sites, Ajanta (mud plaster) and Lepakshi (lime plaster) are given below (Tables 2 and 3).

Deterioration of mural paintings

Before proceeding to consider the various modes of deterioration of mural paintings and their causes, it is useful to remember that a mural painting is essentially a layered structure consisting of (i) a support (which may be brick or stone wall), (ii) a ground (which is usually lime plaster, although clay or mud plaster is the ground in early paintings in this country) and, (iii) the paint layer. Each of these component layers may be subject to factors causing alteration or decay and they have to be studied to assess the actual state of preservation of the painting so as to take corrective action.

The various forms of deterioration may be broadly categorized as physical, chemical or biological, although sometimes more than one type of deterioration can take place under the influence of a particular agency. It may often be appropriate to speak of physio-chemical alteration.

Among the various factors causing decay of the paintings, the single largest is moisture that causes physical erosion and transports soluble salts. (These are explained later.) Chemical reaction cannot take place unless a certain amount of moisture is present. Even the growth of micro organisms such as moulds and fungi is encouraged only when the RH is above 65%. Moisture is also the most ubiquitous of the causes of decay.

Physical deterioration

Wind erosion. Gusts of wind carrying fine particles of sand and dust can cause erosion of the paint surface in the case of external murals.

Heat. When sunlight falls directly on an exposed mural or when there is powerful illumination with electric bulbs placed near the paintings, the temperature of the paint surface can rise appreciably. The differential thermal expansion of the paint layer in relation to that of the ground can cause peeling of the paint surface.

Vibrations. The cumulative effect of ground or air traffic near a monument over a period of years or even the vibrations of large church bells over a sufficiently long period of time may contribute to the detachment of mural paintings from walls.

Moisture

a. *Erosion*: Rain water falling directly on a wall painting can cause rapid erosion of the surface. When seeping water from the roof or moisture absorbed by the wall from the soil through capillary action, causes the painting to remain damp, over a period of time, the entire area of the painting including the ground may be detached from the wall and can be lost. In cold climates,

Table 2. Analysis of the ground (mud plaster) — Ajanta

	Cave II (Dark red)	Cave II (Light red)	Cave VII	Cave VIII	Cave XVI
Moisture	2.02%	1.11%	1.25%	2.79%	2.73%
Carbon dioxide	0.32	0.80	0.02	0.49	0.35
Combined water and organic matter	10.01	5.91	7.23	10.17	14.11
Silica	57.65	68.61	59.10	57.94	54.42
Iron	16.36	13.35	11.76	14.38	15.71
Alumina	9.06	6.85	16.34	10.10	9.47
Phosphoric acid	0.12	0.10	0.09	0.13	0.11
Titanic acid	0.11	0.12	0.08	0.09	0.07
Lime	1.04	1.94	1.25	1.10	0.99
Magnesia	0.77	0.25	0.52	0.62	0.54
Manganese	1.32	0.64	0.23	0.74	0.32
Sulphuric anhydride	nil	nil	nil	nil	nil
Alkalies	1.06	0.26	1.21	1.13	1.02
Nitrogen	0.09	0.13	0.11	0.08	0.10
Total	99.93	100.07	100.09	100.06	99.94

Table 3. Analysis of ground (lime plaster) — Lepakshi

	Early paintings (%)	Late paintings (%)
Moisture	1.2	0.77
Carbon dioxide	14.20	15.24
Loss on ignition (excluding CO_2 and moisture)	5.79	2.12
Silica	53.33	58.91
Iron and alumina	3.86	2.65
Lime	19.65	18.10
Sulphuric anhydride	1.16	0.22
Magnesia	0.36	0.62
Undetermined (mostly alkalies)	0.69	1.17
	100.06	99.80

condensed moisture from the atmosphere could be an additional adverse factor.

b. *Loss of pigment*: Under less severe conditions, the moisture can dissolve or loosen the binding medium and cause the loss of only the paint layer, leaving the ground intact, although the loss is no less significant than in the previous case (Figure 3).

c. *Crystallization of soluble salts*: Water seeping from the roof as well as that absorbed from the soil can carry with it dissolved salts such as chlorides, sulphates and nitrates. Condensed moisture in a saline environment may also cause a deposit of soluble salts on the paint surface.

   When there are conditions for rapid evaporation at the wall surface, crystals of these salts, referred to as salt efflorescence, are deposited on the paint surface. This can cause peeling of the paint layer, besides other effects.

   Under different conditions, the salts may crystallize within the pores of either the ground (lime plaster) or the support (brick or stone wall). Alternate dissolution and crystallization of the salts within the pores can exert tremendous pressure leading to disintegration of the ground or support or both.

d. *Frost*: In extremely cold regions, frost action can cause disintegration of the ground or the support owing to the change of volume involved in the conversion of water into ice.

Figure 3. Vijayanagar period (16th century) paintings at Lepakshi. Note the partial loss of pigments due to water seepage

Chemical deterioration

Photochemical alteration. Mural paintings exposed to sunlight for a long time tend to fade gradually due to photochemical changes induced by the ultraviolet component of the light. Organic pigments are much more sensitive to this action and fade more quickly than mineral pigments. Hence they have been used much less than the latter in mural painting.

Chemical alteration of pigments. In the presence of moisture, certain pigments can undergo a chemical change. For instance, copper pigments such as malachite and azurite turn dark in the presence of sulphur dioxide. Verdigris, which is a copper acetate, hydrolyses with the release of acetic acid, causing damage to the ground. Lead pigments are very sensitive to sulphur. White lead, red lead and other pigments turn black in the presence of hydrogen sulphide. Any exposure to acid will decompose carbonates.

Salt action. Soluble salts, in addition to the physical damage caused by crystallization, may also chemically react with some of the pigments and produce changes. For instance, when sodium chloride is present, it is known to change the pigment azurite (blue) into paratacamite (light green).

Surface deposits. Dust, dirt, soot, oily matter, droppings of birds and bats, insect nests, etc. are found often on surfaces of wall paintings. These can get cemented to the surface with the help of moisture and form adherent deposits which not only disfigure but chemically react with the paint layer.

