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Chapter 7:

The Effects of Fire on Subsurface Archaeological Materials

Fire and Cultural Sites

In this chapter, we concentrate on the effects of fire on subsurface archaeological deposits: the matrix containing post-depositional fill, artifacts, ecofactual data, dating samples, and other cultural and non-cultural materials. In order to provide a context for understanding these data, this paper provides a summary of previous research about the potential effects of fire on subsurface cultural materials.

As a case study, the results of recent archaeological testing at six Ancestral Puebloan sites located in Bandelier National Monument, New Mexico, are presented. The tested sites are all prehistoric structural sites dating to the period A.D. 1200-1500. The specific focus of the study was to define the extent of alteration to subsurface deposits when archaeological materials experienced different burn severities. The results are discussed in terms of the current status of knowledge about fire effects to buried cultural materials.

Investigation of the nature and extent of fire-related alteration of cultural materials represents a significant cultural resources management concern. Wildland fires can be expected to occur naturally wherever there are sufficient fuels. A field researcher could expect that a given archaeological site in a fuel-rich area has been

burned over one or more times in the past. This fact leads some to conclude that the impacts wrought by contemporary wildland fires are negligible, ignoring a crucial element of the contemporary fire scenario—fire exclusion. Since the nineteenth century, most natural fires occurring in rural landscapes have been suppressed as quickly as possible, while in the more distant past most fires were allowed to burn out naturally. Fire suppression has led to large accumulations of fuels and drastic alterations of vegetation patterns. These factors, in turn, support fires that burn faster, more intensely, and potentially wreak more damage to cultural sites and materials than fires of the past. The impacts of contemporary wildland fires on archaeological sites are potentially profound.

Available data, though scant, indicate that in addition to causing the destruction of important sources of information, such as organic materials, the catastrophic wildland fires of the modern era may confound chronometric assays, technological analyses of ceramics and lithics, and more. Understanding the role and function of wildland fires in ecosystems past and present has broad implications for the interpretation of data from archaeological sites located in all areas suspected to have been affected by fire. For managers

of cultural resources, evaluating the degree to which buried archaeological materials have been adversely impacted by wildland fire is an essential part of post-fire assessment and treatment.

For purposes of this discussion, the term “surface” is used in the manner commonly employed by archaeologists. The surface of an archaeological site is generally assumed to be the contemporary soil layer, generally the uppermost stratum at which evidence of human activity can be detected. Architectural stone, items such as sherds and lithics, and other cultural materials are frequently present on a site surface and are considered part of the site’s contents. Vegetation, accumulations of soil and plant debris such as duff, and other materials deposited on the human activity surface following site abandonment may obscure the archaeological surface and frequently must be removed before the site can be mapped or further studied. An archaeological site surface is thus more-or-less analogous to the mineral soil surface as the term is used by the fire community. Frequently, reports of archaeological survey include a discussion of the percentage of ground surface visible at the time the fieldwork was conducted, specifically describing the portion of the contemporary soil layer unencumbered by duff, snow, grass, or other materials that could obscure features and artifacts.

Fire Effects and Subsurface Cultural Resources: Previous Research

Previous investigations of the effects of fire on cultural resources have included both post-fire and experimental studies. Post-fire studies are conducted following a fire (either prescribed or wild), and involve collecting data from features and/or artifacts located within the burn perimeter. Experimental studies have been conducted in field settings as well as laboratory environments. Field experiments generally involve burning a parcel of land or a smaller location—such as piles of slash—and recording the effects on cultural materials, surrounding soils, etc. In laboratory environments, fire effects studies involve heating different artifact types (or raw materials) to varying temperatures and recording thermally induced alterations.

Experimental studies of the first type are primarily concerned with replicating the effects of prescribed or natural fires on surficial and buried archaeological materials, an endeavor with significant implications for archaeological formation processes. Laboratory research addresses fire effects from two perspectives: (1) the effects of post-occupational fires on archaeological materials, and (2) the effects of human fire use to modify materials.

Sidebar 7-1—Subsurface

Long Mesa Fire, Mesa Verde National Park, Colorado, July 8–23, 1989

References: Eininger (1990); Fiero (1991); Fish (1990); Kleidon and others (2007)

General Information:

- Elevation: 2,438.4 m (8,000 ft)
- Vegetation: pinyon-juniper
- Topography: northern 6.44 km (4 miles) of Long Mesa and portions of adjacent canyons and drainages
- Type of research: post-burn site assessment

Fire Description:

- Temperature range: hot and fast burn with variable intensities; 25.5–32.2 °C (78–90 °F) range
- Duration: 15 days
- Relative humidity: 15–85%
- Fuel: high fuel loads with continuous ladder fuels; fire occurred after the dry season in pinyon-juniper vegetation interspersed by grassy clearings
- Type of fire: wildland
- Energy release component (ERC): 39–70
- Burning index (BI): 19–67

Discussion

The 1989 Long Mesa Fire occurred in Mesa Verde National Park, consumed about 12 km² (3,000 acres) of land and burned uncontrolled for 15 days. Damage assessments of known archaeological sites in the burn area were conducted directly after the fire. Twenty-three new sites were located and assessed; 165 of the 194 known sites were successfully relocated.

