Rock Art Preservation: Improved and Ecology-based Methods can give Weathered Sites Prolonged Life

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Rock art is defined as systematic and man-made depressions or paintings on a smooth rock surface. In contrast to other cultural monuments, they have hardly any ecological importance. Nevertheless rock art sites should be regarded as a part of the landscape, both with respect to interpretation and preservation. The method of gluing together fragmented rock art panels with an organic glue, and the repairing of cracks on rock art panels by mortar, are criticised. The author raises doubts about the 'crumbling effect' of mosses and the effect of 'aggressive lichen', postulated by other authors. The need for a long time perspective and international co-operation in rock art preservation and conservation is underlined, and it is emphasized that experiments with new methods of conservation should be done on panels without rock art. Based on observations of an accidentally covered rock art panel in Gudbrandsdalen, Norway, a new and reversible method for stabilisation of severely weathered rock art panels is proposed, using dissolved calcium carbonate which is precipitated in a calcification process on the weathered rock and in cracks.

ROCK ART SITES AND THEIR SURROUNDINGS

In an interesting paper in NAR two years ago, Bradley et al. (2002) conclude that 'If rock art research is to develop further, it may be just as important to study the rock as to investigate the art'. From rock carvings in western Sweden, Nash (2002) argues that the change between wet and dry parts of the panels could represent a map of the landscape, divided into a marine and a terrestrial part. Ross (2001) proposed that future work on rock art should be landscape-based, and in the book *European Landscapes of Rock Art* Nash (2002) this view is also emphasized.

I fully agree with the views presented above when speaking about interpreting and understanding rock carvings, but I want to go considerably further. It is not only the geology of a rock art site that should be taken into consideration when the rock art is discussed as a cultural monument. The whole environment should be taken into consideration, not only in discussions of understanding and interpretation, but especially when dealing with rock art preservation. To explain this a few definitions are necessary. From a technical point of view I will define rock art as 'systematic and human-made depressions or paintings on a smooth rock surface'. This definition excludes glacial striations and natural cracks and grooves. From an ecological point of view, rock art can be defined as 'unessential man-made furrows or paintings on a smooth rock surface, and with no or only quite minimal and unimportant influence on the environment.' (Fig. 1). Rock art constitutes a clear contrast to other parts of the cultural heritage. An ancient ruin, a historic building or just an old stone fence produces marked differences in microclimate, access of nutrition, exploitation, sun and shadows, offers new opportunities for shelter and nesting, etc. Such monuments change the environment markedly, and in contrast to rock art allow the establishment of new species and changes in floral and faunal societies.

Ross (2001) describes the changing trends of rock art interpretations and refers to many researchers who underline the importance of including the nature and environmental factors of a site into the interpretation. If for example the rock art site itself had a shamanistic value, surely this was also the case for the nearby environment. 'Without knowledge of the landscape, and without situating the rock art in relation to the features of the rock and the landscape, we cannot fully understand and interpret informed sources such as ethnography and histories. Rock art is fundamentally based in the land'.

Fig. 1. The rock art itself has no or quite minimal ecological influence on the environment, but should be interpreted and experienced within the natural frames given by the landscape. The author is here standing behind a rock art panel at Ausevik, Florø, Sogn og Fjordane, W. Norway. Photo (2003) O. Holm Pedersen.

Ross (2001) concludes further that ‘By contextualizing rock art within the landscape and incorporating the dimensions of movement, sound, touch and other states of consciousness into our interpretation, we move closer and closer to recreating the world of the hunter-gatherers, and thereby closer and closer to understanding the messages they left behind.’

This brings a new element into the preservation of rock art. Not only should the art itself be curated to reflect the original intention of the engraved signs and figures, but also the environment should be treated as an important part of the magic or imaginative value of the site. Then, the fundamental question is how to treat the vegetation. There are three vegetation categories to consider: actual vegetation, original vegetation and potential vegetation. Actual vegetation is that found *in situ* today; original vegetation is the vegetation before it was influenced by man, especially by agriculture, and potential vegetation is the final succession phase, if the site is protected from modern human influence and can develop freely. It is worth noting that due to changes in soil, climate, etc, it is not probable that the final-phase potential vegetation on a site left to develop freely will be identical to the original vegetation. Many Norwegian rock carvings are today surrounded by a dense wood of Norway Spruce (Picea abies), which is a climax vegetation, but totally unknown at the time when the rock carvings were made. It should also be strongly underlined that treatment of the actual vegetation in order to transform it into the natural vegetation that existed just some generations ago, involves hard work, considerable funding, great patience and skill, and a long time perspective (see Norderhaug 1999). An even more challenging task arises if the aim of treatment is to recreate vegetation present some thousands of years ago.

This view stands in contrast to the management of Norwegian rock art sites as it has been carried out in the last decades. Vegetation has often been considered as noise and disturbance around the site and cut down without reflection. Lichen has been removed by chemical agents, leaving large light spots on the rock (Fig. 1 and 6). The main management aims have been restricted to making access more easy, improving the working conditions when making registrations and drawings, improving the visibility of the rock carvings for visitors, and avoiding physical damage to the carvings from roots, etc. This is to degrade the value of the site as a prehistoric place of importance. If the rock art is likely to have been located in direct connection with trails and paths these structures should be visible and maintained in a proper way at the site. If the carvings on a steep seashore rock panel, like some of the carvings at Austre Åmøy, Stavanger, Rogaland, have had a function for people paddling along the beach, then the rock art should not be covered by dense wood. Such issues have not been discussed enough, and have been suppressed by the more frequently asked question: ‘How far can we come, during just a few hours, in cleaning up this messy and overgrown site?’ The particular problems connected to the vigorous lichen growth on many Scandinavian rock carvings will be treated in a later section.

