CHEMICAL STABILIZATION OF POROUS SANDSTONES BEARING PETROGLYPHS

David A. Grisafe
Kansas Geological Survey

and

Paul R. Nickens
US Army Engineer Waterways Experiment Station

ABSTRACT

Native American rock art sites are affected by numerous types of impacts originating from both cultural and natural sources. Some of the most difficult losses to control are those resulting from weathering or deterioration of the stone itself. This paper discusses the results of field and laboratory experiments that examined the use of a stone strengthener and water repellent to solidify porous and poorly bonded Dakota Formation Sandstone in central Kansas. The results indicate that these chemicals, which are based on organosilicon compounds dissolved in a ketone carrier, provide substantial cementation of the sand grains with no detrimental change in the color, porosity or permeability of the stone. This technology will significantly prolong the existence of important petroglyphs on sandstones.

Introduction

Rock art originating from prehistoric and historic American Indians, as well as early settlers, provide a link to our past. Many of these sites have been subjected to varying forms of vandalism, but as a whole, the most destructive force acting on all rock art is natural weathering. A variety of phenomena gradually attack these sites and include freeze-thaw, wet-dry and heat-cool cycling, wind and water erosion, biological growth, salts, atmospheric pollution and mineral weathering. Naturally, the geographical location of a site with its climatic characteristics and the degree of protection from the elements at a particular site play major roles in determining which one or more agents are more or the most detrimental.

Despite the attempts to protect sites from vandalism, little work has been done in finding a suitable treatment to increase the durability of the stone itself. However, before treating any stone, it is necessary to understand the nature of the stone. For example, there is little point in treating

Paper presented at the 56th Annual Meeting of the Society for American Archaeology, New Orleans, LA, April 24-28, 1991.

a stone with a chemical solution if the stone has no absorption. Thus, it is important to understand certain basic mineralogical and physical characteristics of the stone and be able to evaluate the changes of such properties as a result of any type of treatment.

Field and Laboratory Tests

As noted, it is imperative to have some knowledge of the nature of the stone before any treatment can be considered. In the field, in situ capillary absorption measurements should be made to obtain an idea of the relative absorption or permeability of the stone. This is easily done with small plastic capillary absorption tubes. If heavy biological growth or salts are present on the surface of the stone, the flat edge of a rock hammer can be used to gently remove them. After cleaning the surface, one can proceed and measure the amount of time required for 5.0 ml of water to be absorbed by the stone.

In the laboratory, the mineralogy of the stone is readily determined by the use of an optical microscope or x-ray diffraction instrument or both. Basic physical properties to measure prior to treatment include capillary absorption weight gain determined as a function of time when cores or prisms of the stone are placed on a water saturated sponge, the immersion absorption after 24 hours, the compressive strength and laboratory cycling such as freeze-thaw or wet-dry, the latter being important for stone containing appreciable amounts of clay minerals. By measuring these properties on both untreated and treated stone, one can determine the effectiveness of a given treatment.

Requirements of Cementing or Waterproofing Agents

A simple waterproofing agent on the exterior surface is not the answer to preserving most rock art. There are a variety of paths that moisture can take to reach petroglyphs such as moving from the ground up and outward to the surface, natural joints, fractures and bedding planes of the stone, and also through the natural permeability of the stone. Furthermore, such stone is frequently weathered with the removal of the natural cement or perhaps the stone never contained appreciable chemical cement and is held together by interlocking mineral grains as are many porous sandstones. Therefore, the grains must be cemented together by a chemical cementing agent that increases the durability of the stone by giving it additional strength to withstand the stresses caused by water and wind related weathering, including freeze-thaw cycling.

The requirements that must be met by any strengthening agent are:

1. An increase in the strength of the stone.
2. Good depth of penetration.
3. No discoloration should be produced by the treatment.
4. The pore system of the stone should not be sealed.