Field crews recorded the percentage of each site that was affected by fire and described burn severity. They also noted vegetation loss and impacts to architectural materials and artifacts. Suppression activities caused minor damage to only two sites. This was due largely to the work of archaeological monitors who assisted fire crews in avoiding damage to archaeological sites and to the fact that bulldozers and heavy equipment were not used.

Fire effects on archaeological sites were ranked as low, moderate, or high. High impacts included spalling and oxidation of architectural stone, scorching of artifacts and complete loss of vegetation. Sites with low impacts exhibited little or no observable fire effects; these sites were either burned only over a small section of the site area or subject to low burn intensity. Of the 188 sites evaluated, 139 (74%) were burned; 36 (19%) were highly impacted, 32 (17%) were moderately impacted and 71 (38%) exhibited only low impacts (Eininger 1990).

“Grab samples” of fire-affected and archaeologically important artifacts were collected during site assessments (Eininger 1990). The samples included 674 sherds and 172 lithics. Fire effects on these artifacts included fire-blackening, cracking, change in luster, potlidding, and color change. None of these effects appeared to affect the artifacts’ information value (Eininger 1990).

Soil samples were collected from excavated test units at two of the burned archaeological sites; a few test units were also excavated in non-archaeological burned and unburned areas to provide control for analysis of fire effects on pollen (Eininger 1990; Fish 1990). Site rehabilitation, including erosion control, water diversion, and ruins stabilization, was conducted during 1989 and 1990 (Fiero 1991).

Dome Fire, Bandelier National Monument and Dome Wilderness, New Mexico, 1996

References: Ruscavage-Barz (1999); Ruscavage-Barz and Oster (1999); Steffen (2005)

General Information:

- Elevation: 1,782–2334 m (5,847–7,658 ft)
- Vegetation: pinyon-juniper and ponderosa pine
- Topography: Pajarito Plateau, on the east flank of the Jemez Mountains

Fire Description:

- Temperature range: 10.5–26.7 °C (51–80 °F)
- Duration: 9 days
- Relative humidity: 3–14%
- Fuel: The fire burned on the Pajarito Plateau, and in dissecting canyons, through pinion, juniper woodlands, ponderosa pine, and mixed conifer forests.
- Energy release component (ERC): 49–57
- Burning index (BI): 39–72
- Type of fire: wildland

The 1996 Dome Fire¹ started on April 25th and burned more than 66.8 km² (16,500 acres) of Bandelier National Monument and the Jemez District of the Santa Fe National Forest before it was controlled on May 3rd. Assessments of archaeological sites were conducted immediately after the fire in 1996 and in 1997. Sites were assessed for burn severity and potential heritage resource damage. Of the 515 sites assessed, 276 were impacted by fire. No sites had been disturbed by fire suppression activities. Direct and indirect effects of fire included spalling, cracking, and oxidizing of stone architecture, and soil erosion due to vegetation loss.

¹ This case study refers only to the 1996 Dome fire, not the 1993 Dome Fire that occurred in the same area.

In 1997, Bandelier National Monument conducted a study of subsurface heating effects (SHE) on archaeological resources affected by the Dome Fire. Between May 13th and August 7th, archaeologists excavated five burned sites. Burn severity at each site had been recorded during earlier assessments. Two of the sites were heavily burned, one was moderately burned and two were burned severely. A sixth site, excavated for emergency data recovery during June of 1997, was also included in the study. Data recovered from excavation of the unburned portion of this site were used for statistical control.

Subsurface artifacts, botanical specimens, pollen samples, and faunal remains were collected during excavations and analyzed to assess fire impacts. Researchers examined the extent and depth to which fire affected these subsurface cultural materials and analyzed data to determine whether subsurface impacts reflected burn severity. Subsurface fire effects were found only to be significant near to burned roots and to be independent of fire severity.