Given a rock art site with a stable natural vegetation on the carvings and in the surrounding environment, the site can, as already mentioned, be defined in two contrasting ways: as a unique piece of cultural heritage, or as a natural spot with some shallow furrows or paintings on the rock, and of quite unimportant ecological importance. This is a great challenge for preservation and conservation, but there is a possible way forward: to be patient and humble, not to perform pioneering and irreversible experiments directly on the rock art panels, to treat the environment in agreement with ecological principles, and to develop a sustainable and stable vegetation around the rock art. In the following sections I will present some unsuccessful experiments and ideas from the pioneer phase of Norwegian rock art conservation, and propose a new method of preservation for the most weathered sites.

NO GLUING OF WEATHERED ROCK

The use of a glue-based on synthetic resin (commercial name Mowilith) for stabilising and gluing heavily weathered rock carvings together should not be continued. The method was developed at The University of Bergen by Kristen Michelsen (Michelsen 1992), and is later in this paper referred to as the Bergen method.

I will spend a little time discussing the main publication by Michelsen on the Bergen method, because it can give an insight into the serious problems which come up when a few workers in a small academic discipline, in a short time and with limited funding, attempt to make rapid progress in a narrow field within the generally very difficult preservation of rock art.

According to Michelsen (1992:17), a rock art project was initiated in 1981. After searching in vain for relevant literature on the subject, Michelsen realized 'that I would have to start my research from the very beginning. I considered to withdraw from the project because the available financial support seemed ridiculously low, in the view of the outlay for laboratory equipment, the running expenses and the technical assistance needed. Nevertheless, after further consideration I decided to continue the work but from a different angle. I now had to face the problems from a less scientific point of view, concentrating on the practical treatment of the stone, while simultaneously performing laboratory investigation to the extent this was possible within the limits posed by economy and time.'

Michelsen (1992:17–18) later admits that 'The registration carried out during the first years of the project was, I am sorry to say, not completely satisfactory'. In this phase rock samples were brought to the laboratory, and 'defects and conditions causing destruction of the rock art were discovered'. According to Michelsen these problems should have been discovered in the field, but were not, and this was due to lack of training.

The first attempt with the Bergen method was not done after thorough experimentation on panels without rock carvings. Michelsen (1992:28–29) writes:

'When we in 1979 were doing some work at the rock art site at Ausevik, we noticed that a group of figures had loosened in small flakes with a thickness of about 15 mm. Since the figures were already destroyed it was found permissible to do a panicky experiment. The only adhesive we had brought with us in our field equipment was an emulsion meant as an additive to cement mortar to make it more plastic and give better adhesion. It was raining cats and dogs, and the rock was saturated with water. The glue was poured on the rock undiluted, and just left. Two months later, the site was revisited, and to our great surprise, all loose pieces were properly stuck to the sound rock, and the area felt hard and solid'.

This 'panicky experiment' was later supported by a short and limited testing in climate chamber and 'the effect of the glue on the rocks in question found most satisfactory'. Later the Bergen method also was taken into use on the siliceous sandstone at Vingen (Michelsen 1992:29). It is noticeable that the first experiments were carried out with undiluted glue, but later Michelsen writes 'the glue can be used in quite thin solutions. A 10% solution seemed to be ideal for impregnating pores. For binding stones with coarser cracks, the concentration of the glue solution should be increased'.

The method for using glue based on synthetic resin like Mowilith, developed in 1979 by Michelsen (1992) and later used at the University of Bergen, is against all rules for gluing materials together. According to Bjelland et al. (2001), the glue was first sold, under the commercial name 'Trana Weld', as an emulsion of vinylchloride and different stabilising agents. Later vinylacetate was also added. The product can today be bought as Mowilith DM 123.

Mowilith can be compared to the glue frequently used for gluing wooden structures. They are both based on synthetic resin, have a white, viscous appearance, and are initially water-soluble. After relatively short contact with air they make a very strong, irreversible and waterproof connection. However, some basic rules for gluing had to be followed:

- For full strength the glue should not be diluted. In the case of rock stabilisation the Mowilith has been diluted to as much as only 10% of original strength (Michelsen 1992:29).
- Objects to be glued together should have the same properties, for example different types of wood should not be glued together due to different shrinking with varying humidity. In the case of rock art, an eroded and porous, and sometimes crumbled layer of weathering crust has been glued to the underlying compact and stronger rock. At Ausevik the actual geological structure of the weathered crust has a marked tendency to disintegrate into small, rectangular or elongate fragments (Fig. 2). It is unrealistic to believe that this outdoor complex of geological matchboxes, exposed to heat and frost, sunshine and water, can be stabilised by strongly diluted organic glue based on synthetic resin. When I visited Ausevik in 1997 the treated areas apparently seemed to be stable, but it was a shock to revisit the site in September 2003. Considerable areas of the rock art panels were unstable and the panels that had been treated in 1979 and later had already been ‘reconsolidated’ by new addition of glue, and traces of old glue was visible. This has also been the case in Vingen (see Fig. 3). In my mind an irreversible conservation lasting for less than 20 years is not at all acceptable when dealing with rock carvings some thousands of years old, and a unique cultural heritage. By advanced chemical methods organic substances like blood and bees wax from rock paintings can be detected (Williamson 2000, Dalmeri et al. 2002) Spillage of organic chemicals like glue can also damage the possibility of chemical analysis of rock carvings, now and in the future.

