THE WALL PAINTINGS OF GUNDSØMAGLE CHURCH, DENMARK

Tim Padfield, Peder Bøllingtoft, Bent Eshøj and Mads Chr. Christensen

Abstract

The whitewash on the walls of Gundsømagle church was removed after a fire in 1987, revealing in the chancel a wall painting in Byzantine style from about 1100. The figures of two apostles are clearly visible, with traces of four more. The pigments were mixed with lime and painted on a hardened, porous lime plaster ground. The painting was probably exposed for 400 years before being covered with whitewash in the sixteenth century. The intricate technique and the alteration of some of the colours make retouching impossible without destroying the authenticity of what remains. The structure of the painting is delicate but stable, so impregnation is not necessary. The urgent problem is to prevent dirt accumulating on the painting through the turbulent motion of air rising from the heating system. A study of the microclimate shows that water vapour moves easily to and from the wall as the church is heated and ventilated, buffering the inside climate but risking salt crystallization at the wall surface. The church climate should be controlled to minimize the water vapour flux through the wall, rather than to maintain an arbitrarily chosen relative humidity.

This is a digital version of the article first published as: Tim Padfield, Peder Bøllingtoft, Bent Eshøj and Mads Chr. Christensen, 'The wall paintings of Gundsømagle church, Denmark', Preprints of the IIC (International Institute for Conservation) conference, Ottawa, 1994 pp 94-98.

THE WALL PAINTINGS OF GUNDSØMAGLE CHURCH, DENMARK

Tim Padfield, Peder Bøllingtoft, Bent Eshøj and Mads Chr. Christensen

ABSTRACT
The whitewash on the walls of Gundsømagle church was removed after a fire in 1987, revealing in the chancel a wall painting in Byzantine style, from about 1100. The figures of two apostles are clearly visible, with traces of four more. The pigments were mixed with lime and painted on a hardened, porous lime plaster ground. The painting was probably exposed for 400 years before being covered with whitewash in the sixteenth century. The intricate technique and the alteration of some of the colours make retouching impossible without destroying the authenticity of what remains. The structure of the painting is delicate but stable, so impregnation is not necessary. The urgent problem is to prevent dirt accumulating on the painting through the turbulent motion of air rising from the heating system. A study of the microclimate shows that water vapour moves easily to and from the wall as the church is heated and ventilated, buffering the inside climate but risking salt crystallization at the wall surface. The church climate should be controlled to minimize the water vapour flux through the wall, rather than to maintain an arbitrarily chosen relative humidity.

1 INTRODUCTION

In 1987 a fire destroyed the altar and blackened the walls of the church in the village of Gundsømagle, 11km north of Roskilde in Denmark. The heat destroyed the adhesion of the whitewash to the walls, so it had to be chipped away, revealing fragments of a painting on the chancel wall, now dated around 1100. There are the figures of two apostles (Fig. 1), with traces of four more. The nave is decorated with paintings dated around 1275. These paintings, in early Gothic style, are also of high artistic quality, though badly deteriorated [1].

The importance of Gundsømagle church in the history of European art was recognized by a generous grant from the European Community to aid in its restoration and conservation. The materials and techniques of the painting in the nave were described in an article by Bøllingtoft and Christensen [2]. The climate within the church was measured for a year and a half; these measurements led to an article by Eshøj and Padfield [3] proposing the concept of building museums with porous walls that function as efficient buffers for relative humidity (RH). In the present paper, we return to the original purpose of the data collection: to plan the survival of the wall painting. This article describes the materials and technique of the painting, and the microclimate at the wall surface.

Fig. 1 The Romanesque wall painting on the north wall of the chancel. Notice the white border following the curve of the vaulting, added about 1448. In the foreground is a glimpse of the chancel arch, painted at the same time as the north wall. It was uncovered and heavily restored in 1900.

The efficient RH buffering gives a reassuringly stable climate in the church but this stability is due to the continually shifting equilibrium within the wall between water vapour, salt crystals and liquid water with dissolved salt ions. It is this salt movement that is the main threat to the adhesion of the wall paintings. The other threat is dirt accumulation on the rough porous surface. Any attempt to reduce soiling through interfering with free air movement will also affect the pattern of water exchange through the surface. The authors describe these physical influences on the painted wall surface and present a case study suggesting that the interior climate should be adjusted to minimize water vapour transport through the surface of the wall rather than to control the relative humidity in the church. The study also reveals the main difficulty in achieving this aim: the lack of methods for reliable and continuous measurement of the vapour flux.

