



Chapter 5:

Fire Effects on Rock Images and Similar Cultural Resources

Introduction

Throughout human global history, people have purposely altered natural rock surfaces by drilling, drawing, painting, incising, pecking, abrading and chiseling images into stone. Some rock types that present suitable media surfaces for these activities are fine-grained sandstones and granites, basalts, volcanic tuff, dolomites, and limestones. Commonly called rock “art,” depiction of patterns, images, inscriptions, or graphic representations might be considered today as ‘artistic’ as is Old World Paleolithic “cave art” for example, but most of those early originators attached different cultural values to these expressions. Historic rock inscriptions made by literate persons are also of high value as “documents.”

Images on rock are subject to natural weathering by several processes: freeze/thaw, wet/dry, heat/cold, wind-carried erosion materials, natural salts and minerals, ultraviolet rays, direct moisture and atmospheric conditions (fig. 5-1). Vandalism to these resources is a very serious threat in many areas (fig. 5-2). Rock surfaces may also exhibit numerous small, shallow pits or cupules, formed by pecking, chipping or abrading, or pecked curvilinear nucleated cupules (PCN) (fig. 5-3). The cupules may be in clusters or patterns on vertical or horizontal rock surfaces. Accessible rock surfaces

may also be worked to produce bedrock mortars (BRM) and concave milling surfaces for processing food materials. Stones may be moved to form images, patterns, complex designs or mounds. Some researchers use the term “geoglyph” to refer to these human changes to ground surfaces, often as very large and striking images when visualized from above (fig. 5-4). In arid lands, stony ground surfaces were altered to achieve a contrasting image to lighter colored soils below dark desert gravels. These cultural activities are best considered as patterned behavior, not aimless or haphazard in terms of placement, pictorial content, and variety through time and space. Important evidences of image chronologies may result from re-use of rock surfaces, re-painting, and younger designs superimposed over earlier ones (Hedges 1990).

We distinguish between pictographs (painted expressions using mineral colors or charcoal, often with a binder material) and petroglyphs or images made by pecking, carving, abrading, scratching, and incising, or combinations of these methods. Petroglyphs are usually created with these methods to remove darkened appearance of naturally weathered stone surfaces to expose lighter colored rock matrix to achieve a contrasting image. Both types of images may occur in mixed expressions or only one technique may appear dominant.



Figure 5-1—Natural weathering processes in action. Top: Exfoliation on granite. Bottom: Natural spalling at the Tate Site, Lincoln National Forest (photos, Forest Service, Lincoln National Forest).

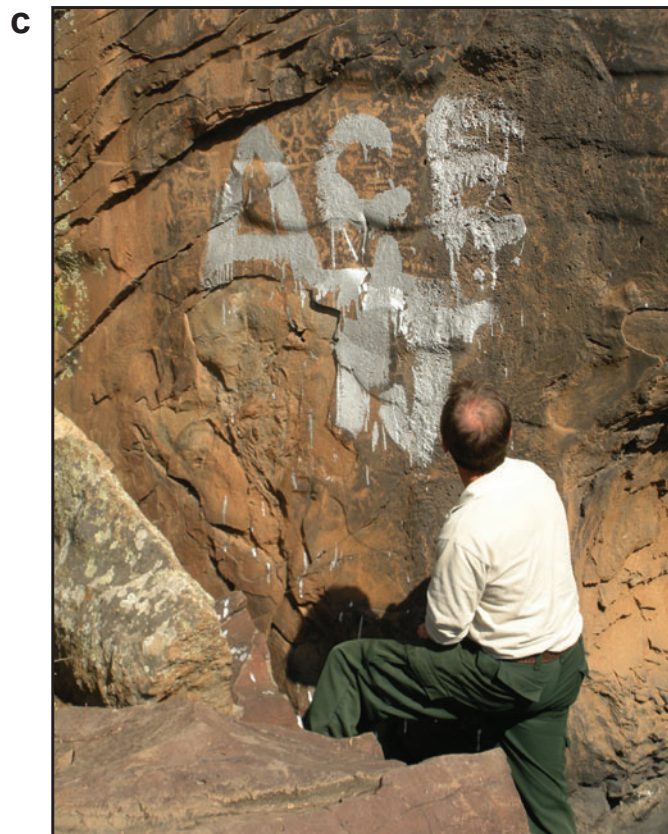


Figure 5-2—(a,b) Natural weathering and vandalism at Inscription Canyon, San Bernardino County, California, 1971. a) Lichen growth beginning to obscure petroglyphs. b) Vandalism, attempt to remove the petroglyphs. (c,d) Vandalism, defaced petroglyph panel at Keyhole Sink on the Kaibab National Forest (photos, Forest Service, Southwestern Region, Kaibab National Forest).