Fig. 2. The rock carvings at Ausevik are made in a strongly weathered crust with numerous vertical cracks, and rock art panels have a tendency to dissolve into loose fragments. Since 1979 curators have unsuccessfully been trying to stabilise the weathered crust by gluing loose rock fragments together, and towards the underlying rock, using irreversible, organic glue. Photo (2003) O. Holm Pedersen.

- The joint between two objects glued together should be as narrow as possible to give maximal strength. However, there is a difference between one-compound glue, which shrinks when drying, and two-compound glue, which hardens through a chemical reaction without shrinking. Unfortunately the glue used on rock art shrinks, and thus, especially when used diluted, leaves cavities when drying in microscopic pores. These cavities are later accessible for water penetration and frost wedging.

Fig. 3. Unsuccessful experiment with gluing loose exfoliation crusts at Vingen, Bremanger, W. Norway, by use of a glue containing Mowilith. The crust has loosened and a whitish-glossy layer of hardened glue is visible in lower part of the picture. The cracking effects of thin herbaceous roots are also visible. Photo (1997) S. Bakkevig.

- In normal gluing procedures the application of glue should be completed rapidly, for wood within 10 minutes, and then the material should be put under strong pressure, to make the glue joint as narrow as possible and to avoid movement during hardening. In the Bergen method Michelsen (1992:30) mentions repeated application of diluted glue for as much as one hour. Even if the surface is kept wet, this time-consuming procedure introduces a great risk of partial hardening of the glue in difficult accessible areas under the surface, and before sufficient glue is applied.

- The surface of the two parts glued together should be strong, fresh, and absolutely clean. In a demonstration at Vingen in 1997 Kirsti Hauge Riisøen and her team from the University of Bergen used diluted Mowilith, which was injected in cracks by a syringe with a thin nozzle, in order to stabilise exfoliation in the rock with carvings on the surface. When an exfoliation has developed, it is obvious that the walls of the crack are not strong, nor fresh, and by the nature of its origin unclean and impossible to rinse through the narrow crack. Also, at Vingen several of the exfoliated areas treated with glue were unstable already on my visit in 1997 (Fig. 3), and restabilisation with Mowilith has been carried out repeatedly.

A report from the University of Bergen about the work on rock art at Vingen and Alta was published in 2001 (Bjelland et al. 2001). One would expect to find some conclusions about the use of glue according to the Bergen method in this report, which is about 20 years after its first application. This is not the case, but it does state that the first, 20-year-old treatment with Mowilith of rock art surfaces 'apparently looks acceptable'. However, a new panel for testing Mowilith was established in 1998, and this time, 19 years after the first test directly on rock art panels at Ausevik (Michelsen 1992), the test panel selected at Vingen are now without rock carvings (Bjelland et al. 2001:130–131). This seems to indicate that there are problems with the Bergen method, and it is regrettable not to get full information about this in the report.

MORTAR FILL IN CRACKS: PROBLEMS AFTER A FEW YEARS

With various and normally limited success different types of mortar have been used for closing larger cracks in rock art panels. It is regrettable that this experimentation repeatedly has been done directly on different rock art sites, without enough experience from test sites without rock carvings. Normally the repair looks satisfactory immediately after the work is done, but after a few years problems appear. They commonly are:

- The edges of the crack become weak, weathered and dirty, and cannot be cleaned sufficiently. The basis for a strong bonding between applied mortar and the rock surface is then not present, and in general the transition becomes a weak point.
- Cement based mortar is delivered in different qualities. Some types of mortar shrink when hardening, thus pulling particles from the cracked walls, and making new cracks.
- Some mortar expands when hardening. Even if this expansion is limited, the force of expansion is very great, which may result in the crack widening, thereby providing access for water.
- Most of the mortars have to be repeatedly showered by excess water and kept wet for some time, after the first hardening. This often takes place long after the team has left, and if mortar is left to dry in sunshine and dry weather, it will not reach sufficient strength.
- A well-known phenomenon in the concrete industry is swelling. Since around 1980 it has been known that certain qualities of concrete contain substances that react with water and produce a kind of jelly, which increases the volume of the concrete. It is mainly connected to the surface of the concrete, and causes the concrete to expand and crack.
- It is desirable to use a mortar or concrete with about the same colour and texture as the surrounding rock. This should be done by colouring the mortar before application. Covering a light grey mortar with a thin layer of mortar coloured by iron oxide and similar substances, and mixing with material from the rock in question, has not been a durable solution at a rock art panel at Åmøy, east of Stavanger.

My main impression after observing several attempts with mortar and concrete filling of cracks in rock art panels in Norway is that they remain stable for far too short a period of time, often considerably less than 20 years. They then become eroded, cracks appear, and they turn light grey and unsightly (Fig. 4). With respect to frost cracking it may be better to have one large open crack, than two narrow cracks, one on each side of a shrinking mortar filling. It is strongly regrettable that thorough and long-term experiments not have been undertaken either outside the rock art sites or in climate chambers, before application of this method directly on rock art sites. Based on my observation of unsuccessful repairs of cracks in different types of rocks and in different parts of Norway, and also abroad, I think it will be very difficult, maybe impossible to develop a fully satisfying mortar for cracks in rock art sites. A fresh mixture of sand and different hardening agents must in a few hours or days harden, and then for hundreds of years withstand leaching, and behave exactly like the surrounding massive rock, which has a quite different morphology, is millions of years old and perhaps has a weathered crust which is 13 000 years old. Is the use of mortar a sidetrack in rock art conservation, which in coming decades will be regarded with great regret?