2 THE CHURCH AND ITS WALL PAINTINGS

The church was built around the year 1100 [4]. The walls are made from blocks of a local lime tufa: a very porous limestone, formed by precipitation of calcium carbonate on vegetation growing around springs of lime-saturated water. The stones are laid in a mortar made of lime mixed with brown sand quarried nearby. The mortar is poorly mixed, soft and friable. The same type of mortar was used to plaster the walls. Soon afterwards the painter began his work in the choir, painting directly on this ground.

The design was laid out with geometrical precision. The marks of the point of the compasses used to draw the halo and the cranium are visible in the plaster. Investigations of more complete paintings in other churches of the same age in northern Europe reveal strict rules for the proportions between various elements of the design [5].

The figures were first sketched in yellow ochre, later reinforced with red ochre. The yellow lines are scarcely visible against the ground if the plaster is wetted, suggesting that the plaster was set and dry before the painter began. The plaster seems also to have been applied quickly all over the wall, without discernible joins. Parts of the underdrawing, such as the perfect circles of the haloes and the meander patterns, were certainly made with compasses and plucked string. They were unlikely to need revision and were only outlined in red ochre. The main body of the painting was built up from pigments which would have been mixed in various proportions with lime to a creamy consistency. The pigments are red and yellow ochres, calcium carbonate white, charcoal, and possibly red lead, now altered to black lead dioxide. There is also a curious brown colour, amorphous, containing iron, manganese and lead. The paint was applied in varying thicknesses over the coloured ground. The robes of the apostle on the left are entirely in shades of white, made up of different thicknesses of semi-transparent white pigment. The figure of St Peter, on the right, has the fine lines of the drapery defined by white laid over and redefining a broader area of pale red paint. This white, in turn, is overlaid by broader areas of red, as shown

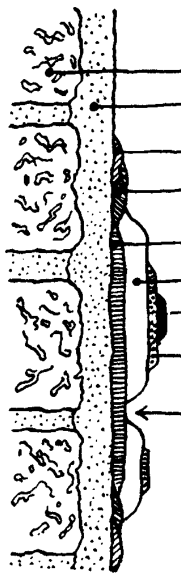

Fig. 2 A schematic section (not to scale) through the wall, the plaster ground and the painting. The section shows how the drapery of St Peter (to the right of the window in Figure 1) was painted, using translucent layers of pigment mixed with lime paste.

schematically in Figure 2. The figures are built up in three shades each of yellow, red and white.

The background is a charcoal black on which are found traces of a copper chloride green pigment. The later paintings in the nave have the green copper chloride, atacamite, as an alteration product of the blue carbonate, azurite [2]. The shadow of the apostle's nose appears to have been painted with a copper chloride green, instead of the green earth traditionally used in southern European paintings of this date. It may well be that the copper chloride is in some places a manufactured pigment, in others a reaction product of copper carbonate pigments with the chloride that is present in the wall.

There is no evidence for the use of an organic binder. The painted surface is very porous and the paint adheres well to the rough ground. The structure is stable but not all the pigments were durable. Only the earth colours survive intact. The yellow, white or red pigments containing lead have all turned black.

The consequence of this widespread alteration of the brightest colours is that retouching such a wall painting can only create an illusory, romantic harmony in a fragmentary picture. It is not possible to recreate an original whose colours cannot now be identified, or to add any information that would not immediately destroy the trust of the viewer in the absolute authenticity of what remains. The colours, with their delineation of form with layers of varying transparency, can only be coarsened by retouching and overpainting. A comparison of the newly exposed paintings on the north chancel wall with the contemporaneous painting on the chancel arch, uncovered and heavily repainted in 1900, shows what has been lost of inspiring, though fragmentary, art through the process of restoration up to modern times.

The painting has been left exactly as it emerged from under the smoke-darkened limewash. There is no retouching, and no consolidation. This might seem irresponsible neglect of a painting from which the pigments rub off on a fingertip passed gently over the surface. In defence of our approach, we shall describe the probable history of this painting and the physical properties of the wall, to show that its porosity and its friability actually contribute to its durability. Many people find this difficult to understand, reared as they are in an age when materials are developed for strength as an intrinsic property, rather than for durability when combined with materials of different physical properties, in a specific context.