Most systems or treatments fail one or more of the above requirements. The need for a strength increase is obvious. Good depth of penetration is necessary to achieve such a strength increase and in the case of a deeply weathered stone, to treat or consolidate the entire zone of weathering. Discoloration is never desirable and is most likely to occur when using a treatment that does not have a neutral pH, thus allowing it to react with iron minerals that are often present. Finally, any system that seals the pore structure of the stone will eventually cause problems since the stone must be able to breathe or retain some of its permeability in order to allow the removal of moisture. Excess moisture can cause problems associated with salts and freeze-thaw.

The Choice of a Suitable Treating Agent

The system chosen for this study, ethyl silicate dissolved in methyl ethyl ketone, satisfies all of the requirements listed above. The ethyl silicate hydrolyzes within the stone to produce a silica-based cement. The low molecular weights associated with this chemical solution, as well as the low viscosity of the solvent/carrier, insure good depth of penetration. The solution has a neutral pH that eliminates discoloration and after curing, the stone retains some of its permeability.

The Site

There are many petroglyph sites in central Kansas, primarily on relatively soft, porous sandstones that comprise part of the Dakota Formation. As an initial study, an easily accessible site that is well-known was selected, namely the Faris Cave Site in Ellsworth County (SE NE NW 04-16S-07W), located on the Smoky Hill River on U.S. Army Corps of Engineers property associated with the Kanopolis Lake Reservoir. The site includes three rooms or "caves" that were carved in the sandstone by the Faris family during the latter part of the 19th century.

Most of the carving is historic graffiti, some of which may cover earlier petroglyphs, but there are still some glyphs remaining that are American Indian in origin. Since the Pawnee are known to have inhabited this area, it is logical to assume some, if not all, petroglyphs are Pawnee. All but one of the glyphs occupy a distance of about 150 feet along the lower portions of a sandstone cliff that is at the edge of the floodplain along the eastern side of the river.

Experimental Procedures

After photographing the site and making in situ capillary absorption measurements near the glyphs, small nearby test panels were selected for spraying to see what effects, if any, were observed on these panels before treating the actual petroglyphs. Small blocks of sandstone that had fallen from the site were taken to the laboratory for fabricating into 1.5 inch diameter cores that were approximately 1.5 inches high. Randomly selected sets of nine cores were given various treatments, allowing three week cures between any additional treatments. One set was untreated and served as a control. Pieces from the blocks were also examined under a reflected light microscope and then ground to -200 mesh powder for examination by x-ray diffraction analysis.

After all treatments were completed, previously mentioned physical property measurements were determined, specifically the capillary and immersion absorptions, the compressive strength and at present, the freeze-thaw resistance. A list of the treatments is given in Table 1. The OH heading refers to the stone strengthening agent, Conservare OH , and H refers to Conservare H , a mixture of strengthener and water repellant. Both products are sold by the Process Solvent Company of Kansas City, Kansas who is the sole supplier of these chemical solutions in the United States.

Results and Discussion

Treatment of the test panels produced the desired effects. After spraying the panels were allowed to cure. After curing, no discoloration was

Table 1

Chemical Treatments and Treatment Times of Sandstone Cores Using Conservare OH and H Products

	Minutes of Treatment Using Capillary Absorption				
Treatment	OH	OH	OH	H	H
Control	0	0	0	0	0
1 OH	2	0	0	0	0
2 OH	2	2	0	0	0
3 OH	2	2	10	0	0
2 OH + 1 H	2	2	0	10	0
3 OH + 1 H	2	2	10	10	10

produced and the surface hardened appreciably. Furthermore, after treatment with two applications of OH and one treatment of H, the absorption was sharply reduced and capillary absorption (in situ) required at least ten times longer to absorb 5.0 ml of water than the untreated stone.

Petrographic analysis indicates the stone has very little bonding and is held together by interlocking quartz grains. The stone is an arenaceous sandstone consisting of over 96% silica, 1-2% iron oxide and no detectable clay.

