# Bare Bones Guide to Fire Effects on Cultural Resources
# For Cultural Resource Specialists

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## I. Introduction

This document briefly synthesizes some of the technical information available on the effects of fire on cultural resources. This synthesis should assist cultural resource specialists with their contributions to fire management planning, compliance for prescribed fire projects, and participation in wildland fire use or wildfire events.

Research on fire effects is on-going. A publication on this topic will soon be released under the USFS Rocky Mountain Research Station "Rainbow" series, and much of the data here is from drafts of articles for that publication. While there is a lot we do not know, there is also a considerable amount of work accomplished on this topic. This brief guide summarizes the results of some of these technical studies.

Fire effects to cultural resources, and the appropriate ways to manage for these effects, are context dependent. Fire itself is dependent on a suite of variables which change across the landscape; fire in grassland is likely to produce different effects to cultural materials than fire through a forest with heavy duff. Different types of archaeological materials, such as varieties of toolstone or types of ceramics may react differently in similar fire-related circumstances. This guide offers technical information which cultural resource specialists can use to craft locally and regionally appropriate strategies for protecting cultural resources within the context of fire.

<u>References</u>: References are cited at the end of the document. Where possible, links are provided to resources that are already available on the web. The "Rainbow" publication on "Fire Effects to Cultural Resources" will soon be available on the web and those links will be added to this document. The Western Archaeological Conservation Center, National Park Service, is currently digitizing many reports concerning fire effects on cultural resources. Those reports will also be available on the web in the next few months, and will be linked to this document.

## II. Fire Basics

Fire effects to cultural resources vary depending on **temperature** and **duration** of exposure to heat. Generally, higher temperatures and/or longer duration of exposure to heat increase the potential for damage to cultural resources. Variables that affect temperature and duration include (Wiltz n.d., Hanes 2001):

- Type of fuel
- Fuel load/ distribution
- Moisture content of fuels
- Soil type, soil moisture
- Weather, terrain

As a general rule, fire does not affect buried cultural materials. Studies show that even a few centimeters of soil cover (10 cm) are sufficient to protect cultural materials (Oster, n.d.). However, there are times when conditions do carry heat below the surface, with the potential to affect buried materials. These conditions include:

- Stumps that smolder and burn have the potential of affecting buried materials that are in the vicinity.
- Heavy duff, surface logs, and roots that smolder and burn also have the potential to expose subsurface materials to heat over a period of time, and hence have the potential to affect cultural materials.

Fires that burn hot and fast through a site may have less of an effect on certain types of cultural materials than fires that smolder in the duff, or than logs that burn for a period of time.

## III. Cultural Resource Basics

When assessing the potential effects of fire on cultural resources there are some fundamental considerations (Hanes 2001, Duke et al. 2003):

- Even if fire affects certain cultural materials, that effect may not be important. That is, the effect may not actually diminish characteristics that make a site eligible to the National Register. For example, high heat may destroy obsidian hydration bands on surface artifacts, but the surface component of the site may not be of particular value in the site's overall assessment. Fire may burn the solder out of a hole-in-cap can, but this effect does not diminish the can's ability to provide chronological information for a site.
- Wildland fire is generally more destructive to cultural resources than prescribed fire, since it includes both uncontrolled fire effects and the effects of fire suppression. Management decisions may need to balance the potential effects of a prescribed burn with the risk of damage from an uncontrolled wildfire.
- Fire history may be important. When assessing the potential effects of fire to cultural resources, cultural resource specialists should consider the nature of past fires compared to the potential for fire at the current time. For example, have fires routinely burned through an area? Have conditions (e.g. fuels and fuel loads) changed significantly over time? Will the effects of fire today be significantly different—and pose a greater threat to cultural materials than in the past?
- Prescribed fire can be controlled. Cultural resource specialists can work with fire managers to determine the predicted temperature and duration of a fire through an area, and possibly to modify burn plans to minimize effects to cultural resources.
- Protecting cultural resources during fire begins with fire management planning. This is the place to define vulnerable cultural resources, appropriate protection measures for them, and appropriate management responses with regard to cultural resources in the event of wildland fire or a wildland fire use event.
- As always, consultation with SHPO, Tribes, and other appropriate entities should be part of the project planning process, especially when designing fire-specific protocols for identification and protection of potentially affected cultural resources.