This chapter also illustrates a problem often observed in rock art preservation: a serious lack of the correct long-term perspective and ethical considerations, especially concerning irreversible preservation techniques. The lack of a long-term perspective could clearly be seen in the major INTER- REG-project. In a final report much attention is directed towards the background and the present, but there are only a few pages on the future (Kallhovd & Magnusson 2000). Eight years after it began, the large Norwegian project *Sikring av bergkunst* (The Norwegian Rock Art Project), under the charge of Directorate for Cultural Heritage, seems to be a great success with respect to documentation, research and maintenance for about 300 of the most threatened Norwegian rock carving sites. However, two years before this important project is finished and the budget is emptied, long-term perspectives have nearly been absent in the plans (Riksantikvaren 2003:16, see also Hygen 2000). When the year 2006 begins we have ten years of valuable experience, but where are the people and the money for future and long-term maintenance? Let us sincerely hope that the Norwegian Rock Art Project will represent a new and permanently better phase for the rock carvings of Norway, lasting into future, and not just a short, 10-year glimpse of hope.

Fig. 4. *Unsuccessful use of mortar on the rock art site Bakke I, Jondal, Hordaland, W. Norway. The mortar has begun shrinking and cracking in less than 20 years. Photo (1998) S. Bakkevig.*

On the subject of ethics, there is undoubtedly the best intention in filling a crack close to a rock art panel, but what about the future? Let us assume that the rock carving itself lasts a further 2000 years. If a mortar fill lasts for, say 20 years, it have to be replaced 100 times during the life span of the carving, and the work will be done by perhaps nearly 100 generations of curators, probably all with their own opinions of how the work should be done, and with changing and different products available. From an ethical point of view, is it appropriate to start a practice on rock carvings that is not sustainable in the long term?

INFLUENCE AND TREATMENT OF MOSSES

It is well known that trees and shrubs, which have secondary annual growth in their roots, have the force to penetrate and crack rocks. This makes them very dangerous in near contact with rock art panels, especially when the rock is weakened by natural erosion. When maintenance of rock art in Rogaland is carried out by Arkeologisk museum i Stavanger, great attention is therefore paid to the removal of ligniferous roots (Walderhaug & Bakkevig 1999, Bakke et al 2002). At a rock art site at Berge, Strandebarm, Hordaland, roots of an ash tree have made several cracks in large blocks and pressed them 10–20 cm apart (Bakkevig 2002b:46).

Can even mosses have dangerous effects on rock panels? In a chapter about ‘weathering caused by plants’ Michelsen (1992:21) presents a fundamental misunderstanding which I fear may have later been kept alive uncritically by other authors: ‘mosses have the ability to make the rock crumble, and it is alarming to note the large amount of sand- like, crumbled rock which will follow when a tuft of moss is removed from a rock panel.’ In my opinion the truth is that mosses do not have the penetrating roots of higher plants, which is a basis for a stable water supply. Neither do mosses have strong and penetrating roots like shrubs and trees, in which both the trunk and the roots grow by annual rings, and thus have the force to a cleave or crumble rock. Mosses only have weak rhizoids, which fasten the mosses to the ground. Rhizoids are long, simple, tubular cells resembling root hairs. It is unrealistic to expect these rhizoids alone to have the power to make the rock crumble. Here Michelsen mixes the observed effect and the acting agent. The crumbling of the weathered surface layer of a rock exposed to a rough climate for say 13 000 years is a well-known geological process, irrespective of whether or not the surface is covered by mosses or lichens (cf. Walderhaug 1998, Walderhaug & Walderhaug 1998). The surface layer becomes weathered and porous and finally a crack parallel to the surface can evolve, at different depths depending on the type of rock. In this phase the rock can crumble, but not by the action of mosses alone. In addition, the sand from a naked rock surface normally gets washed away by rain and the force of gravity. The luxuriant growth of mosses often observed on such ‘crumbled rocks’ is simply a result of the rock being more porous than a less eroded surface, and thus having better capacity for storing water necessary for the growth of the mosses. And when a colony of moss is living on a ‘crumbled rock’ it will retain the sand grains which otherwise naturally loosen continuously from the surface. Accumulation of sand between the ‘roots’ of the mosses is thus no indication of the ‘crumbling power’ of mosses, just of their accumulation power.

Ecologically, the amount of moss growth on a rock art panel is a direct function of substrate and climate, and in particular humidity. The most commonly observed problem is either some water seeping over the panels or shrubs and trees casting shadows and causing a humid microclimate, which favours moss growth. Many curators have experienced that mosses on such panels seem to grow up again as soon as they are removed (See e.g. Bjelland et al. 2001). The use of herbicides will not give any long-term effect, but can have some undesirable side effects, and is not recommended. Here it is of vital importance to understand the difference between mosses and higher plants such as grasses and flowering plants. The latter have a stable water supply by an extensive root system, but mosses have no real roots, and get their water through the leaves, from humid air, precipitation and running water. Mosses, in contrast to higher plants, survive in dry periods by becoming totally dry, and, most importantly, without any growth.

So the art of eliminating moss on rock carvings involves establishing drought conditions as far as possible by removing shrubs and the lowest branches of large trees in order to get more air circulation and sunshine, and removing turf and other vegetation in cracks and grooves, which can act as a water reservoir for the mosses.

Mosses can collect organic litter to a much larger extent than crustose lichens, and even if both play an active part in a succession with gradual soil formation, mosses play a much more active role. Mosses should be removed from rock art panels in early spring, before they produce sporangia with millions of spores, which later in the year could exploit the remains of removed moss and litter as a perfect seedbed for new growth.

AGGRESSIVE LICHENS?