Figure 5-3—Cupule boulders, both examples from Riverside County, California.



Figure 5-4—Examples of intaglios or geoglyphs. Top: Blythe (California) Intaglios along the Colorado River at site CA-RIV-14. Bottom: Close-up of one of the figures.

Setting and Placement

The setting and placement of these cultural resources are often away from customary habitation and may be seen at almost any location. Rock images may be within caves, rock shelters, or overhanging cliffs where vegetation may flourish as potential fuels. Images or patterns may be on above-grade outcrops, vertical surfaces, or at-grade horizontal locations, on expanses of exposed bedrock found along drainages, ridgelines, or topographic features related to water sources. In some locations, pecked handholds, steps, or trail markers may exist with modern hiking trails and other access routes. Since bedrock-milling mortars are associated with food gathering and processing, evidence of temporary camping may also be present in surrounding mineral soils.

Many examples of complex rock images are associated with topographic features, such as canyons, draws, and ridges that support growth of potential fuels today and provide access routes across terrain into higher elevations. Some examples will be found in isolated spots, often with a landscape view, but others are within modern urban/suburban environments (Bostwick 1998). In some western States, circular rock alignments indicate temporary shelters and would not be called geoglyphs. Images or inscriptions on tree trunks—sometimes called “dendroglyphs”—are unique historic resources documenting historic land uses in timbered regions (chapter 6; Coy 1999). Recognized historic trails are sometimes documented by travelers’ names and dates on trees or rocks that may be absent in historical records but may be accompanied by historical archaeological materials at campsites.

Heritage and Research Values

Heritage and research values of rock images, geoglyphs, and other associated prehistoric or historic visual depictions are characterized by the following values that justify active preservation and conservation management:

- ◆ Cultural values for contemporary tribal communities as spiritual places where ancestral practitioners conducted necessary ceremonies, noted astronomic observations, or recorded past tribal events (for example, Writing-on-Stone Provincial Park, Alberta, Canada; Saddle Rock Ranch Pictograph Site within the Santa Monica Mountains of California illustrating Spanish horsemen; Cave of Life petroglyphs in Petrified Forest National Park, Arizona).
- ◆ Design elements indicate past land use by ancestral social units who marked places on customary lands by producing visual signs (for example, Newspaper Rock petroglyphs of Hopi clan symbols in Petrified Forest National Park, Arizona; Hawaiian “ahupua’a” or land use unit boundaries (Cox and Stasack 1970)).
- ◆ Rock image elements distributed over an area or region indicate connections by past native peoples to lands their descendants may not occupy today. Traditional leaders who attribute sacred values to lands as witnessed by “rock art” sites consider these resources as very special identifiers. Such places are included in the May 1996 Presidential Executive Order 13007 “Sacred Places,” directing Federal agencies to preserve such locations as public heritage values to all citizens.
- ◆ Most serious researchers use non-destructive and detailed photographic and other methods of recording, assessing, and describing rock images and geoglyphs, which recognize the complexity and variety of these cultural expressions over time and space (Bock and Bock 1989). American Rock Art Research Association (ARARA) members, affiliated local interest groups, and professional researchers need to follow high standards of field work and publications. Previous methods such as chalking, rubbings, crayon use, castings or applications of latex coatings, even kerosene washes and other embellishments should always be avoided (Labadie 1990; Lee 1990; Whitley 1996a).
- ◆ Use of ethnological information by some leading researchers has produced innovative studies that link stone images to native belief systems, philosophies of life, individual expressions, and past intergroup events (Crotty 1990; Robbins 2001;

Whitley 1994, 1996b). Rock art sites and obsidian artifacts are potential sources for collaborative ethnographic studies regarding Native American uses of fire for manipulation of environments (Arguello and Siefkin 2003; Keeley 2002; Loyd and others 2002; Underwood and others 2003; Williams 2001).