3 THE LATER HISTORY OF THE PAINTING

The church originally had a flat ceiling. Around 1448 the ceiling in the chancel was replaced by brick vaulting. Later, the nave also was vaulted. The paintings of both chancel and nave were partly obscured by this major rebuilding. The painting from 1100 was judged worth preserving, though its unity was destroyed by the intrusion of the vaults, because there is a white band on the wall where it meets the vault (see Figure 1). There is a repaired gash in the face of St Peter, probably caused by the carelessness of a builder. The repair was not retouched. This suggests that the facial features were already faint, otherwise the damage to such a focal point in the composition would have been too disturbing to accept without repainting. The covering of the entire painting with whitewash cannot be dated but may well have happened during the Reformation. It is probable, therefore, that this wall painting remained exposed for 400 years before it was covered with whitewash.

4 THE RESTORATION OF THE CHURCH AND ITS HEATING SYSTEM

The removal of the protective limewash exposed the painting once more to accumulation of dirt. Salt efflorescence on other parts of the wall, and the use of Portland cement in earlier repairs, hint at the menace from salt crystallization under the paint. A study of the microclimate of the church was started, to decide how best to minimize the rate of soiling and reduce the risk of salt crystallization. Before describing these experiments, those details of the structure of the church and of the heating system that influence the microclimate are briefly summarized.

The fire had caused so much damage that the interior of the church was completely stripped. The foundation for the new floor is coarse gravel, covered with cement filled with nodules of fired porous clay. On top of this are porous bricks laid in lime mortar. The construction is designed to be open to diffusion of water vapour but resistant to flow of capillary water with dissolved salts.

The earth outside the wall was replaced by coarse gravel, with a drain at the lowest point. The intention was to reduce the amount of water rising in the wall. These two modifications are of doubtful effectiveness because there is still, six years later, abundant water low in the walls, and luxuriant algal growth.

The new heating system consists of electrically heated metal tubes under the benches in the nave. The choir is heated by metal tubes set in two trenches in the floor. The church is usually maintained at 12°C but is rapidly heated for church services, in less than an hour, to about 20°C. The idea behind this temperature regime is that the background heating to 12°C keeps the average relative humidity at a moderate value, below 75%, with the aim of inhibiting mould growth. The rapid heating for services reduces the relative humidity, but for such a short time that the painted woodwork does not have time to respond and the walls do not have time to dry out significantly. Such a heating regime is used in many churches in northern Europe [6].

5 THE MICROCLIMATE

The first result of the measurement campaign [7] was the discovery that the wall is a perfect buffer for relative humidity. The perfect buffering is not immediately apparent in the thermohygrograph record, which shows a fall in RH during the short periods of heating to 20°C. This paradox is explained by the increased temperature difference between the wall surface and the air in the church. Eshøj and Padfield published the evidence for the unexpectedly perfect, and long lasting, relative humidity buffering by the wall in an article [3] which proposed the use of porous walls to buffer the climate in modern museums. In the present article, the authors concentrate on the less agreeable consequence of this buffering process: the stressing of the painted surface through exchange of water vapour with the church interior.

There is one important difference between the RH buffering exerted by porous walls and buffering by other water-absorbent materials. Filling a room with wooden objects will markedly stabilize the RH. Whether or not some of these wooden objects are officially designated as art treasures, they will benefit from the climatic stability they themselves have caused, suffering a smaller individual variation in water content because the load is being shared among many objects. The sentimental distinction between the valuable wooden object and the wooden shelf on which it rests has no meaning in physics: each benefits climatically from the presence of the other. The same argument emphatically does not apply to the walls of Gundsømagle church. The walls contain soluble ions which can change state between solid and liquid during the buffering process. Saturated solutions of water-soluble salts are used in the laboratory to maintain a constant relative humidity. They will crystallize out, while maintaining a constant relative humidity to the last drop of liquid. The constancy of the relative humidity in Gundsømagle church is therefore no guarantee of the stability of the wall painting. We must look for other measurements to judge the healthiness of the climate, or to regulate it for the benefit of the wall painting.