First, a few words are necessary about rock carvings and lichens in Scandinavia. Unlike rock carvings in dry locations in other parts of the world, the rock carvings of Scandinavia, especially those located in the coastal areas of Norway, are often found on panels with luxuriant lichen growth. Normally the rock surfaces are totally covered by lichens, making the original colour of the rock visible only when the lichens are chemically removed (Fig. 5). The furrows of Scandinavian rock art panels have at many sites traditionally been painted, a different curatorial practice compared to most sites outside Scandinavia. This is a practice that has often been criticised by rock art experts from other countries. However, the criticism frequently directed at Scandinavian curators and their ethical judgement may partly be due to an insufficient knowledge of the local ecological and geological factors. In addition to a cover of lichen and also partly mosses, Scandinavian rock carvings are often found on rock panels that are relatively uneven, weathered, and with cracks and glacial striations. Accordingly, they are more difficult to study both for scientific purposes and for the public. This is an important difference compared to, for example, rock carvings in Australian or American sandstone, which in addition are mainly free from lichens.

From time to time tourists have scratched on unpainted Norwegian rock carvings in order to make them more visible. At the site Bru on the island of Rennesøy, Western Norway, low visibility of rock carvings has led to catastrophic results. Beautiful carvings of two ships were re-chiselled in the intention of making them more visible (Bakkevig 2002b:50). By making them more visible by painting or by emphasizing the contrast between a light lichen free furrow and the greyer surroundings, this destruction of the original prehistoric rock art could probably have been avoided.

Fig. 5. *When all vegetation, in this case lichens, are removed, it becomes more difficult to regard rock art as a part of the landscape. The naked rock only visible where the lichens are removed is here so light that if just the lichen in the grooves had been removed, the rock carvings would be easily seen, even without painting. Photo from Alta, Finnmark, N. Norway (2003) S. Bakkevig.*

My suggestion of cleaning only the lichen growing in the furrows of a figure must be seen as a compromise between optimal preservation and visibility. Painting is a similar compromise. However, the important difference is, to my mind, that paint, especially when thick and long lasting, over a long period of time can actually reduce the relief by delaying deterioration in the furrow relative to the surrounding panel. Seen with long-term geological perspective, we thus may be contributing to a reduction in the life span of a figure by continuously painting the furrow. The opposite alternative, to paint the surroundings and not the furrow, would obviously be better in theory, but not accomplishable in practice.

In connection with the maintenance and conservation of rock art, lichens have mainly been described as a negative factor. Many archaeologists have seen lichens from a negative viewpoint, as they make observation of the rock carvings more difficult, and are suspected to be responsible for etching and penetrating the rock surface.

Concerning the effect of lichen on rock art panels Michelsen (1992:21) writes: 'The actions of the different lichens differ very much. In most cases the lichens seem to leave an etched surface, but some species attack the rock quite seriously.' This short statement without further documentation is in agreement with Bjelland (2002). In her doctoral thesis Bjelland measures the depth of leaching in solid rock and finds a correlation between lichen species and depth of leaching. In particular, the lichen Ophiopharma ventosa is frequently found where the leaching is most extensive and Bjelland therefore concludes that this species is 'aggressive'. Her belief is strengthened by the fact that hyphae from the 'aggressive lichen' Ophiopharma ventosa penetrate more deeply into the rock, and are considered to be partially responsible for the dissolution of calcite and other minerals in the rock. As far as I can see Bjelland does not have a convincing evaluation of the opposite hypothesis, which should be tested: can the observations, which obviously are correct and well documented, simply be a result of different ecological demands of the lichen species? And can one lichen species be expected to live for such a long time on exactly the same spot that the rock beneath is influenced? Rock is not homogenous, and over short distances the mineral and chemical constitution of the rock can vary considerably. Can the explanation be that the 'aggressive lichens' simply prefer the most weathered rock, or are better able to compete on this substrate than other species? Bjelland has examined the underlying rock and found no differences in the rock constitution (Bjelland 2003) and therefore concludes that the areas of most severe weathering is due to Ophiopharma ventosa. Any short-term effect, for example within the life span of a certain lichen colony should here be ignored. The conclusion presented by Bjelland is accordingly only valid if she can document that the mentioned 'aggressive' species actually has grown in the exact same spot for thousands of years with its supposed etching activity, and with less aggressive species as fully stable neighbours all the time. This of course cannot be documented, nor is it likely. Actually, all stone surfaces in Vingen are overgrown by lichens, in dynamic competition to each other, and Bjelland has not found any reference spot without lichen (Bjelland 2002).

The possible negative effects of lichens are difficult to prove in vivo because of the long time span involved. No one has kept half of a rock panel systematically free from lichens for say 100 years and let the lichens grow freely on the other half, and then studied the difference. Wilson & Jones (1983) describe the weathering effects and etching of minerals under lichens. They explain this by the occurrence of crystalline organic salts in the lichen thallus, and oxalic acid, which is produced by the lichen; but again the authors do not compare this to the normal abiotic mineral weathering on sites without lichens. Wilson (1995) finds no obvious proof for lichen being responsible for weathering of the rock, nor is weathering proved to progress faster where lichens are present.

The need for quick results has led to in vitro experiments with lichens. An exact amount of mineral grains have been put in a suspension of finely grinded lichen thallus, which liberates organic acids, such as oxalic acid, in the lichen, and after some time the mineral grains are observed and weighed (Iskandar & Syers 1972). It is no surprise that such experiments show a slight etching effect on the minerals, but how relevant is this when the actual situation is a living organism on the rock, where the juices of the cells are meant for internal activity, not for etching the rock? Lichens mainly get their nutrition from the precipitation and running water, not through active roots. In fact the lichen does not have roots in a normal botanical sense, just weak hyphae fastening the lichen to the rock. A simple experiment shows my scepticism to *in vitro* experiments on the etching of rock by lichens. Put a whole and fresh lemon on a marble plate for a week and nothing happens. Then grind the lemon and lay the pulp on the same marble plate, and you will have a marked etching in less than one hour.