Atmospheric pollutants

a. Carbon dioxide, in the presence of moisture, can react with calcium carbonate in the plaster, producing soluble calcium bicarbonate, which may be gradually leached. Calcium bicarbonate is unstable and tends to be reconverted to calcium carbonate, forming whitish deposits on the surface.

   In enclosed spaces with paintings, it may sometimes become necessary to restrict the number of visitors because the accumulated carbon dioxide of the exhaled air is sufficient to cause adverse effects. The limestone caves of Lascaux with famous prehistoric paintings, where there is strict regulation on visitors, is a case in point.

b. Sulphur dioxide, always present in an industrial atmosphere, is quickly converted to sulphur trioxide and to sulphuric acid in the presence of moisture which reacts with lime producing calcium sulphate. An appreciable change of volume accompanies this reaction and calcium sulphate is much more soluble than calcium carbonate. Weakening and disintegration of the ground will be the ultimate result.

We have already seen the effect of pollutants like sulphur dioxide and hydrogen sulphide on certain pigments.

Bio-deterioration

Micro-organisms such as fungi develop rapidly in an environment with relative humidity exceeding 65%. On surfaces that are persistently damp, even mosses, lichens and algae can grow. In addition to the physical disintegration that these growths can cause to the paint surfaces, the acidic secretions from some of them can have serious chemical consequences.

When the plaster contains organic matter such as vegetable fibres and paddy husk, as at Ajanta, attack by insects such as silver fish, beetles, etc. becomes a serious problem.

Bats are a common menace in the dark recesses of temples and monuments. In some places, one can also find a large number of birds, like sparrows and pigeons. The droppings of the birds and bats form an incrustation on the paint surface that is harmful because of its salt content and also is very difficult to remove.

Use of defective materials and wrong techniques

Use of material of inferior quality in the preparation of the ground, incorrect choice of pigments or binding media and employment of wrong techniques can lead to rapid deterioration of wall paintings. In this context, the fact that in Ajanta and other monuments in this country, mural paintings have survived for so long despite many adverse environmental factors, bears testimony to the excellence of the techniques used by the ancient master painters and their care in the choice and preparation of materials. However, instances of inferior techniques and materials are not altogether lacking.

Use of wrong techniques and inappropriate materials during restoration of paintings can cause serious problems later. Fortunately, this is not a major problem in this country because the tradition of preservation and restoration of wall paintings is comparatively recent. A notable instance, however, is the application of a coat of shellac solution in alcohol by the Italian restorers on the Ajanta paintings in 1920–21. Although it was then considered the best material available, the coat later underwent alteration and turned yellow and even dark brown in some places, completely hiding and distorting the original colour scheme.

Sometimes mural paintings are found completely covered with lime-wash, particularly in South Indian temples. The limewash application was perhaps a part of the temple renovation and was the result of insufficient understanding of the importance of old paintings. Removal of lime-wash for exposing the hidden paintings without causing any damage is a fomidable task requiring much skill and patience.

Conservation techniques

Before undertaking a programme for conservation of mural paintings, the first requisite is that steps be taken to completely eliminate the ingress of moisture into the area in any form. Repairs to the roof and walls of the structure are therefore necessary. When moisture is absorbed through the soil, sheets of suitable material may have to be introduced into the foundation to act as a barrier. In India granite slabs have been successfully used for this purpose. In Italy, lead or aluminium sheets sandwiched between layers of bitumen, polyester resin and other materials have been used for such water-proofing. The humidity of the atmosphere can be controlled by using dehumidifiers.

The moisture level in walls can be directly measured using instruments like protimeter. These measurements enable us to determine whether the moisture content is within permissible limits and also the sources of moisture, so that necessary steps for its control can be taken. The RH and temperature in the room can be continuously monitored over a prescribed period by self-recording thermo-hygrographs. When necessary, the wall temperature can be measured using infrared thermometers.

If, in spite of all the measures, damp conditions in a wall do persist, the preservation of the mural *in situ* may become imposssible and the only course open to the conservator may be to transfer the mural from the wall and to preserve it elswewhere. It should, however, be understood that transfer should be the last resort, because a mural is an integral part of the architectural ensemble and is best preserved in its original setting.

Before commencing any conservation work on wall paintings, it is necessary to carry out detailed photographic documentation of the area to be treated in order to record the condition of the paintings before treatment. It follows that similar documentation is necessary at the end of the treatment. Sometimes photographic records are also obtained of the different stages of the treatment.

Consolidation

In the conservation treatment, the first step is to consolidate and strengthen the painting in order to prevent any further loss through detachment from the support or the ground. To begin with, a careful examination is necessary to test the adhesion of the ground to the support and that of the paint layer to the ground. The former can be easily tested by gently tapping the surface. A hollow sound indicates air space between the ground and wall and hence poor adhesion between the two. Even a bulge may be present. Ultrasonics may be used to accurately map the required area and record the detachments.

Lack of proper adhesion between the paint layer and the ground can be readily detected by visual examination and is indicated by conditions such as cupping, flaking and peeling of the paint layer. Photography under raking light (i.e. illumination directed laterally) can effectively record such conditions. Sometimes the paint layer may be found in a powdery state caused by disintegration of the binding medium. This would give a dull and matt appearance to the paint layer due to dispersion of light by the pigment particles.

In cases of prolonged salt action, the entire ground could be rendered weak and friable.

Loose or bulging plaster needs to be refixed to the support using a suitable adhesive and similarly flaking paint, to the ground. When the ground as a whole becomes friable and needs strengthening, it has to be impregnated with a suitable consolidant. Similar consolidative treatment has to be given to the paint layer that has become weak and powdery.

While adhesive strength is the main property required in an adhesive, a consolidant for impregnation treatment also needs penetrative ability for effective consolidation. Adhesives and consolidants to be used in such work should also satisfy certain other criteria. They should be colourless and should not cause any darkening or discoloration. They should be flexible. They should not shrink on setting (which might result in loss of bonding). They should be resistant to chemical change and biological attack. They should remain soluble even with the passage of time so that they can be completely removed with the help of solvents at any time if the need arises. Any conservation treatment should be completely reversible.