- ◆ Native and non-native inscriptions, trail markers, and food preparation stations have values for interpreting environmental history, landscape change, travel prior to modern methods, and adaptation of subsistence practices by inhabitants through changing land use patterns.
- ◆ Inclusion of rock image resource in Federal or State historic property registers as significant public heritage sites denotes official recognition that triggers specific preservation compliance actions required by legislation, as well as defining public education values (Marymor 2001).
- ◆ Dating of rock art through scientific methods depends on assessing the integrity of the resource in terms of contamination, physical damage and presence of datable organic materials. Notable successes have been developed to give radiocarbon age determinations as numerical values as well as relative (“older than” or “younger than”) ages (Chaffee and others 1994; Dorn 1994, 2001; Francis 1994).

Fire Effects

Some major rock image examples and related archaeological resources clustered together on public land areas may be described or formally documented in existing technical reports, electronic or paper archaeological site inventory records, or summaries of resources in a protected status (Labadie 1990; McCarthy 1990). But often, essential information about location, characteristic, and existing condition is not readily available during emergency situations. Field crews will probably encounter isolated, poorly known, or undocumented ‘rock art’ on vertical or ground surface outcrops that may also include bedrock mortars or grinding surfaces. Protection actions such as those suggested in the **Mitigation and Protection** section should be taken in these situations, under guidance from a fire management trained Cultural Resource Specialist. Some effects are short term while others are longer duration; temporary changes such as soot deposits may be removed naturally. Untrained persons should not attempt direct conservation measures.

Rock shelters, overhangs, and vertical rock faces containing rock image panels may suffer two types of damage from wildland fires: thermal effects from energy (heat) absorbed and depositional damage from

exposure to smoke, soot, ash, smudging, and tars as combustion products (Loyd and others 2002). The energy may result from either radiation or convection but higher temperatures are associated with the former (chapter 2). Common results are discoloration, exfoliation or spalling, and heat absorption (fig. 5-5). Smudging occurs when combustion products precipitate on or adhere to exposed rock surfaces. Chemical and physical changes are probably caused by heat penetration and charring of organic pigment binder materials of painted elements. Spalled or 'pot-lidded' surfaces or the forming of minute cracks in fine grained rock types occur when normally absorbed moisture becomes heated, causing rock grains and moisture molecules to expand and lose normal adhesion.

Illegal campfires in spaces such as rock shelters or caves 30.5 meters (100 feet) or less from images can also produce extensive spalling, sooting, or other damage to natural rock surfaces, but restoration is possible in some cases (fig. 5-6). Prevention of such illegal camping should be a management and enforcement priority.

Wildland and prescribed burn suppression activities including use of heavy equipment has resulted in severe damage to ground level 'rock art' made upon exposed bedrock formations (fig. 5-7, 5-8, 5-9). Foam, fire retardant, or water applied during mop up operations to still hot rock surfaces can also cause spalling. Organic materials in some retardant gels remain on image surfaces or fertilize micro or macro-plant growth.



Figure 5-5—Spalling and exfoliation caused by fires. Top: Spalling of rock art following the 2003 Hammond Fire, Manti LaSal NF, Utah (Johnson 2004). Pictograph damaged by heat from forest fire (photo Clay Johnson, Ashley NF). Bottom: Typical exfoliation of granitic rock where fuels are nearby and burning very hot. No cultural features were affected.



Figure 5-6—Examples of graffiti and illegal campfire built at the base of a rock painting at site (CA-RIV-45) in Tahquitz Canyon, Riverside County, California.



Figure 5-7—Fire-damaged petroglyph in Hawaii.



Figure 5-8—Fire-affected milling equipment noted after the Louisiana Fire Incident in 2002. Top: Granite handstone. Note most of the upper worn, polished surface has weathered away. Bottom: Schist metate surface with only small worn and polished areas remaining.