I thus strongly doubt that lichens significantly enhance weathering of rock art. The term 'aggressive lichen' is misleading, and probably merely indicates a preference for strongly weathered rock. If lichen has a weathering effect it is likely to be very small, compared to other factors influencing the rock, like freeze-thawing cycles and other types of abiotic weathering. When a loose, sandy and etched surface appears when crustouse lichen is removed, this just indicates that weathering is a continuous process, and when the loosened mineral grains cannot continuously be removed by rain and other agents on an exposed surface, they will simply accumulate under the cover of lichen. As a pioneer coloniser of a rock, lichen will also attract other organisms and litter which, when decomposed, can produce weak acids. In reports about the etching effects from organic acids it is normally not clear whether all the acids originate from the lichen or from in part other sources, e.g. litter.

On the contrary, several positive effects can be expected from the growth of lichen on rock art panels. A stable cover of crustose lichen can be regarded as a self regenerating, elastic and shock adsorbing rubber painting which reduces the friction, keeps weak surface particles together and protects the rock from wear. A simple test can demonstrate this. Brush a flat rock surface covered by crustose lichen clean, use a rough shoe meant for mountain hiking or similar, put most of your weight on one leg and turn the leg 90 degrees back and forth a couple of times. Measure the amount of loosened particles: probably most of it is lichen fragments. Repeat the same procedure on a similar rock surface without lichen and note the difference! Without the friction reducing and damping effect of lichen the shoe will tear away easily measurable amounts of rock fragments.

Lichen, especially when dry, can have a small isolating effect when the rock is exposed to temperatures below zero, and thus delay freezing of the rock surface. Wet lichens retain water, and because freezing of water requires energy, nature first has to spend energy and time on freezing the wet lichens. Only afterwards can the frost penetrate down to the vulnerable rock surface. These two phenomena are of little importance in strong frost, but can have a certain positive influence in a mild climate, where the temperature often oscillates around zero. This is a typical situation on the coastal sites of Norway, and has been documented at the Vingen site (Bjelland et al. 2001). According to Walderhaug (1998) freeze-thaw cycles are an important factor for the weathering of rock art sites. Frequent freeze-thaw cycles are observed at Vingen, but in later years they have been less frequent, due to a generally milder climate (Bjelland et al. 2001).

Another positive effect of lichen coverage is the possible depression and smoothing of the freezing point by substances from the lichen. Lichen growth is, like for all other living organisms, a balance between growth and decomposition. Parts of the thallus and hyphae attaching the lichen to the rock is subject to death and decomposition, and substances can be leached from the living organism. In this decomposition different chemical substances are produced. Other microorganisms and insects under the lichen and in small cracks beneath are also in turn decomposed. According to Wilson & Jones (1983) organic acids like oxalic acid can be observed under the lichen. When water freezes even small impurities can have a very marked effect on the freezing process. Pure water freezes at a very exact temperature, 0°C, and has a very strong expanding power when freezing. However, small impurities in the water cause the water to freeze gradually, and over a range of degrees somewhat below zero, and the expanding effect is decreased or eliminated. Just 35‰ salt in sea water has a similar effect on ice. Transferred to lichen, even if some authors claim that the acids found beneath lichens cause etching, the same acids and organic substances can, by acting as a frost-preventor, slightly reduce the risk of rock being weathered by frost. Again this phenomenon, even if it is a small factor, will have the greatest importance in moderate frost, by actually depressing the freezing point a little, and thus avoiding some freeze- thaw cycles, and next by reducing the expansion power of freezing ice at lower temperatures.

Tratebas & Chapman (1994) have produced a brief review of the relevant literature and suggest that the nature and extent of damage caused by biochemical weathering is problematic, and that lichens do not always cause surface weathering. Further, assessing the effects of lichens on petroglyphs should be specific to each site. They also make the significant statement that 'experiments should have been conducted first on rock surfaces that lack petroglyphs. Experiments should never be conducted directly on unique and highly significant rock art and should never include the entire known sample of glyphs at a site' (Tratebas & Chapman 1994:129–131). It is also important to report in detail which type of chemicals have been used, and in which concentrations. Further 'some panels should be saved from chemical contamination for future dating or other studies' (Tratebas & Chapman 1994:131).

The practice of removing lichen from the whole rock art panel is in my opinion absolutely not recommended, and should only be carried out when a detailed documentation is absolutely necessary. On the other hand the practice first started at Arkeologisk museum i Stavanger in recent years, of removing the lichen by brushing with ethanol, but only in the engravings, are reasonable. Thus the surrounding rock is protected by a cover of lichen reducing the wear of shoes, etc, and the visual contrast between clean rock surface and the surrounding lichen makes the carvings more easy to see, even if they are not painted (Fig. 5). A problem is that ethanol is very volatile, so experiments should be carried out to develop a more gel-like fluid, which does not damage the lichen outside the furrows.

Similar to the problem of crack repair by mortar, mentioned before, the removal of lichens from rock carvings has too often been carried out without a long-term perspective. The curators have forgotten that life in nature is a dynamic process, following the rules of nature, and that even the smallest crack is inhabited by different organisms. As a consequence, in terms of preservation it is no use removing lichen and other organisms from the whole panel. It will only lead to a change between a living phase and a short dead phase, a situation which both biologically and ethically is unfortunate.

From an isolated perspective it could be desirable to stabilise a rock carving maximally by keeping the rock dry and totally free from biological activity. However, this is not possible in long term, because at present it is not possible to make binding resolutions which ensure the same type of maintenance will be continued in the long term, preferably several hundred years.