In India poly vinyl acetate (PVA) has been used for a long time as an adhesive and consolidant (and also for surface coating where required) in the conservation of wall paintings with satisfactory results and no adverse effects have been detected. PVA satisfies the criteria referred to in the previous paragraph to a large extent and till now no better material has been found.

i) The paint layer which has become weak and powdery (due to the disintegration of the binding medium) is treated with a 2 to 2.5% solution of PVA in toluene either by spraying or application with a soft brush. The solution strength has to be kept low to achieve better penetration. A second or third application may be necessary. Each application is done after the previous one has dried.

It may be noted in this connection that non-polar solvents (like toluene) penetrate more deeply than polar solvents because their surface tension is lower. For this reason, solutions of the consolidant in organic solvents (preferably non-polar) are better than emulsions where deeper penetration is the objective. The solvent should not be too volatile and should remain on the surface for a sufficiently long time for effective penetration.

With this treatment, the bonding between pigment particles is re-established and the adhesion between the paint layer and the ground is strengthened. With the compactness of the paint layer restored and with the change in refractive index, there will also be change in the optical properties, the pigments acquiring their original saturation and depth.

The impregnation technique can also be employed for consolidating weakened and friable portions of the ground, the success of the operation depending upon the degree of penetration that can be achieved.

ii) Flaking and peeling portions of paint layer are fixed back to the ground with local application of 5% solution of PVA and gentle pressing.

iii) When the ground detaches from the support and the gap between the two is narrow, re-attachment is achieved by introducing a thick solution of PVA (20%) into the gap and keeping the painted plaster pressed against the wall, for a few hours until the adhesive has set, by means of a suitable arrangement. Where the gap is wider, a paste of calcium caseinate (calcium caseinate is prepared by mixing thoroughly 1 part of swelled casein with 9 parts of slaked lime and adding 1 part of PVA emulsion for additional adhesive power and flexibility. Paste of the required consistency is prepared by the addition of water) is the consolidant used.

The ground being usually lime-based, the use of calcium caseinate is appropriate since the use of material very similar to the original is calculated to bring about much better bonding than when a different type of material is used. In the case of clay-based grounds, PVA emulsion mixed with kaolin may be better as a filler-cum-consolidant.

The consolidant solution/paste is introduced into the gap by injection. Where there is no opening available, as in the case of bulges the consolidant is injected through a small hole made in the painted plaster. When the area of the gap to be filled is large, it will be advisable to make another small hole for the air inside to escape as the solution/paste is injected into the gap. During injection, care has to be taken to see that calcium caseinate does not overflow onto the painted surface. Sometime it may be necessary to protect the paint surface with some support during the injection lest any portion of the painted plaster gets detached because of the pressure from inside.

After the injection is complete, it is necessary to keep the painted plaster pressed against the wall for a few hours or even overnight, until the consolidant has hardened (Figure 4). The necessary pressure can be maintained by using a spring or screw arrangement applied over a felt-covered board placed on the paint surface.

iv) When loss of painted plaster has occurred, broken edges of the same are often found exposed. Unless they are attended to promptly, further losses can occur. All loose edges are fixed back to the wall surface by applying a fillet, consisting of plaster-of-paris paste, which is a quick-setting cement. In order that the filleted edges do not look too prominent because of the white colour of plaster-of-paris, it is so tinted as to match with the adjoining wall surface, by adding the necessary colours while preparing the paste.

v) Cracks in the painted plaster are filled with suitably tinted plaster of paris. Very thin cracks or those confined to the paint layer can be filled by using a 10% solution of PVA.

Recent developments abroad. While considering the advances in techniques achieved abroad in this field, it is sufficient if we confine ourselves to developments in Italy, the country having the maximum amount of wall paintings and also the longest experience in their treatment, including the latest improvements in techniques.

The techniques used for the consolidation of wall paintings in India and Italy are basically the same. The recent developments in Italy relate to the use of better material. Experiments have been conducted with a number of different materials, both organic and inorganic[12]. Of the former, mention may be made of poly vinyl acetate, poly vinyl chloride, poly vinyl alcohol, acrylates, methacrylates, polystyrene, polyethylene, polypropylene, nylon, cycloparaffinoid resins, polyacetal resins, derivatives of cellulose, polyglycols and microcrystalline waxes. While thermoplastic resins, with a glass transition temperature above 70° C, are generally suitable for the work, the different polymers tested have advantages as well as shortcomings in respect of different properties like polarity, resistance to