Post-Fire Studies of Archaeological Sites

Post-fire studies conducted in the aftermath of a natural or wildland fire comprise a major focus of research addressing fire effects on cultural resources. A limited number of rigorous post-fire studies of subsurface archaeological materials and contexts affected by wildland fire events have been conducted prior to the research reported here (Connor and Cannon 1991; Connor and others 1989; Duncan 1990; Eininger 1990; Fiero 1991; Fish 1990; Hull 1991; Lent and others 1996; Rowlett 1991b; Traylor and others 1990). In general, these studies tend to describe subsurface heating effects as negligible below certain depths. These statements are typically framed, however, in terms of visible evidence of fire damage to subsurface archaeological materials in comparison with surface materials. A subset of the post-fire studies do not deal with archaeological sites, but instead focus on particular archaeological material types such as ceramics, lithics, etc.

The post-fire studies of burned sites reported here suggest that heating generally does not affect materials at depths greater than 15 centimeters (6 inches) below the ground surface, even at heavily burned sites. The exception to this, as indicated by the subsurface heating effects study described below, is the burnout of tree roots, which can penetrate well below 15 centimeters (6 inches) depending on the size of the root (and the amount of available oxygen) and serve as a conduit to carry heating effects to strata deep within

sites (also see Hvizdak and Timmons 1996; Timmons 2000). Fire may also burn longer and deeper below the ground surface in organic sediments (including cultural deposits), which contain more fuel.

An additional issue of concern is whether fire creates pseudo “features” that could be mistaken for cultural features (Connor and Cannon 1991; Conner and others 1989; Timmons 2000). Fire-created features can result from burning deadfall, which causes soil oxidation in a pattern resembling a hearth or fire pit. In profile, these stains are crescent-shaped, with the thickest part of the crescent forming immediately underneath the deadfall. Treefalls can also leave basin-shaped imprints or displaced piles of rocks that resemble cultural features. Differentiating fire-generated features from cultural features is particularly important for studies that deal with the earliest use of fire by humans (James 1989), and some researchers are developing methods toward this end (Bellomo 1991).

Post-fire data particularly germane to the case study results discussed below were collected from various prescribed fire burn units on the Kootenai National Forest in Montana from 1996 to 1999 (Timmons and others 2000). Monitoring data document a variety of potential and actual fire effects on cultural materials and indicate that severity of effects results from the interplay of many factors, including material composition, provenience, fuel loads, duration and intensity of fire, moisture levels, and degree of heat penetration. Most important for consideration here were data relating to stump “burnouts,” where the most dramatic effects from the Kootenai monitoring projects were observed. In the Dodge Creek prescribed burn unit, massive Douglas fir stumps that burned out left holes in approximately 0.4 percent of the burned area, resulting in numerous stump cavities up to 1.5 meters (5 feet) in diameter and depth, with root cavities extending out 5 meters (16.4 feet) (Timmons and others 2000). Within the boundaries of one 16-acre site approximately 688 stumps were estimated to be present. The Kootenai data also indicated that the age of the stumps affected their susceptibility to fire. In the Green Basin prescribed burn unit, the older and drier stumps were found to be more likely to burn out in a single event, while green stumps only burned partially (Hemry 1996).

Experimental Studies Dealing with the Effects of Heat on Artifacts, Ecofacts, and Datable Materials

Experimental studies of fire and heating effects can be divided into laboratory and field experiments. The latter can be further subdivided into those that attempt to replicate the conditions found in prescribed

fires, and those that attempt to replicate the conditions found in wildland fires. Instances of the latter are extremely rare due to the danger of an experiment running out of control and becoming an actual wildland fire. For this reason, such experiments are rarely conducted. The only case of an “experimental wildland fire” documented in the literature was carried out in a grassland environment, where the grass was cut and the soil surface was exposed in an area surrounding the burning experiment to prevent its uncontrolled spread (Bellomo 1991). Such procedures are less practical in forested areas, and experimental studies conducted under these conditions, while still very useful, inevitably produce results that reflect the more sustained heat and longer burn times created by slash piles (Sackett and others 1994), and may not actually reflect the conditions occurring in a wildland fire, except possibly in cases where large fuel loads have accumulated.

Both experimental and post-fire studies have dealt with the effects of fire on various artifact types. The goal of the post-fire studies is simply to understand and recognize the effects of wildland and/or prescribed fires on these materials. The goals of the experimental studies, however, are not limited to the study of effects from these two types of fires, but rather extend their breadth of inquiry to include understanding and recognizing the effects of intentional heat treatment on archaeological materials. Flaked stone represents the most common focus of the latter type of study, as researchers have attempted to establish the means for differentiating intentional from unintentional heat treatment and also to understand how heat treatment changes the “workability” of particular types of stone.