## III. Fire Effects on Lithics (Deal n.d., Buenger 2003)

Fire can affect chipped and groundstone tools, primarily through changes in morphology rather than in chemistry. Residues on artifacts are not necessarily destroyed by fire. As a general rule-of-thumb, hotter temperatures and longer exposure to fire may affect lithic materials. When these materials are important, it may be necessary to take protective measures.

**Obsidian**

Fire can modify or destroy obsidian hydration rinds, but does not affect obsidian source analysis (Shackley and Dillon 2002). High temperatures, such as those experienced in a catastrophic wildfire, may be sufficient to cause obsidian to bubble and crack, loosing shape as well as hydration capacity.

The exact temperature at which obsidian is affected varies, probably due to components of the field environment and/or differences in source materials. Duration of exposure increases the effect of heat on obsidian. High temperatures and smoldering fires can both affect hydration bands.

**Obsidian: Approximate Temperature Guide (Deal n.d., Buenger 2003, Loyd et al. 2002)**

| Temperature | Effect |
|---|---|
| 300 C (572 F) | Hydration band begins to become diffuse |
| 400 C (752 F) | Hydration band not visible |
| 450 C – 800 C (842-1472 F) | Enhanced fracture lines |
| 760 C (1292 F) | Obsidian may melt |

**Chert**

Fire can also affect chert (including various silicates), through fracturing, pot-lidding, crazing, shattering, changes in color and internal luster, and other such effects which might reduce an artifact's ability to render information about the past. Temperatures which affect chert vary, possibly dependent upon source or other variables such as prior heat-treatment for tool manufacture. Generally, longer and/or hotter fires produce more intense effects upon chert artifacts (Deal n.d., Waechter n.d.).

**Chert: Approximate Temperature Guide (Deal n.d., Buenger 2003)**

| Temperature | Effect |
|---|---|
| 350 C (662 F) | May become distorted, brittle or explosive |
| 350 - 550 C (662 – 1022 F) | Cracking, Fracture |

**Basalt**

Fire can produce changes in basalt including spalling, potlidding, crazing, and fracturing; these effects possibly result from rapid cooling. There is little experimental data for fire effects on basalt. One study indicates that spalling or flaking may occur at temperatures around 350 – 400 C (662 - 752 F) (Deal n.d.).

**Groundstone**

Rock types vary in their response to fire. Sandstone reportedly cracks or fractures at a lower temperature than basalt. Granites and quartzites withstand higher temperatures. Severe wildfire may cause portable groundstone to crack or fracture. Thermal shock—such as rapid heating or cooling--can cause fracturing and exfoliating of groundstone artifacts, including bedrock mortars. Burning or smoldering fuels on groundstone artifacts or features (e.g. a fallen tree on a bedrock mortar) may contribute to increased damage during a fire. As is true for other tool types, longer exposures to heat and/or hotter fires increases the potential for artifact damage (Deal n.d., Buenger 2003).

## IV. Fire Effects on Ceramics (Rude n.d., Buenger 2003, Haecker n.d.)

Different types of clays, inclusions, and manufacturing techniques lead to different effects among distinct pottery types. Since all pottery—historic and prehistoric—has been fired to some degree, heat damage is not as significant a consideration for this artifact type as it is for others. Generally, structural damage does not occur until temperatures exceed the original firing temperature. The main type of damage noted is to the surface decoration or glaze.

### Prehistoric Ceramics

Temperatures do not exceed the original firing temperature for most prehistoric ceramics until about 600 C (1112 F) (Andrews 2004). Fire can, however, affect the appearance of pottery shards, possibly leading to mis-identification. Effects from fire include surface spalling, alteration of painted decoration, blackening and sooting, and loss of appliqué designs which may break off. In one experiment painted designs faded and turned color at temperatures greater than 800 C (1472 F). However, sooting or blackening may be removed by cleaning in a lab, and discoloration does not necessarily prevent identification of pottery type (Rude n.d.).

Fire may affect the potential for thermoluminescence (TL) dating. However, surface potsherds are generally not used for this technique, and buried potsherds are not likely to be affected by fire. Another study also showed that TL dating was not affected at temperatures below 400 C (752 F), indicating that moderate intensity wildland and prescribed fire may not have an impact on TL dating (Rude n.d.).

### Historic Ceramics

Historic ceramics consist of earthenwares, stonewares, and porcelain. These types of pottery are differentiated in part by the heat of firing. All of these pottery types may be glazed, and the glaze or other decoration is likely to be the most vulnerable characteristic. Some early glazes (e.g. majolica glaze) and glazes on "whiteware" (refined earthenware common at nineteenth and twentieth century sites) may crackle or spall even in a low temperature fire.