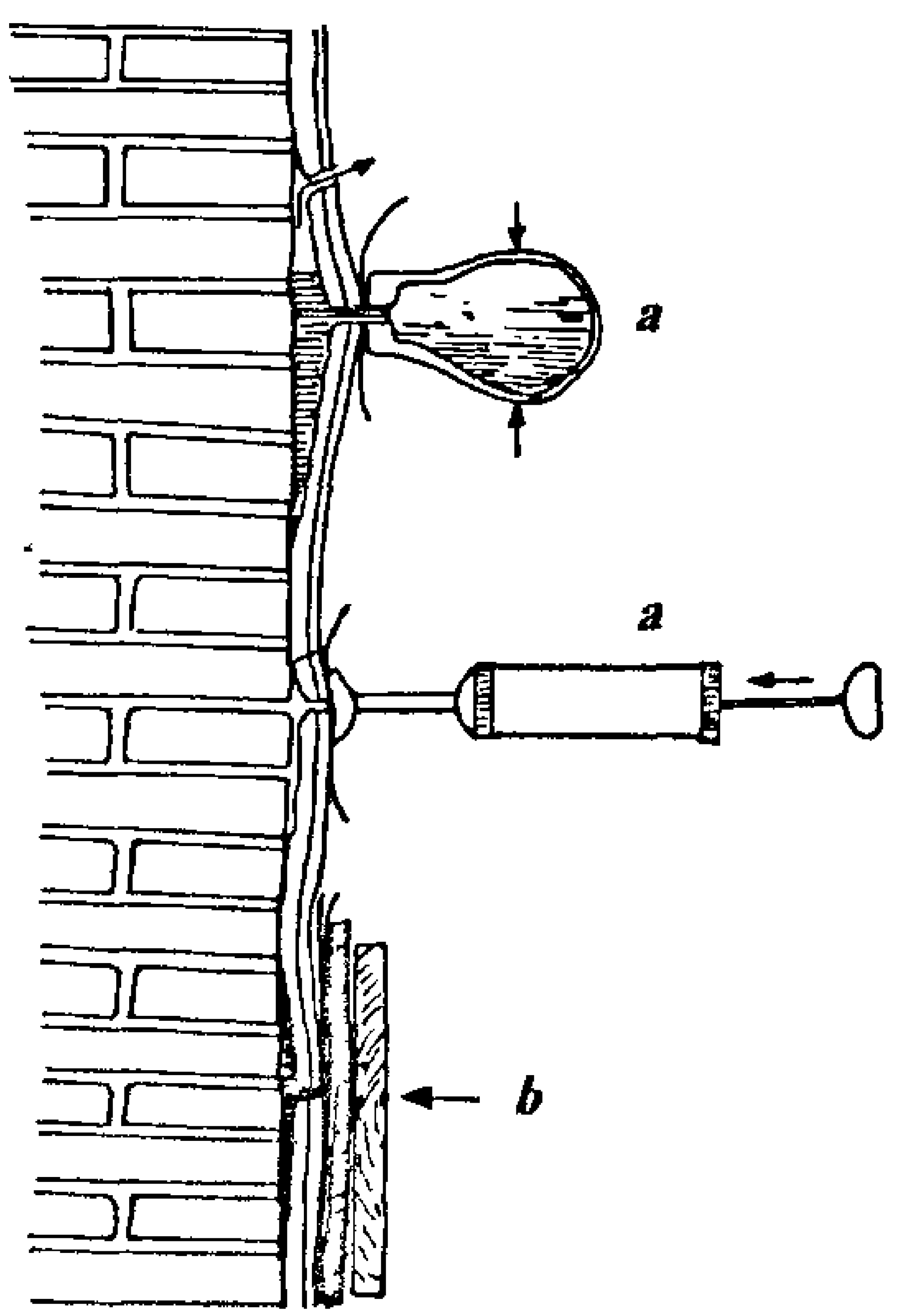

Figure 4. Consolidation of peeling or bulging portions of painting against the supporting wall: **a**, Methods of injecting consolidants. **b**, Application of pressure to the surface until the consolidant has set. [adapted from Conservation of Cultural Property in the Tropics, UNESCO, 1968.]

ageing, flexibility, etc. PVA is among the most acceptable with its medium polarity and good ageing characteristics. A co-polymer of acrylate and methacrylate, with the trade name of Paraloid B72, was found to have very satisfactory mechanical and aesthetic properties, besides good resistance to ageing. It has been rated as even superior to PVA.

Among the inorganic substances, lime water has been in use in Italy for a long time as a consolidant. Being a saturated solution of calcium hydroxide, it reacts with CO_2 of the atmosphere to form calcium carbonate which fills up the pores and reinforces the plaster surface. The same result can be achieved more effectively by using a solution of calcium bicarbonate, prepared by blowing CO_2 into a suspension of calcium carbonate in water. The former being an unstable compound is quickly re-converted to calcium carbonate.

Tests have been conducted with a number of other materials, including alkaline silicates, fluorosilicates, silicon esters, etc. Each one had some shortcoming or the other such as producing efflorescence, lack of sufficient penetration and formation of a glossy coat on the surface.

Lewin's process[13] for consolidation of lime stones by using barium hydroxide and urea has been used in a modified form for consolidation of lime plaster. The painting layer is first protected with a sheet of Japanese tissue paper over which is applied a layer of cellulose pulp impregnated with the solution. The solution is kept in contact with the surface for four to six hours. Small areas are treated at a time.

Cleaning

In the conservation procedure, cleaning forms an important part not only from (i) the aesthetic point of view of removing ugly deposits and accretions and restoring the paint surface to its original condition as much as possible, and (ii) from the archaeological point of view of uncovering the details that the accretions may be hiding (sometimes even inscriptions) but also (iii) from the purely conservation point of view because the constituents of the deposits may be reacting chemically with the paint layer causing irreversible changes.

Obviously the reagents for cleaning have to be chosen with care. Only those that are effective in removing the accretions but have no reaction on the paint layer can be used. They also should not be too toxic because they have often to be used in enclosed spaces, without proper ventilation, and may prove hazardous to the health of workers.

One major difference between the situation prevailing in India and that in other countries may be mentioned here. In Italy, for example, the paintings are mostly true frescoes in which, as seen already, the paint layer is practically insoluble and so even aqueous solutions can be safely used for cleaning. Since water is a powerful solvent on account of its high polarity, this is a clear advantage. In India, however, all the paintings are either in tempera or secco technique and the paint layer cannot stand treatment with water. Hence only organic solvents have to be used for cleaning. If the use of aqueous solutions is unavoidable in special circumstances, they have to be used for the minimum possible time and with some protection to the surface such as Japanese tissue paper.

Cleaning is undertaken only after experimenting with the solvents in an inconspicuous corner of the painting to ascertain their safety and effectiveness. Often a mixture of solvents is found to have more desirable properties than individual ones.

Cleaning is most often accomplished by the process of dissolution. Sometimes, however, the solvent cannot completely dissolve the accretion but can only swell it and convert it into a gel, which is later removed by gentle mechanical means. The use of surface-active agents like detergents sometimes becomes necessary to loosen firmly adhering deposits. Non-ionic detergents are used for this purpose because they do not react with the constituent materials of the painting and because of their greater effectiveness in cleaning. They are used in an alcoholic medium and are completely removed from the surface with alcohol after the cleaning is complete. In some cases, it becomes necessary to remove the accretion by using reagents that react chemically with it. The use of amines like butyl amine for the removal of oily and greasy matter from paint surfaces, is an example. Though mildly basic substances (like the amines) can be used in required cases with care, acids —even the weakest ones—are completely ruled out because of their high reactivity with materials constituting the painting.