I have to make it clear that these views are written on the basis of general ecological knowledge, and so far not proved by own experiments, even if some preliminary observations and positive tests have been carried out. They are also written in protest against the often-observed view that lichen is guilty of considerable damage on rock carvings. A long-term and fully open minded project on the subject 'positive and negative effects of lichen growth on rock art panels' would be most welcome.

PROPOSALS FOR A NEW CONSERVATION METHOD FOR SEVERELY WEATHERED SITES

The use, directly on rock art sites, of organic chemicals like Mowilith and other types of glue based on synthetic resin should not be continued. At the same time heavily weathered sites like Ausevik and Vingen on the western coast of Norway are in desperate need of an agent that can stabilise the porous and cracking rock. Does a natural and reversible alternative exist? In rock containing calcite this mineral is far more dissolvable than other minerals. According to Walderhaug (1998) carbonates dissolve several million times more rapidly than most other minerals found in Norwegian rock. Naturally, when a rock crust containing calcite is weathered one of the first elements to be dissolved is calcite. Can calcite be redistributed through the process known as calcification?

Calcification is a process going on in large scale in nature all over the world. In coral reefs, in the shell of snails and mussels, when groundwater rich in dissolved calcium carbonate reaches the surface, the calcium is excreted as carbonates, which form tufas, in stalactites and so on. The precipitation of calcium carbonates is complex and can have different reasons, but normally takes place when water containing calcium carbonate loses carbon dioxide.

Strangely enough this calcification has once laid a natural, reversible and protective coat over a Norwegian rock carving, thus being able to protect it for hundreds of years. This cover was, ironically, later chiselled away, and the rest of the protective cover washed away with diluted hydrochloric acid!

This happened at Fåberg in Gudbrandsdalen. A supposedly loose block of stone right above the rock carving was secured by moulding a bar of concrete to support and stabilise the stone, and cracks above the rock art was filled with concrete. This was done in 1963 (Løken & Løken 2000). Then the same chemical process happened that can commonly be seen on concrete buildings, bridge fundaments, concrete staircases, etc. Dissolved calcium from the concrete was transported by water to the rock panel, came in contact with carbon dioxide and was precipitated on the panel. Already in 1970, only seven years after the work vas done, it was reported that the figures on block III was partly covered by calcitic crust, and this process was seen to continue in the 1980s and 1990s (Fig. 6).

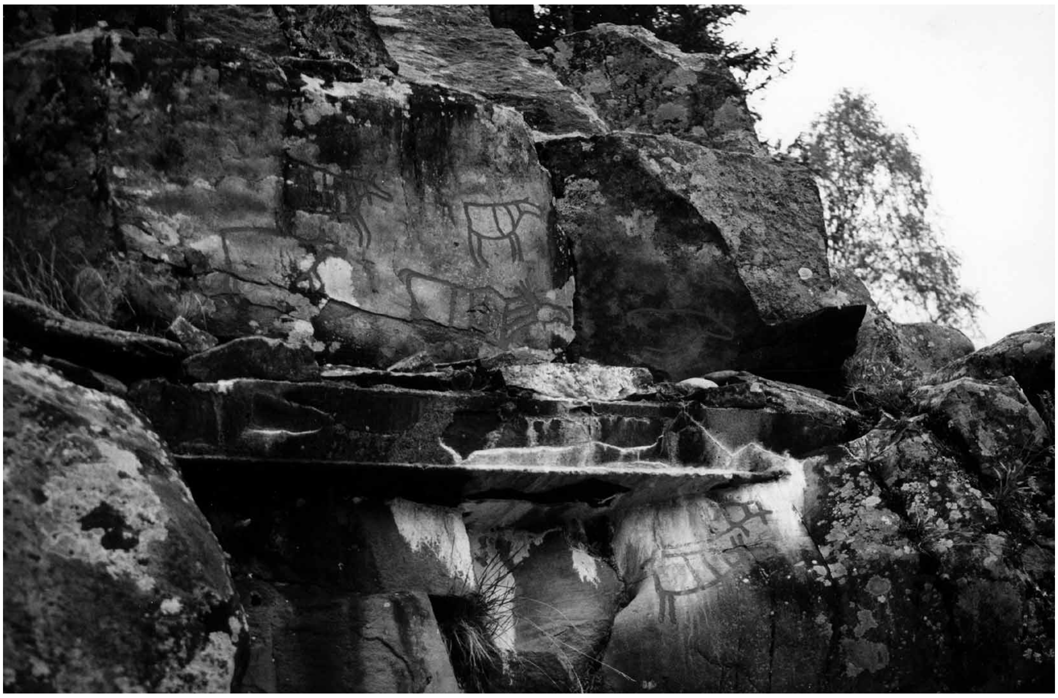

Fig. 6. *The rock art site Drotten, Fåberg, Gudbrandsdalen in year 2000. Calcium from the level concrete bar, and from concrete fill in cracks above, has leached and then re-deposited as calcite on the rock and partly on some of the carvings. The result at Fåberg is an unexpected and ugly curatorial mistake, but can this process under controlled conditions be used for strengthening heavily weathered rock art panels? Photo: I. M. Olsrud.*

When the 'cleaning' of the rock art at Fåberg by chiselling and use of hydrochloric acid was presented in a lecture on the yearly rock art conference at The Directorate for Cultural Heritage in 2001, I, in a comment to the lecturer, regretted strongly that the protective calcium carbonate coat was taken away. I here propose that the process observed at Fåberg should be thoroughly tested for possible use on heavily weathered rock art sites, like Ausevik and Vingen. The testing must be carried out by a institution with good skill in geology and chemistry, and preferably both in climate chamber and in nature, preferably by choosing a rock panel with similar properties as found on weathered rock art sites, and most importantly, not directly on rock carvings.