A summary of the absorption properties is given in Tables 2 and 3. Increased treatment cycles decreases the capillary absorption rate and overall

Table 2

Average Capillary Absorption Values as a Function of Time and Treatment for Sandstone Samples

Treatment	Percent Weight Gain Per Unit of Time					
	Minutes					
	0.5	1.0	2.0	5.0	60	120
Untreated	15.3	15.8	15.8	15.8	--	--
1 OH	6.0	8.7	11.8	12.8	12.9	12.9
2 OH	1.6	2.7	4.3	7.8	10.1	10.1
3 OH	0.8	1.2	1.6	2.3	6.4	7.1
2 OH + 1 H	0.9	1.2	1.6	2.3	6.6	7.2
3 OH + 2 H	<0.1	0.1	0.2	0.3	1.0	1.3

Table 3

Comparison of 24 Hour Absorption Values by Capillary Absorption and Immersion for Sandstone Samples as a Function of Treatment

	Values in Weight Percent	
Treatment	Capillary Absorption	Immersion Absorption
Untreated	15.8	16.1
1 OH	12.9	13.8
2 OH	10.2	11.0
3 OH	7.3	8.7
2 OH + 1 H	7.4	8.6
3 OH + 2 H	1.5	4.3

absorption. Table 4 shows the increased weight and compressive strength as a results of the different treatments. Note that a single treatment of the stone strengthener more than doubled the compressive strength of the stone. The data also indicate the retention of the stone's permeability (it continues

Table 4

Percent of Solids Deposited and Compressive Strength as a Function of the Treatment for Sandstone Samples

Treatment	Percent Solids	Compressive Strength in psi	Percent Improvement
Untreated	0.0	1,080**	---
1 OH	5.3	2,550	136
2 OH	9.8	3,050	182
3 OH	13.4	4,750	340
2 OH + 1 H	12.9	4,640	330
3 OH + 2 H	17.5	7,650	608

** Denotes maximum value for untreated cores. Because of the somewhat irregular surfaces of the tops and bottoms of the cores, all were capped with a high density plaster material to insure uniform distribution of the load. Three of the six cores were so weak that the caps became loose and yielded much lower values that were considered inaccurate. Had all six cores of the control set been used to obtain an average value, the treated cores would have shown an even greater percent improvement.

to absorb liquid by capillary action during the fifth treatment) thereby eliminating the need for a vapor permeability test. In other words, the stone is still able to breathe and rid itself of moisture.

The use of freeze-thaw testing in the laboratory has further confirmed the success of this treatment. A set of treated cores and a control set of untreated cores were exposed to 25 freeze-thaw cycles. Each of the untreated specimens failed with two of the three cores having completely disintegrated. By contrast, none of the treated cores has shown any failure.

Summary

When the project was initiated, it was felt that a strength improvement of at least 30-40% should be obtained to justify the expense of treating the petroglyphs. Clearly, as shown in Table 4, this goal was exceeded with a single treatment. However, the very weak nature of the stone suggests the stone at this site is held together by interlocking grains and has little or no chemical bonding. This fact, coupled with high permeability and breathability of the stone after several treatments, has justified the use of two treatments of strengthener on the petroglyphs, followed by two applications of the strengthener-water repellent mixture. This, of course, increases the expense associated with increased chemical consumption but the additional cost is more than justified to preserve these petroglyphs.

Finally, the testing methods and chemical treatment outlined in this report indicate this methodology would be suitable for the preservation of rock art on soft porous sandstone and also has the potential for use on any type of stone possessing some degree of permeability.

Note: This paper has been condensed from a draft Technical Note prepared by David A. Grisafe, entitled "A Method of Testing and Treatment to Increase the Durability of Porous Sandstones Containing Petroglyphs." This Technical note is scheduled to be published in late 1991 in The Archeological Sites Protection and Preservation Notebook, issued by the US Army Engineer Waterways Experiment Station, Vicksburg, MS. The tests described and the resulting data presented herein, unless otherwise noted, were obtained from research conducted under the Environmental Impact Research Program of the US Army Corps of Engineers by the Kansas Geological Survey. For additional information on this methodology or the results, contact the senior author at the following address: Kansas Geological Survey, 1930 Constant Ave., Campus West, The University of Kansas, Lawrence, KS 66047. Phone No. (913)864-3965.