Rate of evaporation is an important characteristic governing the choice of a solvent. While very volatile solvents evaporate too quickly and may not get enough time to react, those with high boiling points tend to remain in contact with the surface too long, which also is not advisable. Those with medium range boiling points are most suitable.

i) The first step is to remove all loose dust, dirt, cobwebs etc. by careful use of a small air-blower or soft brushes. Insect nests and cocoons are sometimes found on the surface which can be removed by careful mechanical means.

ii) Adhering dirt is removed by using an organic solvent such as rectified spirit applied with soft brushes. The use of a non-ionic detergent like Teepol in 1% to 2% solution in ethyl alcohol sometimes becomes necessary. At the end of the cleaning, any detergent still remaining on the surface is thoroughly removed with alcohol.

iii) Grease and oily matter can be usually removed with solvents like benzene and toluene. For thicker deposits hardened with age, *N*-butyl amine or cyclohexyl amine is used in 5 to 10% strength, the diluent being a neutral solvent like petroleum spirit. After cleaning, the last traces of amine are removed with the solvent.

iv) Any wax coating or splashes can be removed with the help of trichloro ethylene or carbon tetrachloride.

v) In India, mural paintings are often found in living temples and deposition of soot on the paint surface from oil lamps, camphor burning, etc. is a common problem. For the removal of soot, triethanol amine is first applied on the affected surface and allowed 15 to 20 min to react, at the end of which the area is cleaned with cotton swabs soaked in toluene. The swabs remove the dissolved soot as well as the triethanol amine. At the end of the cleaning, all traces of triethanol amine (which is a very high-boiling and viscous liquid) are removed with toluene.

vi) Though wall paintings do not usually have a varnish coat (unlike oil paintings), it is sometimes found that, due to some special reason, such a coating had been applied on a wall painting and it has undergone discoloration or ageing. For the removal of varnish, solvents like acetone, amyl acetate, cellosolve (ethylene glycol monoethyl ether), diacetone alcohol, *N*-butyl and isobutyl alcohols, ethylene dichloride, etc., have been found to be useful; mixtures of these solvents in suitable proportions often proving much more effective than single solvents. The constituents of the mixture and their proportions, best suited for a particular work, can be arrived at after tests conducted on unimportant areas of the painting.

The solvent/solvent mixture is first applied over a small area with a brush and after allowing a few minutes for reaction, the dissolved varnish is removed by gently swirling cotton swabs, soaked in the solvent, over the area. The swabs have to be rolled such that the dissolved varnish is lifted out and not rubbed in into the pores of the paint layer.

If there is any indication that the solvent action has proceeded too far, i.e. if there are any signs or traces of pigment coming on to the swabs, the action is arrested by immediately flooding the area with a restrainer such as turpentine.

vii) Sometimes it may be found that the paint surface is too fragile to be cleaned by normal methods. In such cases a filter paper sheet soaked in the solvent mixture is applied over the surface and kept in contact with it for 10 to 15 min. The sheet is covered with a tin foil to slow down the evaporation of the solvent. When the filter paper sheet is removed at the end of the period, it will be found to have absorbed the dissolved varnish. After the surface has dried, a second application may be made. The process is repeated till cleaning is complete.

In this method, even the mild abrasion involved in the use of cotton swabs on the paint surface is avoided or minimized. The bulk of the varnish can be removed with the filter paper application and use of cotton swabs may be limited only to the removal of the last remnants.

viii) As seen already, wall paintings are sometimes covered with lime-wash. Since only acidic reagents can react with lime and help in its removal and since the use of acid in any form on paintings is completely ruled out, the only means available for the removal of lime-wash is the mechanical method with careful use of tools like spatulas, scalpels, etc., after softening the lime coat slightly by applying alcohol mixed with a little water. When the coat is sufficiently thick, chiselling may help. The work requires a high degree of skill and patience.

ix) The problem of salt action on wall paintings, although not very common, does occur in a few places. The salt efflorescene is first carefully removed mechanically as much as possible. Next a sheet of Japanese tissue paper is applied over the area on which is applied a layer of moist paper pulp. The process has to be repeated a few times for completing the salt removal. Care must be taken to keep the paper pulp for the minimum time to avoid over-soaking the painted plaster risking the dissolving of binding medium. The Japanese tissue paper is for protecting the paint layer. It may sometimes be necessary to further protect the paint layer, if fragile, with a coat of 1% solution of PVA before start of the treatment. The PVA film is not completely impermeable to water and allows the passage of salt solution from the plaster into the paper pulp.

x) Deposits of bat and bird droppings are most difficult to remove from paint layers. They have to be removed mechanically to the maximum extent possible and the thin whitish film still left can be removed by careful use of ammonia (5%) solution in alcohol.

xi) Biological growths like fungi, mosses, lichens, algae etc., are first mechanically removed and the last remnants are removed using a dilute solution (2 to 5%) of alcoholic ammonia. The affected area has to be treated with a fungicide. A 2% solution of formalin or pentachloro phenol of the same strength may be used. The latter reacts with copper pigments and cannot be used when they are present.

Recent developments. In rare cases, there may be accretions, containing insoluble salts, that are not amenable to any of the normal methods of treatment. In order to tackle such deposits, by rendering them soluble, some new formulations have been developed in Italy recently.

A typical mixture[14] which has given good results in practice and known as AB 57 is as follows:

Ammonium bicarbonate	...	30 g
Sodium bicarbonate	...	50 g
Desogen of 10% strength (Geigy)	...	25 g
Carboxy methyl cellulose	...	6 g
Water	...	1000 ml

The solvent action on incrusted material is essentially due to bicarbonate ion. When incrustation is sulphated it is likely to be converted into soluble ammonium sulphate. Desogen serves a two-fold purpose. This ammonium quaternary salt is not only a surfactive reagent ensuring effective contact of the mixture with the surface but also acts as a powerful disinfectant against micro-organisms. The addition of carboxy methyl cellulose (CMC) gives a paste-like consistency to the mixture and ensures its remaining in moist condition for a longer time for reaction with incrusted surface.

The mixture is applied to vertical surfaces through compresses of Japanese tissue paper to ensure better contact and to prevent the solution from flowing down. When a paste of thicker consistency is required, the proportion of CMC is increased.

As with solvents, the mixture is used only after experimenting over small areas of painting to observe the effects. It has to be used with caution on Indian paintings since they are susceptible to water.