The sites already treated with Mowilith can, even if unstable, never be stabilised by calcification, due to the traces of organic glue in the cracks. The possible chemical disturbance from the calcification process is a problem that should be particularly investigated. With respect to later analysis of, for example, trace elements, this problem can probably be avoided by using highly pure chemicals.

In fact, if only a pure quality of calcium carbonate ($CaCO_3$) is used, and a equally pure hydrochloric acid (HCl) for cleaning, the elements used are commonly found in nature, and none can be connected to future chemical analysis from rock art panels.

I believe the calcification process can be carried out on two levels:

1. For a slow and long-term calcification process the situation at Fåberg can be simulated on any flat or inclined panel by mounting a very strong (and protective) net over the panel and fixing small globes of calcium rich concrete to the net. When it rains, water will dissolve calcium from the globes and after dripping and running on the panel carbon dioxide in the air will keep the calcification process going. The process can be accelerated by spraying water with an adjusted pH on the concrete, and thus simulating rain.
2. For a more rapid calcification it is possible to cover one or a couple of rock art panels with a transportable tent or climate chamber where dissolved calcium, water and carbon dioxide can be added under controllable conditions. It is of course important to avoid excess depositions: there should be just enough to fill microscopic cracks and strengthen the weathered rock surface.

I have seen many calcite excretions from concrete on different types of rocks, but never seen them unstable, shrinking or cracking. The calcification is also a reversible process. Due to the much more rapid dissolution of calcite compared to other minerals (Walderhaug 1998), the calcite can be removed by application of weak acids which will dissolve the calcium carbonate but not the rest of the rock.

For filling of larger cracks, a suitable block or a coarse mixture of crushed or ground rock from a nearby cliff can be embedded in calcium carbonate in the laboratory, the shape adapted to the crack and then put in place and later fixed through an onsite calcification. This will make a crack fill which behaves like the local rock and thus avoiding the problems with mortar.

I strongly underline that this proposed method should only be an alternative for very heavily weathered sites, like Ausevik and Vingen, in which a great part of the panels are in risk of being fully destroyed in a few decades. The rock carvings at Kåfjord, Finmark represent a special problem. In contrast to Vingen and Ausevik the main problem is not exfoliation, but intersection of two sets of fractures, one vertical and the other about 45 degrees to the surface. These cracks loosen both small parts and larger blocks of the rock from a panel containing rich rock carvings, and possibly the calcification-method could be used here. We must learn from earlier mistakes and unsuccessful experiments, and take the time necessary to test new methods on panels without rock art, before any application on real rock art sites. As some of the most important monuments from prehistoric time, and with irreplaceable value for coming generations during the next hundreds and thousands of years, rock art should not be exposed to irreversible conservation methods which only last 20 years.

The main threat to the Scandinavian rock carving can normally not be identified as one specific factor, but lack of a curatorial long-term perspective and ecological understanding has for decades been a considerable problem (Bakkevig 2002a, b). The greatest threat to the rock carvings is the accumulating effect of smaller and larger negative episodes which in sum can destroy the rock carvings long before they are destroyed by the inevitable and slow decomposition of all exposed rock surfaces (Bakkevig 2002b).

Much of Norwegian rock art is obviously different to rock art sites in other parts of the world, but with respect to rock art preservation there is a need for more international cooperation and exchange of experience. Before we apply new methods of conservation directly on rock art panels, we must be sure that the results are positive and long lasting. New burdens should not be laid on the shoulders of the already threatened rock art.

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EDITORIAL NOTE

Rock Art Preservation

Sverre Bakkevig's article in this volume is related to the challenges in the extensive Norwegian Rock Art Project (*Bergkunstprosjektet*). Since the early 1970s, archaeologists in the cultural heritage management have worried about the alarming situation of the preservation of rock art. This problem was brought to the agenda of the Norwegian parliament in 1993. In May 1995, the Minister of Environment decided that the Directorate for Cultural Heritage (*Riksantikvaren*) should present a national plan of action for securing and preservation of rock art (Riksantikvaren 1995, Solli 1997). The plan intended to embrace an estimate of the number of rock art sites, the state of preservation; damages, and propositions for action. Archaeologists in the cultural heritage management, directorate, museums and counties made a collective effort contributing to the plan. Pilot studies uncovered a dramatic damage-picture: the number of rock art sites in Norway was estimated at 1100, with a total of 31789 figures. Archive studies and field studies suggested that more than 90% of the sites had alarming preservation problems, both damage inflicted by humans and 'natural' causes (chemical, geological and botanical processes).

The plan of action presented to the Minister on 27 April 1995 proposed an inventory of the conditions of preservation, documentation of sites, preservation of sites, individual maintenance plans, plans for public access on especially chosen sites, and development of long-term plans for the management of rock art sites.

The preliminary action plan resulted in the establishment of the *Bergkunstprosjektet*, aimed at securing rock art in Norway, starting in 1996 and scheduled to be finalised in 2005 (*Riksantikvaren* 1995). Sverre Bakkevig has been one of the experts associated with the project. His paper here focuses on some of the issues raised in the project, and clearly illustrates the impact and scope of the challenges, and the problems of the handling of the situation (see also Walderhaug & Walderhaug 1998). Bakkevig is especially critical of what he calls the Bergen method. Right or wrong, the editors of NAR have decided that it is sound to pursue this debate outside the enclosures of heritage management. We hereby call for comments on the issues raised in Bakkevig's article, both in general and more specifically. The forthcoming issue of NAR will present comments, and reply to comments.

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See Bakkevig's article