Most experiments mimicking prescribed burns have attempted to replicate low-intensity fires rather than the high intensities characteristic of wildland fires. Comparisons of impacts between the two types of fires are valid. When considering subsurface materials, however, one must remember that soil serves as an insulator to mitigate the effects of fire, even fires of very high intensity. For this reason, even high-intensity wildland fires may not impact subsurface deposits—except in certain instances. Fires ranging from low to high intensity could yield similar subsurface effects due to this insulation.

Five experimental studies dealing with the effects of subsurface heating are particularly important for consideration. One dealt specifically with prairie fires (Picha and others 1991), two dealt with burning slash piles (Hartford and Frandsen 1992; Sackett and others 1994), and one dealt with moderate and high intensity fires (Pidanick 1982). The results of the prairie fire indicated negligible effects to subsurface artifacts because of only minimal heat penetration to subsurface

deposits. The subsurface ground temperature showed a 2 to 4 °C (35.6 to 39.2 °F) increase during the fire, which would not be enough to damage archaeological materials or soils.

A study by Henry (1996) in the Green Basin prescribed fire unit attempted to assess the effects of prescribed light intensity fire on groups of historic and prehistoric materials at varied depths and with exposure to a variety of combustible surface materials. The historic materials were placed in test holes designed to simulate a historic dump, while the prehistoric items (consisting of replicated mudstone and quartzite tools, and antler) were placed in small groups at four different depths and on the surface. A variety of fuel types were located on or over the cultural materials. Post-fire surface observations and excavations documented a variety of fire effects on items located on the ground surfaces and within the first 4 to 5 centimeters (1.6 to 2 inches) below the surface. The most severe effects were noted where a stump had burned out completely, to a depth of 80 centimeters (31.5 inches). A week after the experimental fire, a tree root was observed, still burning, approximately 3 meters (10 feet) away from its stump (Henry 1996).

Thermal Alteration of Cultural Materials and Features

Both experimental and post-fire studies have investigated the effects of fire on various types of artifacts and raw materials. Post-fire studies generally focus on documentation and explanation of the effects of natural or prescribed fires on these materials. While providing data that are useful in the interpretation of naturally induced fire effects, experimental studies also include investigation of the effects of intentional heat treatment. Flaked stone, in particular, has been a primary focus of many experimental studies, as researchers have attempted to differentiate intentional from unintentional heat treatment and also to understand how heat treatment changes the “workability” of particular raw materials. The results of previous studies that have considered the effects of heat on ceramics, chert, obsidian, ground and architectural stone, bone, paleobotanical materials, and chronometric samples are briefly reviewed below.

Ceramics—Given that ceramics are produced by exposure to heat, any subsequent refiring of ceramic materials may change attributes of appearance and technology. Refired ceramics may be difficult to analyze due to fire-induced changes.

Studies of thermal alteration to prehistoric and historic ceramics are thoroughly discussed in chapters 3 and 6, respectively. Post-fire studies that have considered ceramic materials describe sooting or smoke

blackening as the most common fire effect (Eininger 1990; Jones and Euler 1986; Lent and others 1996; Lissoway and Propper 1988; Picha and others 1991; Pilles 1984; Schub and Elliott 1998; Traylor and others 1990). Those studies with a subsurface component note that subsurface ceramics are minimally affected by fire (Lent and others 1996), and that, in general, only those ceramics located immediately below the surface are impacted. The studies suggest that surface ceramics have the greatest potential for fire damage, and exhibit a range of effects including sooting, spalling, cracking, and oxidation.

The “direct effects” of heating are not the only factors to consider with regard to damage to ceramic artifacts. Chemical retardants are often used during fire suppression, and can have an effect on ceramic artifacts. Oppelt and Oliverius (1993) carried out a study of the effects of Firetrolä on prehistoric ceramics. Firetrolä is a foaming detergent used to extinguish forest fires; it is not the same chemical used in “slurry.” Ceramic sherds were placed in experimental fire plots and covered with pine duff. As the plots burned, they were sprayed with different concentrations of the foam. The results indicate a negligible effect to sherds from the foam. Sherds were primarily blackened from oxygen depletion, which caused a reducing atmosphere. However, the duff covering, and not the foam, may have caused this condition. Sherds sprayed with a 1 percent concentration of foam exhibited heavier smudging than those sprayed with a 0.3 percent concentration. Sherds in the 1 percent foam group exhibited carbon impregnation to depths of 0.5 millimeters (0.02 in.) into the sherds. The only potential problem with the use of foam is that it may give some ceramics the appearance of being smudged, which could be mistaken for a product of the original firing process.