The danger to the wall painting arises during the evaporation phase. The movement of capillary liquid to the surface draws with it salt ions. Evaporation of the water causes crystallization. It is very difficult to find out when, and where, this process occurs, apart from the obvious evidence of visible crystallization. The walls of Gundsømagle church buffer so perfectly that it was impossible, even during times of rapid heating, to discern a gradient in RH at the surface that would indicate the direction of flow of water vapour. In other words, the wall reacts so quickly to changing RH at its surface that it is always apparently at equilibrium. A series of experiments and calculations, described in reference [3], convinced us that the wall is the main RH buffer, and therefore suffers repeated episodes of evaporation and reabsorption during the heating cycles.

It is important to know how water exchange is distributed over the surface of the wall and how it is distributed in the thickness of the wall. The latter measurement is a significant indicator of risk because, if a considerable depth of the wall is involved, the buffering could be achieved by small changes in concentration of salt solution rather than by the drying of a small quantity of solution close to the surface. The authors are interested in the possibility of continuously measuring this vapour movement, with the aim of designing a form of air-conditioning that can minimize the transport of water vapour through the wall surface. The possibility of automatic limiting of the flux by enclosing the painting behind glass is also being investigated. This would reduce the rate of dirtying of the painting, thus solving two problems but raising strong objections from those who do not like looking at wall paintings through glass.

This idea of conserving paintings on the outer walls of buildings by controlling the ambient climate to minimize the vapour flux out of the wall, rather than to assert an arbitrarily chosen RH, is quite radical and immediately presents the simple practical problem that one cannot buy a flux sensor to replace the relative humidity sensor of conventional air-conditioning.

There is also the problem that the wall is not uniform in its reaction to atmospheric moisture. The entire wall is not functioning as a buffer. The relative humidity in the church over the whole year is nearly always higher than the value calculated for outside air, raised to the inside temperature. In other words, the water vapour concentration, as well as the temperature, is generally higher inside the church than outside. There must be a source of water to provide this extra humidity and to replace the loss through air leakage, which is about one air change every four hours. The possibilities are evaporation of groundwater from the floor and the wall, or rainwater penetrating the wall.

Such a relatively thin (800mm), porous wall might be expected to allow diffusion to the interior of rainwater and fog absorbed on the outside surface. The authors studied the record of surface electrical resistance inside and out and concluded that the only occasion on which the inside resistance measurement showed evidence of water penetrating the wall was when the church was limewashed outside, a process that involves thorough soaking of the wall. Analysis of the data suggests that the source of excess water is groundwater evaporating continuously from the lower half-metre of the wall, with a negligible contribution from the floor. Since the ideal is to ensure a slow movement of water vapour into the inside surface of the wall at the level of the painting, this excess water is not entirely a bad thing, although the accompanying ions are a long-term threat to the wall paintings and the lush algal growth at the foot of the wall is an unsightly nuisance.

6 MEASUREMENT OF THE WATER VAPOUR FLUX

Several techniques were used to determine the buffering capacity of the wall, its equilibrium water content at various heights and the vapour flux through the surface.

The equilibrium relative humidity was measured in a cup sealed against the wall. The indicated RH fell as the cup was moved up the wall, from 90% at 250mm to 70% at 2m.

At the same time, the capacity of the wall to absorb water when challenged with air at 100% RH was measured, using the principle of the psychrometer. The apparatus is sketched in Figure 3. Moisture evaporates from the wet cloth into the small

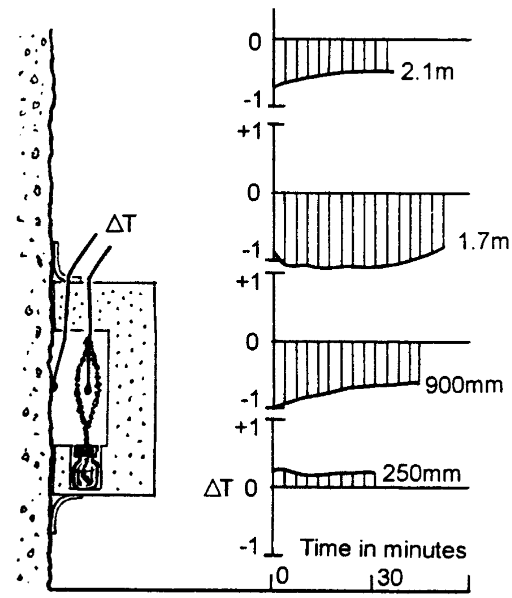

Fig. 3 Thermocouples measure the temperature difference between the wall surface and a wet cloth held close to the wall in an insulated cup. A temperature difference arises through transfer of water vapour from cloth to wall. The graphs show the temperature difference as a function of time at different heights above the floor.