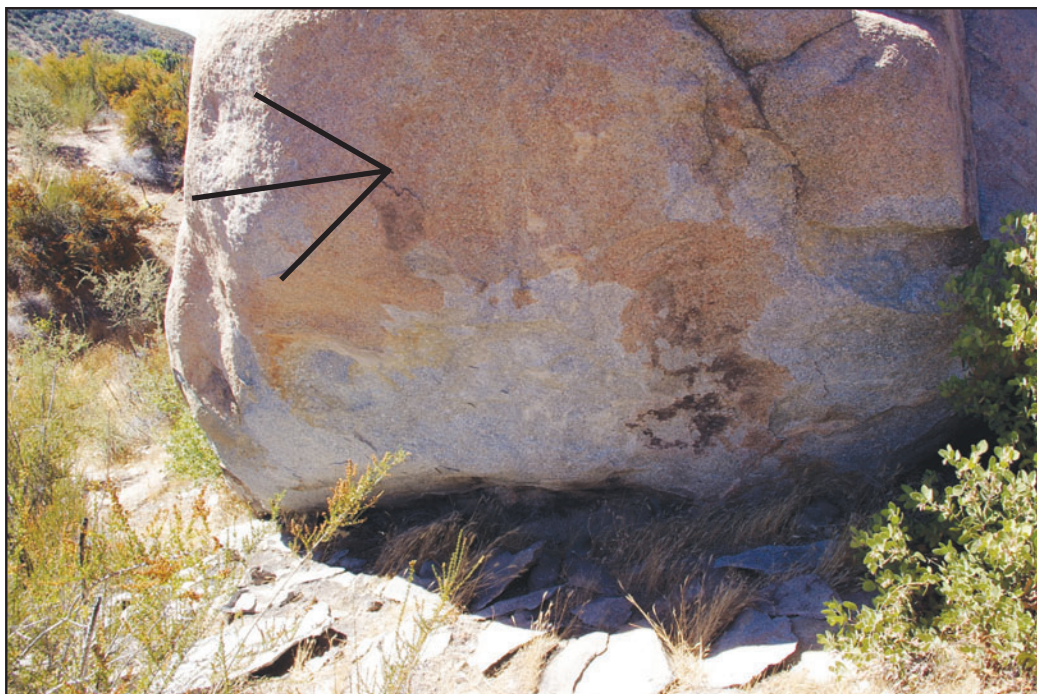


Figure 5-9—Cupule boulder damaged during the Louisiana Fire Incident in 2002. Top: View showing the north rock exposure. Cupule Panel 1 shown by arrows and extent of damage to rock surface. Bottom: Detail of damage to panel.

Certain types of lava flows are thinly covered by fragile silica coatings—which native peoples removed to produce petroglyphs—that are very easily damaged by foot traffic, hose lines, or hand tool use. Stone arrangements or ‘geoglyphs’ can also receive damage from machinery, hand lines, fire camps, heliopads, and vehicle parking.

Field Examples

Over the past two decades, at least 20 examples of ‘rock art’ resources impacted by wildland fires or vandalism have been reported within several States (Kelly and McCarthy 2001, 2002). While these examples are only a few from an unknown number of “rock art” resources impacted by fires, they illustrate fire-generated impacts on different rock types and images, issues of fuel loading near archaeological resources, and post-fire observations.

Hawaii

On the Island of Hawaii, brush firefighting in March 1990 included zig-zag dozer tracks over a lava flows

with numerous native Hawaiian petroglyphs, destroying and severely damaging scores of unrecorded elements (Lee and Stasack 1999). Burning of private sugar cane fields prior to harvesting resulted in generation of high heat from long flame length fires and accumulation of ash and soot on rock art examples (J. Mikilani Ho, personal communication; NPS 1999); the use of bulldozers for this activity also resulted in damage to basalt outcrops with rock art. Examples of increased visibility for rock art, as well as covering by fresh flows, ash, or acidic moisture are documented for Hawaii Volcanoes National Park (Edward and Diane Stasack, personnel communication, 1999).

Arizona

Within Coconino National Forest, the Deadman Wash locality contains 48 rock art sites, which were partially subjected to a wildland fire in 1996 (fig. 5-10) (Kolber 1998). One site was heavily damaged by high heat on basalt surfaces, causing exfoliation and substantial to total loss of element clusters (fig. 5-11).



Figure 5-10—Lava flows on the Island of Hawaii are often exposed to damage from fire, fire suppression, and other cultural practices (a) Puuloa Petroglyphs (b) Puuloa Petroglyphs; (c) Puako Petroglyphs.

Figure 5-10—(Continued)

b



c





Figure 5-11—Heavy fuel accumulation and consumption around basalt outcrops at the Deadman Wash site Coconino National Forest, Arizona.

Texas

Hueco Tanks State Historical Park near El Paso contains spectacular American Indian rock art dating from Archaic period to historic Mescalero Apaches, Kiowas, and Comanche tribes. Guided visitor tours and a management program, including conservation projects, are positive steps ensuring preservation and study of these well-known examples. Soot coatings and sprayed graffiti at one site were treated with mixed results, but more elements were revealed after smoke blackening was removed (Ronald Ralph, personal communication, 2000). A recent fast-moving fire at the Alibates Flint Quarries National Monument near Amarillo caused spalling of dolomite outcrops and boulders, some of which contained rock art; no images were damaged. Whether high heat caused micro-fracturing of stone surfaces near petroglyphs or not is unclear but may increase deterioration of the images in the future (Dean 1999).