Chert—Chert has been the subject of numerous experimental studies, particularly because of its abundance at many archaeological sites, its desirable flaking qualities, and the frequency with which it was intentionally heat-treated by prehistoric peoples. The effects of heating on chert are discussed in detail in chapter 4. Post-fire studies that have considered lithic materials generally do not differentiate chert from other lithic materials. These studies have, however, produced some interesting observations that are applicable to chert as well as other stone tool source materials. Discoloration, fire blackening, and luster appear to be the most common fire effects that have been noted on lithic artifacts (Lent and others 1996; Schub and Elliott 1998). Patina develops on some materials (Traylor and others 1990), while other thermally altered materials exhibit crenated (“potlid”) fractures and crazing. Obviously any of these effects could compromise interpretations of intentional thermal pre-treatment.

Obsidian—The effects of prescribed and natural fires on obsidian have recently become a “hot topic” due to the concern with the reliability of obsidian hydration as a dating technique. Thermal alteration of obsidian artifacts that have been through a fire is discussed in chapter 4, including the implications of fire-damaged obsidian for obsidian hydration. Unlike chert or other cryptocrystalline silicates, thermal pretreatment of obsidian does not improve its “workability.” Thus any thermal effects observed on obsidian artifacts are presumed to be unintentional, resulting from accidental exposure to a heat source.

Ground Stone and Architectural Stone—The appearance of ground stone and masonry can be significantly altered by fire. These materials may take on the appearance of fire-cracked rock (FCR), which results when rocks are naturally or culturally exposed to high temperatures resulting in thermal alteration, including spalling, fracturing, and discoloration. Concentrations of archaeological FCR are often interpreted as thermal features such as hearths, stone boiling middens, or roasting pits. Ground stone or masonry thermally altered by an intense fire may be mistaken for FCR from thermal features. Stone from thermal features—such as hearths or stone boiling features—or other types of features may also be displaced due to the creation of holes or pits resulting from stump burnouts.

Ground stone and masonry have been the subject of a limited number of experimental studies. Those that have been carried out, however, provide general information regarding temperature thresholds for damage and visible effects of fire. If the rocks contain sufficiently high natural iron content and the right chemical composition, oxidation of their outer layers by fire may produce a reddish halo effect (Peter Bennett, personal communication 1997). This effect may be observed by breaking the rocks open, or by examining rocks already broken by thermal shock caused by exposure to heat. Evidence of thermal shock such as spalling and cracking is also an index of fire alteration (Lissoway and Propper 1988). Damage of this type apparently does not occur until temperatures exceed 300 °C (572 °F) (Pilles 1984).

A number of post-fire studies have documented thermal alteration to ground stone and architectural stone attributable to fire (Eininger 1990; Elliott and others 1998; Lent and others 1996; Lissoway and Propper 1988; Schub and Elliott 1998; Traylor and others 1990). Fire effects include smoke blackening, spalling, cracking, discoloration, and oxidation of surface materials. For architectural stone, the combination of fire effects and erosion may confound identification feature type and number of features from surface observation (Lent and others 1996).

An experimental study conducted by archaeologists from the Center for Environmental Archaeology and

Texas A&M University investigated fire effects as site formation processes on artificial rock features in several different settings on the Kootenai National Forest (Thoms 1996). Subsurface basin, platform, and pile features intended to simulate thermal features typical for cultural sites on the Forest were built around both young (10-centimeter [3.9-inch] diameter) and maturing (30+ years old) ponderosa pines; each feature contained stream-worn cobbles and pseudo artifacts. Surface observations following the treatment of the sites by fire included the creation of a “tree well” or hole where one of the older trees burned. Field observations collected several months after the fire documented that rocks from the experimental feature were collapsing into the hole where they were redeposited in a pile some 40 centimeters (15.7 inches) below the surface. The archaeologists interpreted their preliminary results as indicating that “rock-rich” features adjacent to burning trees or stumps may become disarticulated and redeposited as “reconstituted” features that may, however, retain potential information (Thoms 1996).

Bone—Studies that address the effects of heat on bones, both human and animal, are usually geared toward understanding the changes that occur in bone at different temperatures. Bone is significantly affected by heat, even at relatively low temperatures (Bennett and Kunzmann 1985). Old bones (i.e., those likely to be encountered at archaeological sites) exhibit a slight darkening of the edges at 300 °C (572 °F), acquire a chalky appearance at 400 °C (752 °F), and become “severely” chalky at 500 °C (932 °F), resembling bone exposed to arid conditions for a great length of time. Shipman and others (1984) have noted changes in color, microscopic morphology, crystal structure, and shrinkage in bone exposed to fire. All three color components (hue, value, and chroma) become progressively more diverse as temperatures increase; changes in low and neutral values begin to occur at 400 °C (752 °F).