Application of protective coat

After the consolidation and cleaning processes are complete, the last step in the treatment is the application of a protective coat to the paint surface. In its normal condition, a wall painting has a matt appearance since it does not have any varnish coat, unlike an oil painting which has. However, on a wall painting which has been exposed to decay-causing factors and which has received conservation treatment, it is advisable to apply a coating as a final step. The coat firmly fixes the paint layer to the ground and also presents the colours in their full saturation. However, it should not give a glossy appearance to the paint surface. This can be ensured by controlling the strength of the solution being used. The coat also affords a certain amount of protection from environmental agencies.

As mentioned earlier, many of the paintings are in living temples exposing them to constant smoke, dust, etc. After treatment, such deposition takes place over the coating and its direct contact with the paint layer is avoided. Future cleaning involves only the removal of the coating with a solvent and is much easier.

The material used for coating should give a colourless, transparent and flexible film. It should be resistant to alteration; nor should it have the slightest reaction with the paint surface. It should also be resistant to biological attack. It should retain its solubility and one should be able to remove it any time with a solvent.

PVA meets the above requirements to a large extent and has been in use in India for a long time. Even after two or three decades of application, adverse effects have not been noticed. There is no discoloration. Only in a few instances, under highly humid conditions, does PVA undergo partial hydrolysis and the film loses its transparency to some extent. The coating can be easily removed by brushing on toluene. Even otherwise, it may be advisable to replace the old coating with a fresh one, once in ten years or so.

PVA solution (1%) in toluene is used for coating. It may be either sprayed on to the surface or applied with a flat, soft brush so as to form a thin, uniform film. If need be, a second coating may be applied after the first one has dried.

In Italy, the practice of applying a protective coating to mural paintings is not generally prevalent because the paint layer in true frescoes is usually much stronger than in tempera paintings and the need for fixing does not arise. Where coating was found necessary, Paraloid B72, considered to have properties superior to PVA, was used.

Treatment of losses

Sometimes there may be lacunae, small or large, within the body of the painting, which have a jarring effect on the viewer. Reconstruction of the missing portions of the painting is not permitted, according to the conservation principles strictly adhered to in this country, because such reconstruction has to depend on guess-work and interferes with the authenticity of the painting as a whole. To remove such jarring visual effect, the lacunae are covered with plaster-of-paris and tinted with water-colours (which are similar to the pigments used in paintings) so as to merge with the surrounding areas of the painting (See Figure 5).

In Italy, selective retouching is done on small areas if the missing portion can be visualized with some certainty. Larger lacunae are filled with thin, transverse lines in the selected colour.

Transfer of murals from the wall

As mentioned earlier, under situations such as persistent damp conditions in the wall, salt action, etc., which cannot be easily remedied, the only possibility of saving the mural painting is to remove it from the wall and remount it on a fresh support. This transfer process has been in practice in Italy for a long time. Whenever

ARCHAEOLOGICAL SURVEY OF INDIA

Figure 5. Ajanta painting (5th century AD)—Lacunae in the paint surface filled with plaster and tinted with neutral colour

the transfer technique had to be used in India, the Italian methods have been adopted with suitable modifications.

In Italy, three methods are in use: (i) Stacco a massello, in which the painting is removed along with its ground and a part or whole of the support, i.e. the wall itself or part of it is cut away. Evidently this is a drastic method involving damage to the building and is used only in rare and unavoidable circumstances. (ii) In Stacco, the paint layer is removed along with the ground. (iii) The third method is Strappo, in which only the print layer is removed.

In all the three methods, the first step is to apply a protective facing of cloth to the paint layer. The facing consists of a cotton gauze followed by two layers of hemp canvas. The adhesive used for applying the facing is usually glue mixed with mollasses (to give flexibility to adhesive), vinegar (for fluidity) and oxgall (surface active agent). In the Strappo process, the molasses is omitted to allow the glue to shrink on drying, which exerts a pull on the paint layer and facilitates its detachment. It may be noted here that, at the end of the transfer, the last step is the removal of the facing and when glue is the adhesive, it can be removed only with the help of hot water. This presents no problem in the case of true frescoes but when the finishing has been done in Secco or tempera, the paint will be sensitive to water. In such cases, a synthetic resin adhesive in an organic solvent, in 10 to 20% strength, is used for applying the facing. The final removal of the facing is easily accomplished with solvent. PVA and Paraloid B72 have been used as facing adhesives.

After the facing has thoroughly dried, lateral and horizontal cuts are made along the edges up to the required depth and the detachment done by careful use of chisels etc., starting from the bottom right-hand corner. In Stacco a massello, the painting surface is provided an additional wooden support before commencing the cutting of the wall. In Strappo, the facing cloth, along with the adhering paint layer, needs to be pulled away from the wall.

The next step is to provide a new support to the detached painting. The back of the painting is first made perfectly even by filing down any protrusions and filling any gaps with lime. Two layers of open-weave canvas are attached with lime-casein as adhesive. Next a layer of polyurethane foam is applied, using PVA solution. The last layer is a rigid support. Many different types of support such as metal grids, sheets of plastic material such as PVC had been used earlier. At present, fibreglass is considered the best. It is light, strong and chemically stable. Epoxy resin is used for attaching the fibreglass support. (The insertion of the sheet of the foam as an intermediate layer enables removal of the support and redoing its application, if such a need arises due to any errors etc.)

Some case studies

Ajanta

Reference has been made to the problem that arose at Ajanta due to the application of a shellac coat on the paintings by the Italian restorers in 1920–21. Natural products are usually more susceptible to alteration than synthetic materials and the shellac coat has turned yellow and even dark brown in some places (due to atmospheric oxidation), hiding or distorting the original colours of the paintings. Secondly the thick coating is exerting pressure on the paint layer due to movements in response to changes in atmospheric temperature and humidity, which has resulted in the formation of a pattern of fine cracks in the paint layer. It is therefore evident that, when work started at Ajanta in 1954 soon after the Archaeological Survey of India took over the caves, one of the first tasks was to remove the shellac coat. Cleaning had to be undertaken on priority basis.