**Ceramics: Approximate Temperature Guide**
**(Rude, n.d., Haecker n.d., Duke et al. 2003))**

| Ceramic | Firing Temperature | Temperature Effects |
|---|---|---|
| Prehistoric | > 350 C (662 F) | Minor effects (sooting, fading, discoloration) |
| Prehistoric | > 600 C (1112 F) | Structural change possible |
| Prehistoric | > 400 C (752 F) | TL dating potential compromised |
| Historic: Unrefined Earthenware | 500–900 C (932–1652 F) | Glazes may crackle and spall at low fire temperatures |
| Refined Earthenware | 1100–1500 C (2012-2732 | Glaze may crackle at low |

| | | |
|---|---|---|
| (“whiteware”) | F) | fire temperatures |
| Stoneware | 900–1100 C (1652-2012 F) | Temperatures above firing point may oxidize glaze or crack shards |
| Porcelain | 1250-1450 C (2282-2642 F) | Temperatures above firing may oxidize glaze or crack shards |

## V. Fire Effects on Organic Materials

**<u>Organic Materials</u>**

Organics will usually burn or alter at lower temperatures than inorganic items. Artifacts (e.g. basketry, digging sticks, clothing, textiles) and features (e.g. structures, bow-stave trees, wikiups, dendroglyphs) made of or containing organics such as wood, leather and hide, or cordage will need protection or treatment before any fire burns through a site containing such items.

**<u>Bone and Shell</u>**

Bone and shell can sustain some degree of burning without complete destruction (Buenger 2003):

**Bone and Shell: Approximate Temperature Guide (Buenger 2003)**

| Material | Temperature | Effect |
|---|---|---|
| Bone | 200 C – 400C (392-752 F) | Bone chars, becomes darkened |
| Bone | 600 C – 800 C (1112-1472 F) | Bone becomes calcined |
| Shell | >300 C – 400 C (572-752 F) | May delaminate, burn |

**<u>Organic Residues</u>**

Plant and animal residues may survive exposure to fire. Pollen may be destroyed at temperatures greater than 300 C (572 F), but animal proteins survive to 800 C (1472 F) (Jones n.d.)

## VI. Fire Effects on Historic Materials

The following chart provides melting points for materials commonly found at historic sites. Fire may produce complex interactions which affect these baseline temperatures, however. Metal alloys may react differently, and metal artifacts/ materials which do not melt may warp. The chart is derived from Haecker (n.d.).

**Melting Points of Materials Commonly Found on Historic Sites**
**(Haecker n.d.)**
Temperatures are Approximate

| MATERIAL | TEMP (F) | TEMP (C) |
|---|---|---|
| Plastics | 167-509 | 75-265 |
| Solder (tin-alloy) | 275-350 | 135-177 |
| Tin | 449 | 232 |
| Pot Metal (copper-lead alloy) | 572-752 | 300-400 |
| White pot metal | 572-752 | 300-400 |
| Lead | 621 | 327 |
| Zinc | 707 | 375 |
| Glass | 1100-2600 | 593-1427 |
| Unrefined Earthenware | 1112 – 1832 | 600-1000 |
| Aluminum | 1220 | 660 |
| Brass (yellow) | 1710 | 932 |
| Silver | 1760 | 960 |
| Stoneware | 1832-2192 | 1000-1200 |
| Gold | 1945 | 1063 |
| Copper | 1981 | 1082 |
| Refined Earthenware | 2192-2912 | 1200-1600 |
| Cast Iron | 1920-2550 | 1350-1400 |
| Steel (stainless) | 2600 | 1427 |
| Nickel | 2651 | 1455 |
| Steel (carbon) | 2760 | 1516 |
| Iron | 2795 | 1535 |
| Porcelain | 2822 | 1550 |

**Cans**
Cans from late nineteenth and twentieth century sites are made from rolled, tinned steel. Fire may damage labels, melt solder on the older "hole-in-cap" cans, and burn off the tinned surface. However, can morphology (size, shape) which is usually the key to identification is unlikely to be affected by fire (Haecker n.d.).

## VII. Fire Effects on Inorganic Architectural Materials (Buenger 2003, Haecker n.d.)

**Sandstone (Architectural)**
Fire will damage architectural stone. Above about 300 C (572 F) sandstone will begin to oxidize and at higher temperatures (pervasive at 700 C, 1292 F) it will spall and fracture. These effects can significantly alter features constructed of this material and may constitute a significant effect to sites with these features (Buenger 2003).