Because post-depositional processes can also affect bone color, changes in color cannot stand alone as indices of the temperature to which archaeological bone has been heated in the past. Fortunately, however, structural changes may be documented. When examined microscopically, bone tissues appear normal at temperatures below 185 °C (365 °F). An increase in tissue roughness occurs by 285 °C (545 °F), with tissue becoming glassy by 440 °C (824 °F). Tissue becomes frothy by 800 °C (1472 °F), and the frothy areas coalesce into smooth-surfaced nodules by 940 °C (1724 °F). Bone heated to temperatures higher than 645 °C (1193 °F) tends to exhibit larger crystals than bone heated to temperatures below 525 °C (977 °F). The most ambiguous results occur for shrinkage, where the mean percent shrinkage is not constant at different temperatures.

These data indicate that heat effects on bone range from minimal to extreme. The rate of temperature increase also affects how quickly bone is broken down. The more rapid the temperature increase, the faster bone is hydrolyzed, chemically altered, and destroyed. One can infer from these studies that subsurface bone probably will not be significantly altered due to the insulating effects of the surrounding sediments.

Pollen and Other Botanical Remains—Analysis of fossil pollen grains, or *palynology*, can be used to reconstruct the vegetation history of an area. It thus provides information about paleoecology that can be extremely useful for both cultural and natural resources managers. It is also sometimes used for archaeological cross-dating (Michels 1973).

Pollen analysis takes advantage of the fact that wind-pollinated species of trees, shrubs, and grasses release large quantities of tiny pollen grains (0.025-0.25 cm [0.01-0.1 in] diameter, less than 10^{-9} grams in weight). The grains are propelled by winds up to distances of 100 to 250 kilometers (62 to 153 miles). Throughout the year but especially during flowering season, pollen grains from the composite vegetation of a region accumulate on the ground as “pollen rain,” depositing several thousand grains per square centimeter. Stratified sediments of pollen rain constitute recoverable records of past vegetation and, considered in sequence, can sometimes provide a relative dating technique for archaeological sites. Regional climatic change leaves traces in the pollen sequence by changing the relative composition of key floral species, thus each period in a pollen chronology has a “signature” that can be compared to the regional pollen spectrum.

Archaeologists collect samples for pollen extraction during excavation. First, a control sample of soil containing modern pollen rain is collected from a site surface for comparative purposes. Subsurface pollen samples are collected from undisturbed loci with clear archaeological contexts, such as within defined features or beneath fallen building stones. Within stratified sites, samples are collected from each stratum or level, highest to lowest, as pollen “columns.” Occasionally, artifacts such as metates are given a “pollen wash” to secure a sample.

In order to “type” pollen grains, numerous attributes of the size, color, and the precise shapes of the walls of the grains are examined under binocular microscopy, at magnifications from 200 to 1000x. In the laboratory, samples are prepared for analysis in a variety of ways, depending upon the kinds of pollen anticipated—some species are more fragile—and the kind of soil matrix the pollen is extracted from. Generally, the pollen is sieved, washed, and stained. In order to be useful, pollen grains must be identifiable as to genus and, if possible, species. Fire effects to pollen can include

consumption (as with any organic material, but less likely in below-ground contexts) as well as thermal alteration.

Macrobotanical specimens analyzed by archaeologists are preserved portions of plants. These can include pieces of formerly cultivated species such as corn, beans, squash, amaranth, and sunflowers, as well as other vegetative materials that were economically important (such as fibers used for cordage, matting, and clothing). Such specimens are extracted from soil samples collected during excavation, preferably from undisturbed features. The soil samples are processed by combining them with water. The heavier soils and rock fragments sink, while the floating “light fraction” is skimmed off with a strainer, placed on cheesecloth to dry, tied off, and bagged in paper. Once drying is complete, the specimens are classified according to species. In some cases, the heavy fraction is screened and any identifiable botanical fragments are also identified. Macrobotanical specimens damaged by fire can be consumed or so altered by exposure to heat and soot that identification is difficult or impossible.

The few fire studies that have been conducted on botanical samples have documented minimal damage to subsurface materials (Fish 1990; Ford 1990; Scott 1990). Palynological analysis of subsurface samples from the 1977 La Mesa Fire in Bandelier National Monument indicates that pollen grains in these contexts are not affected by “...even the most intense ground fires” (Scott 1990). Fish’s (1990) pollen study in the wake of the Long Mesa Fire also attests that fires have minimal effects (if any) on subsurface pollen.