As the work made progress, it was realized that the cleaning did not involve the removal of shellac alone. After the discovery of the caves in 1819, some prominent artists like Lady Herringham and Griffith had made copies of the paintings and before each copying session, a coat of varnish (mastic or sometimes even copal) used to be applied on the paintings to make them brighter. The Italian restorers of 1920–21 were probably not able to completely remove these earlier varnish coats, before their own application of shellac. (The testing of the coating material removed with cotton swabs during the cleaning showed the presence of mastic and in some cases copal, in addition to shellac.)

Due to repeated application of coats in the past, some of the varnish had seeped into the cracks. When the solvent/solvent mixture is applied, the coating on the surface is removed and the paint layer apparently seems to have regained its original clarity. After a few days, however, the varnish solution within the cracks migrates to the surface during evaporation of the solvent. After the solvent completely evaporates, the varnish remnants present on the paint surface appear like a thin whitish deposit. The whiteness is because the varnish is now no longer a cohesive film transmitting light but consists of broken-down particles, each of which reflects light. This white deposit is referred to as chalking. When the last traces of the varnish are removed and the cleaning is complete, chalking no longer appears.

In some places, particularly the upper portions of the wall, the whitish deposit is also due to remnants of bat droppings. There also the Italian restorers had perhaps not succeeded in removing completely. The shellac coat had merely masked them. A combination of extremely careful mechanical methods and selective use of alcoholic ammonia solution (5%) was successful in removing these deposits.

When there was some criticism after the appearance of chalking and loss of pigment was feared as a result of the cleaning, small paint samples from the cleaned area were mounted in polyester resin and their cross-section was examined under the microscope. The pigments were found to be intact and the whiteness was found to be only a superficial deposit. The cleaning methods used were thus found to be safe and continued with for complete removal of shellac and other coatings.

Several organic solvents were found to be useful and one mixture which proved particularly effective is as follows:

Acetone	– 1 part
Amyl acetate	– 1 part
Diacetone alcohol	– 4 parts
Cellosolve	– 4 parts
Morpholine	– a few drops.

Turpentine or petroleum spirit was used as restrainer, whenever needed. Dimethyl formamide was found to remove copal varnish effectively.

Lepakshi

The paintings of the late Vijayanagar period (16th century) at Lepakshi (Dt Ananthapur, AP) are in the secco technique.

On the painted ceiling of the main hall, measuring 10 m × 4 m, there is a single figure (Veerabhadra) of 4.80 m length at the centre (one of the largest single figures in painting in India) with a number of smaller attendant figures and decorative designs all round. The entire ceiling was covered with a thick coat of soot and only some faint outlines of the paintings were visible through the covering.

Cleaning tests showed that the paint layer had been reduced to a very fragile condition (through reaction with the soot deposit) and could not stand even the gentle friction of cotton swabs dipped in solvent. It was therefore decided to use the filter paper technique to remove the soot layer.

The solvent used was a 1:1 mixture of triethanolamine and a 2% solution of Teepol in rectified spirit. A filter paper sheet of 30 cm × 30 cm was dipped in the solvent and applied to the paint surface with gentle pressure to ensure close adherence and allowed to remain for 20 min. When the paper was carefully removed after 20 min, it was found to have absorbed dissolved soot and turned dark. After the area had dried completely another application was done. The soot removal was usually complete with three applications but sometimes a fourth application was required. While treating adjacent areas, it was ensured that the edges overlapped so as to avoid the formation of lines at the borders. At the end of the soot removal, the excess of triethanolamine and Teepol remaining on the surface were removed with careful application of rectified spirit with a sable hair brush.

After thorough drying, the paint surface was preserved with the application of two coats of 1% PVA solution in toluene.

Bagh Caves

The paintings in the Bagh Caves (near Dhar in Madhya Pradesh) are contemporaneous with the later Ajanta paintings and equally renowned. They are also on a mud ground like the Ajanta paintings and done in tempera technique.

A serious conservation problem had to be confronted here due to seepage of water into the caves from the roof. There were major technical difficulties in getting the rocky ceiling repaired and the repair work took several years for completion. In the meantime however, there was no let up in the seepage of water into the caves and the walls as well as the mud plaster of the paintings remained continuously damp. As a result, the paintings were reduced to a very fragile condition and the only means of saving them was to transfer them from the wall. It was decided to start the work in cave 4, where the situation was particularly bad.

In view of the conditions prevailing, it was decided that the stacco process of detaching the paint layer along with the ground would be the best.

First a facing of thin muslin cloth was applied on the selected area. Overlapping pieces of the cloth of about 25 cm × 25 cm were applied. The adhesive used was 20% solution of PVA in toluene. The first layer of facing was allowed to dry completely before applying the second layer The drying took 2 to 3 days because of the condition of the paint layer and was speeded up by using infrared lamps. The second layer of facing was a strong cotton canvas. This was also allowed to dry completely.

Before commencing detachment, the top portion of the faced area was secured by putting on a wooden reeper, supported by props. (Without such a support there is the danger, towards the end of the operation, of the detached painting falling down.)

The detachment was done with the help of chisel and hammer, starting from the bottom right-hand corner. Since the adhesion between the wall and the mud plaster had been weakened, the detachment was relatively easy but great care had to be taken in view of the fragile condition of the whole ensemble.

The detached painting was placed face down on a table and the plaster at the back was allowed to dry out completely. Next the surface of the plaster was made even by filing down protrusions and by filling the lacunae with a paste of Kaolin and Fevicol.

The next step was to apply two layers of strong, open-weave cloth to the plaster surface with Fevicol adhesive, the second layer after the first one had dried. Application of a sheet of polyurethane foam of about 8 mm thickness with 20% PVA solution as adhesive, was the next step. Finally a layer of glass fibre mat was applied using araldite as adhesive. The concluding step of the operation was to remove the cloth facing from the front surface. Since PVA is the adhesive, the removal could be easily done by brushing on a toluene–acetone mixture (9:1) and carefully lifting the cloth. Excess adhesive on the paint surface was removed with cotton swabs dipped in the same mixture.