California

Within Cleveland National Forest, a single pictograph panel of an anthropomorphic figure—a ‘rake’ pattern—and other images were subjected to a high temperature fire from nearby fuels (Cavaoli 1991). Only two elements were undamaged and red hematite elements were discolored and altered from rock surface spalling and high temperatures. In 1982, another rock art site was damaged from spalling due to burning of heavy fuels nearby and target shooting later. At Vandenberg Air Force Base, burning of brush in proximity to a major rock image site caused spalling of rhyolite surfaces and loss of painted design elements (Hyder and others 1996). In the 1999 “Willow Fire” in San Bernardino NF, intense heat caused blistering of two unrecorded painted panels and loss of details (McCarthy 2000).

In the southeastern California Mojave Desert, Bureau of Land Management’s Black Mountain locality, fast-burning grass fires did not alter rock art on basalt

outcrops but did result in greater visibility and light smudging, which faded with time. An intentional campfire set in the early 1990s near a small rock art panel on local granite resulted in significant spalling and blackening, which faded later. Damage to rock art on granite surfaces depends on fire heat, nearby fuels, and rate of ignition (Sally Cunkleman, personal communication, 1999).

Colorado

Mesa Verde National Park contains superlative ancestral Pueblo rock art associated with village communities occupied between the 12th and 14th centuries. During the 1996 Chapin 5 wildfire (Sidebar 5-1), three panels on the sandstone of ' Battleship Rock' sustained discoloration and extensive spalling (Cole 1997; Floyd-Hanna and others 1997-98). This significant rock art site had been documented several times since 1989 by chalking, photography, and written descriptions, tracings, and replication for Visitor Center display. Of the three major panels, two sustained extensive damage as compared to earlier documentation. Standing trees, brush, and considerable duff fuel loading indicated absence of fire until 1996 in the vicinity of Battleship Rock. A monitoring program has been instituted to watch further changes since Park management, in consultation with local tribal authorities, decided not to attempt stabilization or restoration of damaged surfaces (Desert News Archives, AP: December 1, 1996).

A 9,000-acre fire occurred in 1996 within Comanche and Cimarron National Grasslands, near La Junta. A 'Volunteer in Time' project revisited 19 of 77 sites to assess any fire damage (Mitchell 1997). About 16 unrecorded rock art panels were observed but only two sustained damage. Close proximity of standing trees as fuels to rock surfaces (0.3 to 0.6 meters [1 to 2 feet]) accounted for spalling of sandstone rock faces, fortunately without images. Spot fires and light ground fuels resulted in minimal damage to sites and rock art panels but exposed additional sites for recording (Mitchell 1997).

Utah

In 1981, Canyonlands National Park sustained a 200-acre wildland fire named for a petroglyph panel called 'Four Faces' (Noxon and Marcus 1983). While not damaging the four elaborate anthropomorphic figures directly, nearby sandstone exposures sustained smoke blackening and extensive exfoliation due to moisture expansion within the local type of sandstone. Pinyon-juniper fuels in quantity and short distances from the Four Faces panel provided sufficient heat source for convection transfer to sandstone cliff faces at a height of 12.2 meters (40 feet) above ground surfaces.

Sidebar 5-1—Rock Art

Chapin 5 Fire, Mesa Verde National Park, Colorado, August 17–24, 1996

References: Floyd-Hanna and others (1997); Ives and others (2002)

General Information:

- Elevation: 2,078.7 m (6,820 ft) at the south end canyon to 2,561.8 m (8,405 ft) in the north rim of the mesa
- Vegetation: Ranges from shrub communities, to pinyon-juniper woodland, to semi-desert vegetation on shale outcrops at the lower south end of the mesa; riparian vegetation in canyon bottoms
- Topography: Chapin V Mesa slopes from north to south and is cut by canyons
- Type of study: Post-fire assessment

Fire Description:

- Temperature range: 15.5-29.4 °C (60-85 °F)
- Duration: 7 days
- Relative humidity: 23-85%
- Intensity: 23% of area burned at high intensity, 55% at moderate burn intensity, and 18% at low burn intensity; 4% unburned area
- Type of fire: wildland
- Energy Release Component (ERC): 39-70
- Burning Index (BI): 19-67