Although Fish concludes that the Long Mesa Fire event did not affect subsurface pollens, she provides a useful discussion of methods for evaluating potential fire effects on pollen samples. According to her interpretations, intense heat can damage pollen grains to the point that their diagnostic morphological features are unrecognizable, thus analysis should include a calculation of the proportion of grains too damaged for identification. Fire-altered pollen grains may take on a dark yellow-brown color, will not absorb the staining agent (thus obscuring morphological attributes), and will have thickened or swollen walls. Finally, pollen samples from fire-affected sediments may exhibit high ratios of charcoal fragments, as occurred in Fish’s study. It is possible that charcoal generated by post-occupational fires may be indistinguishable from charcoal resulting from prehistoric cultural activities as reflected in archaeological pollen samples.

Ford’s (1990) study of subsurface flotation samples from the La Mesa Fire sites demonstrates that these samples were not damaged by the fire, even though the site surfaces had experienced intense heating.

Ford also notes that archaeological charcoal may be more friable than recent charcoal, a characteristic that could potentially be used to differentiate fires resulting from prehistoric activities from those occurring as post-occupational natural fires.

Dendrochronology

Tree-ring dating, or dendrochronology, is a chronometric technique that has been applied with great success in the Southwestern United States and elsewhere (Michels 1973; Smiley and others 1953). Because the method involves counting the annual growth rings and matching them to the known master sequence for their species, the consumption of wood by fire may make it difficult or impossible to tabulate the rings. Robinson (1990) concluded that the La Mesa Fire did not significantly affect either of two tree-ring samples submitted for analysis from subsurface deposits. Unless a wood specimen is sufficiently damaged by fire, it still has the potential to yield an accurate date.

Radiocarbon Dating (^{14}C)

This dating technique is one of the most common and useful in archaeology. Although charcoal is not the only material that yields radiocarbon dates, it is certainly one of the most frequently available; other suitable materials include bone, shell, wood, and iron (Michels 1973). Destruction of perishable materials is the most harmful effect that fire can have on radiocarbon samples. Charcoal is often very fragile when recovered from archaeological contexts, thus it is more likely to be totally consumed during a later fire than other materials. As noted in Fish's 1990 study, however, mixing of modern and archaeological charcoal may occur at fire-damaged sites. This mixing could result in erroneously young dates for particular contexts if charcoal from a post-occupational fire is submitted for radiocarbon dating. Alternatively, contamination of the archaeological sample with modern charcoal could simply confound the radiocarbon assay.

Stehli's study of radiocarbon dates from sites burned over during the La Mesa Fire was inconclusive because no control samples from unburned sites of the same age were available for comparison (Stehli 1990). One of three radiocarbon dates run on archaeological charcoal collected from one of the burned sites appeared to be erroneously young (A.D. 1910). Without unburned control samples, Stehli could not determine whether this date reflected effects of the La Mesa Fire. The charcoal in the sample may, of course, have resulted from a post-occupation fire event.

Archeomagnetic Dating

This technique relies on the known variance of the earth's magnetic field through time (Michels 1973). The magnetic minerals in clays orient according to the polarity of the earth's magnetic field when clay is heated to a sufficient temperature, and retain this orientation when the material cools. This magnetic orientation is compared to an independently established known variation curve to derive a date for the sample, thus it is important to record the sample orientation before collection, and to collect the sample from a non-portable object (Rice 1987). Clay linings or hearth rocks containing magnetite and hematite in archaeological hearths or kilns and burned wall or floor plasters are ideally suited to this chronometric technique. The date obtained from the archeomagnetic assay reflects the last time that the sample was heated. The assumption for archaeological samples is that the last heating of the material took place sometime during the occupation of the site, and that the date obtained thus represents the date that pertains to the occupational history of the site. Reheating clay-containing features at sufficient temperatures during post-occupational fire events will reorient the magnetic minerals, thus significantly compromising the interpretive value of archeomagnetic samples taken from features in burned-over sites.

Results from archeomagnetic dating of material from hearths excavated after the La Mesa Fire indicated that although an erroneously young date was obtained from one set of samples, the problem could be compensated for, and an apparently accurate date was obtained from a second set of samples from the same feature (DuBois 1990). The subsurface heat probably did not reach a temperature that compromised the potential of the hearth to yield a reliable archeomagnetic date.

Obsidian Hydration

Of all the dating techniques discussed thus far, obsidian hydration (OH) has received the most attention in terms of fire effects. Although OH is not a heat-dependent dating method like archeomagnetism, the results can still be significantly affected by fire. This dating method measures the thickness of the hydration layer or band (sometimes referred to as a "rind") on the surface of obsidian artifacts, where water has been absorbed through a freshly broken surface (Beck and Jones 1994; Skinner and others 1997). The rate at which the hydration layer forms is influenced by several factors including chemical composition of the obsidian, temperature, and relative humidity (see Beck and Jones 1994 and Friedman and Trembour 1983 for a discussion of the effects of these variables). The

band can be measured and used to provide relative or, more rarely, estimated chronometric dates for obsidian artifacts¹. It is, however, extremely vulnerable to the effects of fire.