Brihadisvara Temple, Tanjavur

In respect of the transfer of paintings, an unprecedented problem arose in the Brihadisvara temple at Tanjavur, Tamil Nadu. The Chola paintings (11th century AD) on the walls of the circumambulatory passage around the sanctum had, in the 16th century, during the period of the Nayaka rulers been overlaid with lime plaster all over. Painting was done in the Nayaka style on the fresh plaster. Thus there were two layers of paintings of different historical periods, one superimposed over the other. While it was evidently necessary to expose the hidden Chola paintings, it had to be done in such a way as not to damage the superimposed Nayaka painting in the least because the latter too had its own historical and artistic importance. In other words, the Nayaka layer of painting had to be detached from the Chola layer without the slightest damage to either. The method that suggested itself first was Strappo because of certain advantages but since the Nayaka paint layer did not have the necessary strength for the Strappo process, the only remaining alternative was Stacco. Even in the Stacco process the extraordinary difficulty was that what lay behind was not the wall surface, as in the normal case, but another paint layer. Therefore during detachment, chisels, etc., had to be used with a high degree of skill and patience so as not to scratch or damage the underlying Chola layer.

This delicate work could be accomplished by the present author with complete success and several panels of Nayaka paintings were detached and remounted and very interesting Chola paintings, that lay hidden for centuries, were brought to light[15]. This was perhaps the first time anywhere that two layers of old mural paintings had been successfully separated and preserved, on this scale.

The adhesive used for applying the facing was 20% solution of PVA in toluene. The incision in the Nayaka layer, as a prelude to detachment, was done cautiously so as not to cut into the Chola layer. The detachment itself was done with the utmost care, almost inch by inch, with the help of rubber-tipped chisels. The Chola layer, slowly coming into view, was kept under constant watch and, if it showed any tendency to peel or flake, it was immediately consolidated with PVA solution and only after that, further detachment work was proceeded with (See Figure 6.) Each panel of about 1 m × 1 m took about four days for detachment, on an average.

The detached Nayaka panels were mounted on fibreglass according to the procedure outlined above (see Figure 7). The exposed Cholá painting was first cleaned with a mixture of butyl lactate and rectified spirit and then preserved with two coats of 1% PVA solution in toluene.

Conclusion

Mural paintings are an important component of our cultural heritage and the need for properly conserving them is obvious. The conservation methods described above are based on a knowledge of the properties of materials used and have been developed through experimentation and observation. In some cases, techniques used abroad have been adopted after modifying them to suit the climatic and other conditions here. While the treatments have, on the whole, stood the test of time and no adverse effects have been noticed even after 20 or 30 years, the methods can hardly be considered ideal ones. There is

Figure 6. Separation of two layers of painting in the Brihadisvara temple. Tanjavur, detaching the superimposed Nayaka layer of painting (16th century) from the Chola layer (11th century).

Figure 7. Detached Nayaka painting mounted on fibre-glass support.

always scope for improving them. The deterioration process itself has still to be understood in depth and there is need for further research in this area. The study of pigments, media and techniques used in older times may have relevance even from the technological point of view. Another important area for research is the long range effect of the organic solvents, used for cleaning, on the media of the old paintings. Only after a detailed study can one arrive at really safe solvents.

Considering the importance of research in this field, it is an encouraging development that the Department of Science and Technology, Government of India, propose to evolve a national programme on the application of science and technology in the conservation of cultural heritage, as part of their scheme to encourage research in frontline areas. It is hoped that more and more research scientists will start taking interest in this field, so that light may be thrown on hitherto unsolved problems and we may be able to conserve our heritage better.

1. Wakankar, V. S and Brooks, R. R. R., *Stone Age Painting in India*, D B Taraporevala Sons and Co. Pvt Ltd, Bombay, 1976, p. 4.
2. Wakankar, V. S. and Brooks, R. R. R., *Stone Age Painting in India*, D. B. Taraporevala Sons and Co. Pvt. Ltd., Bombay, 1976, p. 5.
3. Tewari, R., *Rock Paintings of Mirzapur in Utter Pradesh, Rock Art in the Old World* (ed. Michel Lorblanchet), Indira Gandhi National Centre for the Arts, New Delhi, 1988, p 286.
4. Mora, P, Mora, L. and Philippot, P., *Conservation of Wall Paintings*, Butterworths, London, 1984, pp 64–65
5. Doerner, M.,*The Materials of the Artist*, Harrap, 1949, p. 265
6. Duell, P. and Gettens, R. J. *A Review of Aegean Wall Painting, Technical Studies in the Field of Fine Arts*, Harvard University, 1942, vol. X, pp. 179–233.
7. Paramasivan, S, *Annual Report of the Archaeological Department of H E.H the Nizam's Dominions*, 1936–37, pp. 25–30.
8. Paramasivan, S, *The Mural Paintings in the Cave Temple at Sittannavasal—An Investigation into the Method, Technical Studies in the Field of Fine Arts*, vol. VII, Harvard University, 1939, pp. 82–89.
9. Paramasivan, S., *Nature* 1938, 148, 757.
10. Paramasivan, S, *The Paintings in the Brihadeeswara Temple at Tanjore—An Investigation into the Method, Technical Studies in the Field of Fine Arts*, Harvard University, vol. V, p 236
11. Subbaraman, S, *The Mural paintings in Brihadeeswara Temple, Thanjavur—A New Approach to their Study and Preservation, Indian Archaeological Heritage*, Agam Kala Prakashan, Delhi, 1991, vol II, pp. 748–749.
12. Mora, P., Mora, L. and Philippot, P., *Conservation of Wall Paintings*, Butterworths, London, 1984, pp. 224–236.
13. Lewin, S Z and Baer, N, *Rationale of the Barium Hydroxide–Urea treatment of Decayed Stone, Studies in Conservation*, IIC., London, 1974, vol. 19, pp. 24–35.
14. Mora, P., Mora, L. and Philippot, P, *Conservation of Wall Paintings*, Butterworths, London, 1984, p. 342.
15. Subbaraman, S, 1st International Colloquium on the Role of Chemistry in Archaeology, the Birla Institute of Scientific Research, Hyderabad, 1991, pp 76–80.

Received 17 September 1992; accepted 7 December 1992