The Chapin 5 fire occurred in August of 1996 and burned 19.3 km² (4,781 acres) of Mesa Verde National Park. Red-carded archaeologists worked closely with firefighters and monitored fire suppression impacts to heritage resources. About 150 sites, including 75 previously unknown sites, were encountered during suppression activities. About 295 sites were known to exist in the burn area and an additional 366 unrecorded sites were located after the burn (USDI 1999). Sites included numerous masonry pueblos, 27 cliff dwellings, pithouse complexes, agricultural features, burial sites, historic summer shelters, hogans, and sweat lodges (USDI 1996).

The fire burned two of the four Battleship Rock petroglyph panels, causing extensive damage (figs. 5-S1, 5-S2). Following the fire, the ground surrounding the petroglyph panels was covered with ash. Spalling and discoloration (reddish, black, and gray areas were noted) affected some glyph elements to the point that they could not be recognized as complete forms. Fragments of spalled sandstone lay at the base of panels (Ives and others 2002).

Immediately after the fire, a Burned Area Emergency Rehabilitation (BAER) team assessed the extent of burn damage. They submitted an emergency treatment plan in September of 1996 and fieldwork began shortly thereafter. Teams of archaeologists and hydrologists worked for over three field seasons to assess archaeological sites and establish erosion control. They adapted new methods of damage assessment from methods established at Bandelier National Monument after the 1996 Dome Fire. Hazard trees were cut down, water-bars constructed and excelsior strips laid over the ground to prevent soil erosion and promote vegetation growth. Much of the burned area was also seeded with grass. A 1999 assessment (USDI 1999) found the project successful. Significant damage to sites had been avoided, 661 sites had been assessed and 333 had been treated to prevent damage.

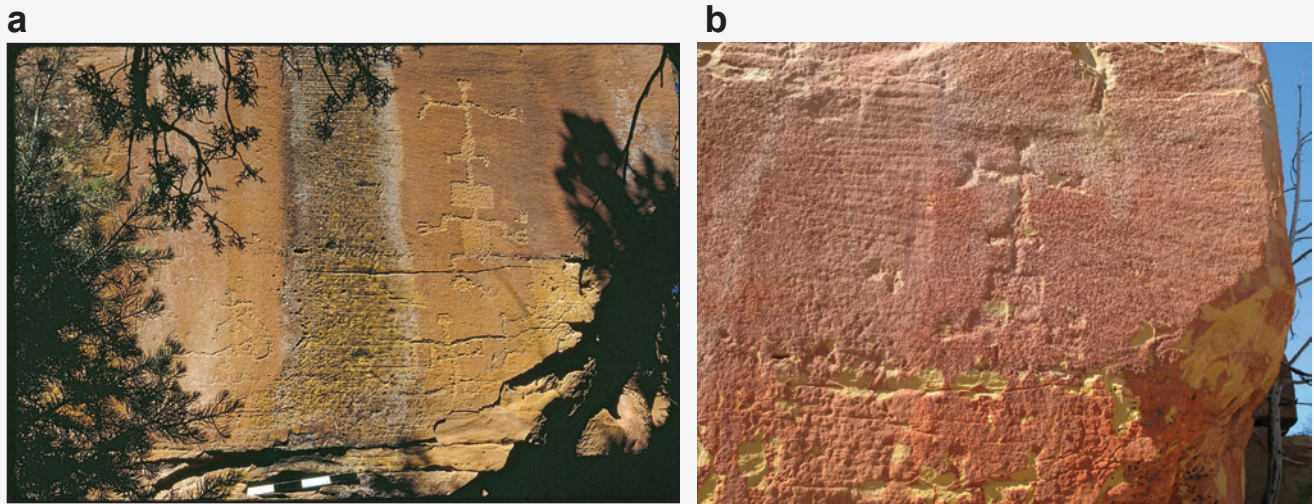


Figure 5-S1—Direct effects of the 1996 Chapin-5 Fire, Mesa Verde National Park, Colorado on the Battleship Rock petroglyph; Panel 3R, before (1989) (a) and after (2006) (b) (compliments of S.J. Cole).