chamber held against the wall. If the wall is capable of absorbing water from the humid air in the cup, the cloth will cool down as water evaporates from it, just like the wet thermometer of a psychrometer. The surface of the wall, however, will warm up, because water vapour releases heat when it condenses into the capillaries of the surface. The temperature difference between wall and cloth in the thermally insulated container is a measure of the rate of absorption of water. By following the temperature difference over a period of time, it is possible to assess the capacity of the wall for absorbing water vapour.

At 250mm up from the floor there was no absorption. The cloth was actually a little warmer than the wall, because of the normal temperature gradient. At 900mm above the floor there was an absorption, shown by the low temperature of the cloth, which warmed up with time, indicating a lack of buffer capacity. This is attributed to a saturated zone just below the surface. At 1.7m there was stronger absorption which diminished more slowly with time. Higher up, on a coarser plaster surface, the absorption was steady but slower. This suggests, reassuringly, that a considerable depth of wall is available for humidity buffering.

Next, we attempted to detect the natural flux of water through the wall at the prevailing relative humidity, instead of at 100% RH. Strips of very thin, impermeable plastic foil were pressed onto the wall. An infrared camera was focused on the wall. The uncovered wall would rise or fall in temperature relative to the covered strip, according to whether water vapour was being absorbed or released. Figure 4 shows the temperature contours around the strip. The lower part of the strip, 250mm from the floor, is clearly warmer, indicating evaporation from the wall. The slight bulge in the temperature contours at the top of the strip hints at a weak absorption of water vapour higher up the wall. One would expect a small signal because the wall area available for humidity buffering is large; therefore the flux per unit area will be small, with a consequently minute temperature difference.

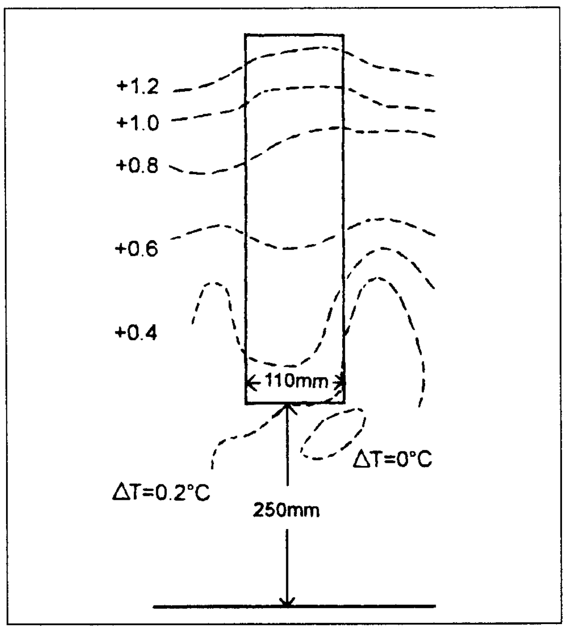

Fig. 4 Temperature difference contours on the wall on and around a rectangular plastic strip which prevents evaporation or absorption of water vapour. The lines join points of equal temperature difference from the coldest point in the field of view, just below the strip. The bottom of the strip is warmer than the exposed wall at the same level, indicating evaporation. Higher up, the wall seems to be absorbing slightly.

The authors attempted to devise a sensor that could be used for continuous monitoring of water vapour flux. The infrared camera was replaced by a differential thermopile consisting of 10 chromel/alumel junctions arranged in series, with alternate junctions resting on the plastic and on the porous wall nearby. The thermocouple wire was 0.1mm thick and bent to follow the wall for about 10mm before each junction, to ensure good thermal contact with the wall. Such an arrangement will measure temperature difference with very high precision. In the laboratory it worked perfectly, being well able to detect the water absorption of a single sheet of writing paper resting on a thermally insulating surface when the RH increased by 5%, at constant temperature, over 10 minutes. It was much less reliable on the church wall because of the varying temperature gradient through the wall during periods of heating and because of turbulent motion of the air close to the wall. This turbulence is discussed further in section 7.