**Adobe**

Adobe bricks and mortar and rammed earth walls are created from non-flammable sand, silt, and clay. These materials may be mixed with straw, however, and construction of adobe structures will often include wooden poles and posts, which may burn. Walls may be smoothed with adobe plaster. When intact, an adobe structure will resist fire. Plaster that is made with gypsum will spall when exposed to sufficient heat, which may expose more flammable parts of a structure. If the straw used in the adobe burns, the structure may also be weakened (Haecker n.d.).

**Cement-mortared Fieldstone, Firebrick, Cinder Block, Cement Aggregate**

These materials are generally resistant to fire. Low-fired, non-commercial, locally made brick may weaken and crumble in a hot fire. Hot fires will also calcinate lime-based mortar, causing it to crumble and the wall to eventually collapse. Masonry and cinder block may spall, resulting in damage to the surface of the structure (Haecker n.d.)

## VIII. Fire Effects on Rock Art

Fire has a high potential for damage to rock art. Though there are no specific temperature guidelines for rock art, fire effects include soot smudging and discoloration from smoke, which obscure the rock art images; degradation of the rock surface from spalling, exfoliation, and increased weathering; changes in organic paints due to heat; and damage to rock varnish which may destroy its potential to date the art (Tratebas 2004, Kelly and McCarthy 2001).

Fire retardants, slurry, foam, and water should never be dumped/ sprayed on rock art during a fire.

## IX. Effects of Fire Suppression on Cultural Resources

**Ground Disturbance**

Fire suppression activities have considerable potential to damage archaeological and historic sites and materials from many activities, including fireline construction (hand line and bulldozer line), establishment of helicopter bases, fire camps, and related activities.

**Fire Retardant/ Chemical Products**

Application of fire retardant and other chemical products has the potential to affect cultural resources, although use of fire retardants on historic structures may protect them from destruction during a fire. Cultural resource specialists may need to consider the effects of fire itself versus the effects of retardant use or the possibility of other protection options during a fire. See these references for further information: Saleen 2004, Corbeil 2002, and the USDA Wildland Fire Chemical Systems website. This website (see references at end of this document) has brief descriptions of the types of chemicals used and their potential effects on structures.

There are various types of products:

- Long-term retardants, which contain salts (fertilizers) with additives that may color covered items red or which may turn metals bluish;
- Foam fire suppressants, which are detergents and surfactants (wetting agents);
- Water enhancers which increase the effectiveness of water.

There are various potential effects from use of retardants, foams, and water:

- Rapid cooling: dumps of any of these materials on hot surfaces may cause effects to archaeological materials (e.g. artifact fracture) from rapid temperature change;
- Materials dumped onto fragile archaeological features may break/ displace them;
- Long-term retardants contain salts which can be desiccants, which damage old, fragile wood and may cause spalling in sandstone; chemicals may cause corrosion in metals; iron oxide additives may leave a permanent red stain and corrosion inhibitors in the retardant may turn surfaces, especially metals, blue or black;
- Foams may hasten rusting on metal surfaces by removing protective coatings and may cause wood to flake due to swelling and contracting;
- Water enhancers are desiccants and may damage wood surfaces, strip surfaces of finishes, and damage sandstone; they are also difficult to remove from wood surfaces, especially for old or fragile wood.
- Retardant should be washed off important structures as soon as possible. Pre-soaking, then hand-brushing with water and a mild detergent may work for sandstone or painted wood. Metals and glass may be wiped with water and a mild detergent. Power washing, sand-blasting, and acid based washes may damage historic materials.

## X. Effects of Fire on Archaeological Sites

There are a number of potential fire effects to cultural resources which do not depend upon effects to specific materials, including :

- Increased visibility from vegetation burn-off and consequently greater vulnerability to vandalism
- Physical damage to sites from snags/ trees falling
- Soil erosion and loss of archaeological data
- Increased damage from rain, new drainage patterns, flood
- Increased rodent and insect activity within site soil matrix

## XI. Protection Protocols

### Management Measures

There are a number of actions which cultural resource specialists can take or promote to help preserve cultural resources from the effects of fire, including fire suppression:

- Serve as a technical specialist during fire events; the best protection for cultural resources during a wildfire is to have knowledgeable professionals ready and able to participate in the suppression effort.
- Prepare plans for protecting high value cultural resources before a fire occurs, and make sure that appropriate authorities know about and have access to these plans. Define ahead of time those high value cultural resources which are really worth saving. “Fire proof” vulnerable sites ahead of time when possible.
- Work with prescribed fire project planners to accommodate cultural resource concerns in the burn prescriptions.
- Ensure that cultural resource concerns are included in fire management plans, especially with regard to appropriate management responses to fire whenever it might occur in specific areas. For example, where there are areas of high value cultural resources and these are also areas where fires will be

suppressed, ensure that plans include the necessity for “ordering up” a cultural resource specialist when a fire occurs.
- Track fire effects on cultural materials in local contexts, and share that information regionally. When possible, do “before/after” experiments of prescribed burns, to assess the effects of fire in specific, local contexts on those archaeological materials which are typical in your area.

**Protection measures**

There are many actions which will help protect cultural resources from the effects of fire. Cultural resource specialists should work with fire specialists to implement these measures.

In some cases there may be adverse effects associated with implementing the protection measures, such as using retardant on historic structures during a fire, or clearing vegetation which screens sites from vandals. In these cases, of course, the effects of the protection measures must be weighed against the potential for loss of the resource due to fire. In all cases, prescribed fire offers the chance of greater control over fire effects than does wildfire.

Some of these protection measures are pertinent to prescribed fire, some to wildfire, and some to both. This list is not exhaustive.

- Identify and avoid vulnerable cultural resources. Note that avoidance may contribute to greater likelihood of wildfire in the future when sites have high fuel loads, or that avoidance may create “vegetation islands” that identify sites to vandals. If necessary, work with fire planners to minimize these effects.
- Record and collect information that would be lost during a fire. For important rock art, thorough recordation and collection of samples of the surface varnish for dating may be the best protection possible.
- Manually reduce fuels on and/or around vulnerable sites; pile debris offsite.
- Create fire breaks near/ around sites. This may be an effective way to protect rock art panels, for example.
- Use retardant or foam to protect structures.
- Wrap structures in fire proof materials to protect from fire.
- Remove logs/ heavy fuels from vulnerable sites/ features (e.g. clear snags off bedrock mortars), or cover with foam or retardant prior to burn.
- Flush cut and cover stumps with dirt, foam, or retardant, where burnout could affect subsurface cultural resources.
- Modify burn plans to minimize effects to cultural resources, such as burning when duff has high moisture.
- Identify and reduce hazard trees next to structures.
- Use low intensity backing fire in areas near historic features.
- Saturate ground/grass adjacent to vulnerable structures with water, foam, or gel before burning.
- Preburn site at lower intensity than planned for surrounding areas.
- Limit fire intensity and duration over vulnerable sites.
- Use a fast-moving, higher intensity fire over lithic scatters, where rock materials are vulnerable to longer-duration heating.
- Wrap carved trees, dengroglyphs, and other such features in fire retardant fabric.
- Limb carved trees to reduce ladder fuels, if possible to do so.

- Cover rock art in fire retardant fabric.
- Minimize fuels and smoke near rock art.
- Cover fuels near rock art with foam, water, or retardant, avoiding the rock art.

For a good discussion of protection measures for historic structures, see Matz (2002)

## XII. Summary

Fire effects are context-dependent. The effects of fire on cultural resources depend upon factors which vary from place to place, including physical factors such as fuels, terrain, site type, and cultural materials present. Managing for fire effects also depends upon the value of the cultural materials at risk. In areas where surface materials have little integrity, for example, due to collecting, erosion, past fires, or other factors, surface effects from fire may be of minimal consideration.

The brief synthesis of fire effects information in this guide should assist cultural resource specialists to address the conditions that apply to their local/ regional circumstances. There are few hard and fast answers; local circumstances and conditions require appropriate strategies based on good technical information.

## XIII. References

Some of these references will be available on-line in the next few months. They will be added to this document as they are posted on the Web.

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USDA Wildland Fire Chemical Systems

Links to information on wildland fire chemicals: http://www.fs.fed.us/rm/fire/

Wildland Fire Chemical Products: (Brief descriptions of chemicals used): http://www.fs.fed.us/rm/fire/documents/defin.pdf

Wildland Fire Chemical Products Effects on Structures: http://www.fs.fed.us/rm/fire/retardants/current/gen/pdf/effstructure.pdf

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