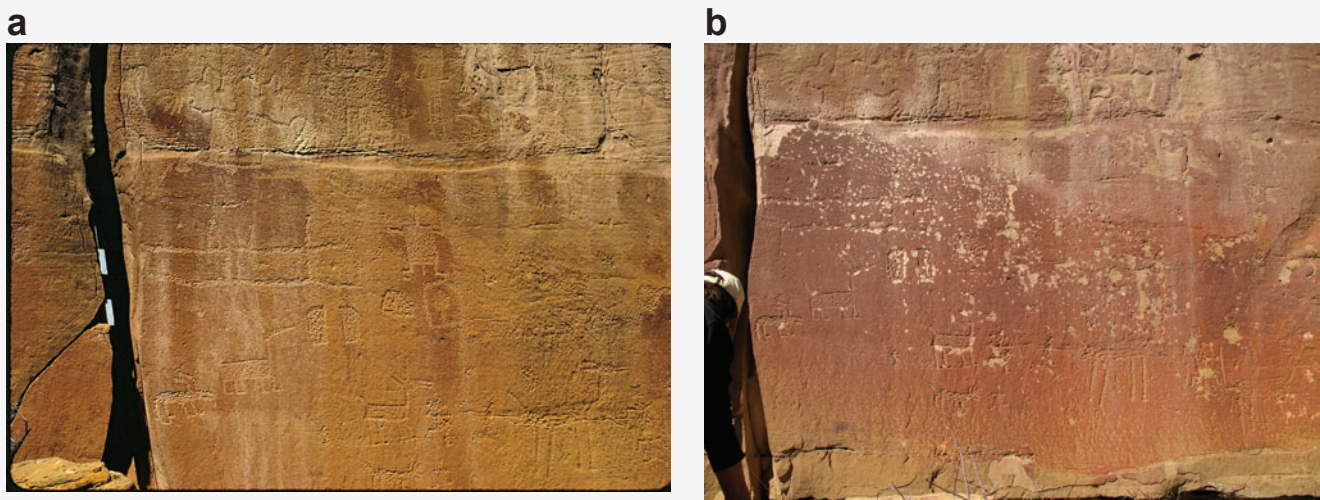


Figure 5-S2—Direct effects of the 1996 Chapin-5 Fire, Mesa Verde National Park, Colorado on the Battleship Rock petroglyph Panel 2L, before (1989) (a) and after (2006) (b) (compliments of S.J. Cole).

Washington

In 1997, Horsethief State Park at Dallesport, sustained a fire caused by a train spark. Images on basalt outcrops along the northern shoreline were damaged and the glassy or silica-like surfaces were exfoliated by heat.

Kentucky

In Daniel Boone National Forest, a wildland fire extensively damaged one rock art site (site number 15Ja234).

Nevada

In eastern Nevada, a rock art site composed of several panels within a series of overhangs at Reed Cabin Summit was totally destroyed by brush fueled fires. Rhyolite rock surfaces exfoliated, spalled, and were smoke-blackened, obscuring or rendering the images destroyed. Some informal documentation had been done earlier but was not systematic. An arson fire in Condor Gulch also impacted known rock art sites in similar ways (Mark Henderson, Bureau of Land Management, personal communication, 2001).

Field Examples: Observations

- ♦ Major fire damage to these resources and natural stone used in the production of the cultural images is usually left untreated and unrestored. Decisions not to carry out conservation or restoration actions seem based on assumed lack of fiscal resources, incorrectly assuming that such damage cannot be treated or restored, and that loss of resource integrity is an acceptable consequence of a natural process for wildland fires. Some technical studies on chemical and physical applications to damaged rock art show that conservation and treatment are possible (Dean 1999; Grisafe and Nickens 1991a, b; Ralph 1990; Silver 1982). Funds for mitigation of fire damage to cultural resources are included in the Burned Area Emergency Response (BAER) program. Reprogramming of fiscal year funds to meet specific cultural resource preservation needs should be considered. In some cases, a professional conservator's assessment to let natural processes "clean" images temporarily obscured may be the best decision.
- ♦ Some reported field examples describe post-fire characteristics of a rock image resource, without comparison to pre-fire condition or estimates of convection-radiation energy levels reached, or other fire behavior data at the location. Those field reports that offer a "before and after" com-

parison show extensive discoloration, exfoliation, and greater exposure of the cultural resource for potential vandalism. When heat levels or duration times were comparatively mild, soot deposits were successfully removed and the resource returned to pre-fire condition.