These experiments showed that flux measurement is possible but needs refinement before it can be used for climate control. The sort of control envisaged is a form of heating which can mix direct air heating with heating of porous materials that are normally quite high in moisture content, such as the floor bricks. If the heated floor bricks are in relatively poorly ventilated areas they will regain their lost moisture from the ground rather than from the air. Intermittent heating with humidification would prevent drying of the wall and would give a slight pulse of water vapour into the wall surface during the cooling period.

The alternative conservation strategy, passive control by placing glass close to the painting, also seems quite feasible. A small chamber with an opening of 200mm was sealed to the wall at the height of the painting for 18 months. The climate inside the chamber was close to that in the church, unless the church ventilation was increased from the usual 25% of an air change per hour. The influence of water diffusion from the outside of the wall is very slight, as mentioned earlier. Glazing of the painting should not extend below approximately one metre from the floor, to avoid humidification from the rising groundwater.

The natural movement of water vapour in the church during its long calm periods at 12°C is summarized in Figure 5. The

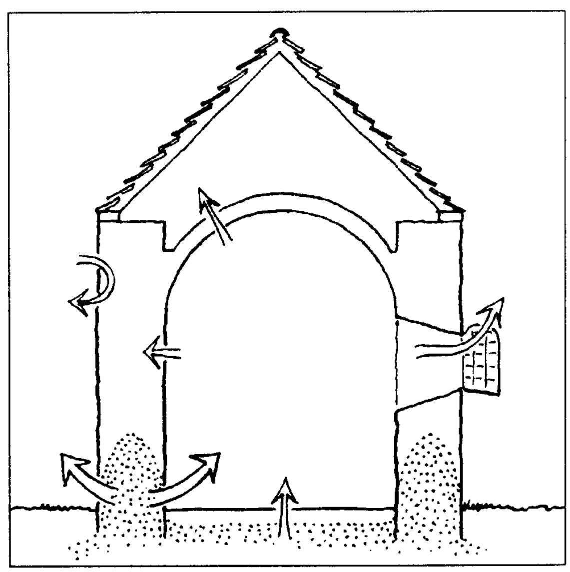

Fig. 5 Suggested water distribution in the church walls (stippled). The arrows show the general direction of water vapour flow during the colder eight months of the year. The measured air exchange with the outside is once every four hours. There is no evidence that rainwater on the outside wall influences the interior climate.

measured stability of RH is the result of competition between the sources and the sinks of water vapour. Quite minor changes in heating or ventilation can alter the direction of water vapour flow through the wall painting, with important effects on the pattern of salt crystallization.

7 HEATING FOR CONSERVATION

The second threat to the paintings in Gundsømagle church is that they will quickly become dirty. Cold walls become dirty through the thermophoretic effect: fast-moving molecules of warm air push small dirt particles towards the wall because the air molecules bouncing back off the wall have given up energy to the cold wall and therefore have less kinetic energy to drive away the dirt particles.

If the air movement is partly towards the wall instead of parallel to it, another effect dominates. Larger particles are now carried towards the wall in the airstream. Their inertia carries them on into the wall as the airstream turns away. The heating system in the church has one bad feature. The warm air rising from the choir floor heater, set 800mm out from the painted wall, pushes aside the denser cool air above and soon breaks into chaotic vortices that brush against the wall, thrusting dirt particles into the porous surface. The process is easily demonstrated by blowing soap bubbles into the rising air, and it was the main cause of instability of the thermocouple flux sensor. The trenches in the floor collect dust which becomes airborne when the heating is started. This is also the period when the temperature difference between wall and air is at its maximum.

Warm air heating should ideally be by laminar flow of warm filtered air injected at ceiling level to replace cool air drawn out from the floor.

The principle of using cool background heating, supplemented for church services by rapid heating to 20°C without humidification, is not good for wall paintings because it provokes a rapid and efficient RH buffering that dries the surface of the wall. It also causes condensation on poorly ventilated or unusually exposed or massive parts of the structure because the parts of the wall that heat up fast increase the water vapour concentration in the air, thus raising the dew-point. Condensation was observed at the base of the wall in Gundsømagle church early in the heating cycle during cold weather, suggesting that condensation as well as capillary rise of groundwater contributes to the dampness of the lower wall.

8 DISCUSSION

As conservators, we tend to regard the RH of the air in a room as the cause of, rather than the result of, change in water content of the materials in the room. If we look at the steady RH record in the church, it seems that all is well. If we look instead at the evidence for water movement in and out of the wall surface, the situation is more disquieting.

If one boils a litre of water in a submarine, where almost every surface is metal, the RH rises fast. There is a very slight accumulation of water on the metal surfaces, but the increase in rate of corrosion caused by this microscopic layer of conductive liquid is dramatic. Many litres of water could be boiled in Gundsømagle church without measurable change in RH, but the water is invisibly moving through the wall surface, and carrying water-soluble ions with it. In such a situation it is more important to measure, and then control, the water vapour flux through the wall surface than to maintain an arbitrarily chosen value of relative humidity.

In Gundsømagle church the permeability of the wall is adequate to ensure a small water vapour flux per unit area. If, however, the wall is covered with impermeable paint or varnish, or even a compacted plaster, the unevenness, cracks and faults that inevitably develop will channel this movement of water so that the salt ions will concentrate in particular places. There they will begin to crystallize and push off the outer layer of the wall, causing further unevenness in the permeability of the wall.

The authors present two linked principles in the conservation of porous wall paintings on the inside surface of outer walls: the pore structure should be kept as open as possible and the room air should be maintained at a water content that ensures a slow movement of moisture into the surface and towards the outside of the wall.

REFERENCES

1 Haastrup, U., 'Nyfundne kalkmalerier fra 1100-25 og o. 1275 i Gundsømagle kirke' (Newly discovered wall paintings from 1100-25 and from about 1275 in Gundsømagle church), *ICO: Iconographisk Post* (Nordic Review of Iconography) 2 (1989) 1-20.

2 Bøllingtoft, P., and Christensen, M. Chr., 'Early Gothic wall paintings: an investigation of painting techniques and materials of 13th century mural paintings in a Danish village church' in *ICOM Committee for Conservation 10th Triennial Meeting*, Washington DC (1993) 531-535.

3 Eshøj, B., and Padfield, T., 'The use of porous building materials to provide a stable relative humidity' in *ICOM Committee for Conservation 10th Triennial Meeting*, Washington DC (1993) 605-609.

4 Græbe, H., Hansen, B.A., and Stiesdal, H., 'Gundsømagle kirke. En bygningshistorisk undersøgelse' (A study of the history of the building) in *Nationalmuseets Arbejdsmark*, National Museum, Copenhagen (1990) 141-156.

5 Bøllingtoft, P., 'Undersøgelse af metoder og materialer i romanske monumentalmalerier', thesis, School of Conservation, Royal Danish Academy of Fine Art, Copenhagen (1992) (unpublished).

6 Künzel, H., and Holz, D., 'Richtiges Heizen in historischen Gebäuden', *VDI Berichte* 896 (1991) 121-137.

7 Eshøj, B., 'Klimaundersøgelser i Gundsømagle Kirke', thesis, School of Conservation, Royal Danish Academy of Fine Arts, Copenhagen (1993) (unpublished).

AUTHORS

Tim Padfield, born 1937. MA from Oxford University (chemistry). Now head of the laboratory of the Conservation Department of the National Museum of Denmark. Main interest: conservation of buildings and their contents through close study and subsequent control of the microclimate. Address: Conservation Department, National Museum, Brede, 2800 Lyngby, Denmark.

Peder Bøllingtoft was educated as a conservator at the School of Conservation of the Royal Danish Academy of Fine Arts. He is now a conservator of wall paintings at the National Museum of Denmark, specializing in the Romanesque period. Address: as above.

Bent Eshøj, born 1952. Conservator. Teaches technical museology and the repair of glass, ceramic and stone at the School of Conservation of the Royal Danish Academy of Fine Arts. Address: School of Conservation, Esplanaden 34, 1263 Copenhagen K, Denmark.

Mads Chr. Christensen received his degree in chemistry and biology from the University of Odense, followed by research in organic synthesis. Since 1981 he has taught chemistry at the School of Conservation in Copenhagen. Address: as above.