- ♦ Sandstone, granite and rhyolite parent rock types suffered damage from high levels of energy releases from nearby fuels and fire behaviors, but images on basalt or lava rock types sustained only light soot deposits and temporary increase to visibility. Rock art on Hawaiian lava flows, however, often sustains considerable damage from ash, toxic moistures, soot deposits from fresh flows, and use of fire-fighting equipment during periodic field fires (fig. 5-12) (Kelly and McCarthy 2001).
- ♦ Useful site inventories of 'rock art' resources exist at some institutions (for example, Rock Art Archive of UCLA's Institute of Archaeology; Sink 1998) and compiled bibliographies have been annotated (McLane 1993). Specific management plans for rock art resources are few but offer better stewardship regarding public access, fire management, preservation, and research (Labadie 1990; Lee 1990; Marymor 2001; Whitley 1996b).
- ♦ Preservation strategies such as removal of potential fuels, documentation of major at-risk sites by skilled specialists, and use of GIS overlay maps during a suppression campaign by Incident Command staff are recommended. NPS Pacific West Region archaeological staff works with prescribed fire specialists to conduct pre-burn terrain and archival records checks to avoid inadvertent impacts to undocumented sites (Malony and Zimpel 1997).

Mitigation and Protection

Specific fuel removal will lessen potential smoke damage and heat impacts to rock surfaces (fig. 5-13). "Black line," protective foam barriers, fire resistant tarps, hand-lines, and hose lays around known sites or fire resistant tarps can be deployed with resource advisor's participation. Technical documentation by skilled specialists can establish a photographic, video, narrative, and graphic record prior to a local fire event; this record provides a baseline condition assessment for monitoring activities later. Increased visibility may also prompt unwanted visitation.

Preventing loss of color, design elements, complexity of panel or cluster relationships to outcropping configuration may be impossible. Through documentation using ARARA accepted techniques and approaches we may preserve rock art characteristics (Dean 1999).



Figure 5-12—Sooting (a) and exfoliation (b) of rock art images on basalt outcrops at the Deadman Wash site Coconino National Forest, Arizona.



a



b



Figure 5-13—Vegetation surrounds cultural features, posing a threat from fires. Top: Example of a bedrock mortars surrounded by grasses, at risk from a fire. Bottom (a,b): Fire effects after Piute Fire (photo, Mark Howe 2008). Many milling features are likely in poor condition due to past fires dispelling the notion that stone artifacts are not perishable. Repeated fires over time along with seasonal freeze and thaw cycle contribute to destruction of milling features uncommonly faster by accelerating exfoliation of the rock layers.

Prescribed fire plots may include rock art sites, so management of nearby fuels would be required in the burn plan. Malicious damage during fire suppression is subject to law enforcement, either using Archeological Resources Protection Act 1979 (amended 1988), Code of Federal Regulations regarding Federal property damage, State resources codes, or local county ordinances. Post fire suppression reports, rehabilitation plans, and other incident reports should include details regarding rock art and other archaeological sites within burned terrain. Expert advice from an experienced conservator will be necessary.

Restoration and Stabilization _____

Major damage to significant rock art, geoglyphs, or related modifications of natural stone is often left unrestored. Pioneering studies of chemical stabilization of porous stone types such as sandstone have been performed (Grisafe and Nickens 1991a, b; Turner and Burke 1976). These authors used experimental stone samples to determine effectiveness of various chemical materials to artificially strengthen weakly bonded stone without changing color, porosity, or permeability. Grisafe and Nickens (1991a) studied a Kansas rock art site and found stone samples taken nearby were strengthened by an organo-silicon compound dissolved

in a ketone fluid medium. Bonding of sand grains with no change in appearance or permeability resulted from their experiments. Turner and Burke's (1976) study used stone samples from Davis Gulch in Lake Powell near known rock art sites and from Natural Bridges area of northern Arizona. The most successful material was a polymerized methyl methacrylate, applied in a wet method to sandstone samples. These early efforts may not be allowed in current times because of recognized hazardous nature for some chemicals used and absence of monitoring data over time regarding weakening or disintegration of applied materials.

Resources Available _____

The American Rock Art Research Association website: www.arara.org.

University of California, Los Angeles Institute of Archeology Rock Art Archive. Information available: <http://www.sscnet.ucla.edu/ioa/rockart/>.

International Newsletter on Rock Art (INORA), sponsored by UNESCO's International Council on Monuments and Sites (ICOMOS). Information available: <http://icomosdocumentationcentre.blogspot.com/2009/01/inora-international-newsletter-on-rock.html>.