Several experimental studies have examined the temperatures at which obsidian hydration bands are modified in order to understand the effects of fire on band width (Bennett and Kunzman 1985; Green 1997; Skinner, Thatcher, and Davis 1997; Trembour 1990). Trembour's (1990) work with obsidian after the 1977 La Mesa Fire is one of the earliest studies to address the problem. He notes that the hydration band on obsidian becomes increasingly diffuse when heated, starting at about 350 °C (662 °F), and eventually is lost at about 430 °C (806 °F). Although the band may eventually reappear after cooling, it apparently does not return to its original thickness, remaining deep and somewhat diffuse. Other studies of the effects of heat on hydration bands have yielded similar results (Green 1997; Skinner and others 1997).

Obsidian artifacts deposited on or near the ground surface are the most vulnerable to thermal alteration. Previous studies considering the effects of fire on hydration bands in subsurface contexts have recorded minor damage, if any. Subsurface artifacts with damaged hydration bands have generally been recovered from strata occurring from 5-10 centimeters (1.97-3.9 in) below the ground surface (Skinner and others 1997).

Deal (1997) examined the effects of prescribed fire on obsidian hydration bands in an innovative field experiment. Using obsidian artifacts that had previously been sourced and hydrated, she placed specimens at and below the ground surface in a variety of contexts with respect to the fuels present (light, woody, and log) in two different prescribed burns. Temperature and duration of heat were measured throughout each fire event. Following the burns, the samples were resubmitted for hydration measurements at the same lab where the original measurements were taken. The results indicated that both exposure to elevated temperatures as well as long duration of heat exposure, even at relatively low temperatures, affect obsidian hydration bands in similar ways. For the fall burn, which had particularly significant results, Deal recorded a maximum ground surface temperature of 523 °C (973.4 °F) 2-1/2 hours after the flaming front passed over the obsidian specimens. The temperatures for this sample declined slowly, finally reaching 46 °C (114.8 °F) after 44 hours.

¹ An estimated date is derived from the width of the hydration band combined with the rate of band expansion.

Case Study: Investigation of Subsurface Heating Effects at Bandelier National Monument, New Mexico

The Dome Fire of 1996 at Bandelier National Monument provided an opportunity to investigate the impacts of catastrophic fire effects on subsurface archaeological materials. The timing and duration of the wildland fire event were known. The severities at which affected sites were burned were calculated using information collected during the post-fire assessment of sites within the perimeter of the burn. These data, in turn, were used to select a sample of sites burned at varying severities (as well as an unburned control site) for testing through excavation. The Subsurface Heating Effects (SHE) study examined the extent to which fire impacted subsurface archaeological materials, and whether burn severities were reflected in the subsurface archaeological record.

The examination of subsurface materials from sites *systematically* documented as affected by different burn severities marked a significant departure from previously reported subsurface fire studies. Data from the post-fire assessment that began immediately following the 1996 Dome Fire allowed for classification of burned sites into light, moderate, and heavy categories; archaeological *and* ecosystemic data were collected and used in making site assessments. These data, in turn, were used to select sites for testing. Specific characteristics (such as stump burn-outs) that could have particularly serious implications for archaeological sites were also examined. Tested loci within the Dome Fire perimeter included one unburned control site, one lightly burned site, one moderately burned site, and two heavily burned sites. In addition, a site that had been through a recent prescribed fire (as well as several natural fires) outside of the Dome Fire area was selected for purposes of comparison.

The SHE study investigated a number of categories of information related to thermal alteration of subsurface cultural resources:

1. Thermal alteration of soils and other ecofacts, artifacts, and cultural features, including variations of observable changes at different intensities.
2. Correlation between measurable heating effects on archaeological materials and visible changes in soil or rocks or other materials with which they are associated.
3. Degree to which the subsurface heating effects observed in the wake of a wildland fire correspond to those reported from experiments that mimic prescribed burns.
4. Datable materials compromised by thermal alteration.

5. Potential for detecting ancient fires in archaeological excavations by visible correlates and/or consistent heating effects that may skew the results of materials analyses.
6. Correspondence of surface and subsurface burn severity data.

Thermal Alteration of Ecofacts and Cultural Materials

Investigation of changes in soils, artifacts, ecofacts, and other cultural materials began with examination of the stratigraphic profiles from each excavation unit to determine the depth of heat penetration from the Dome Fire. The fire, represented by Stratum I in all of the soil profiles from the burned sites, was characterized by a distinct layer of ash, charcoal, and burned organic materials. The thickness of the burned layer for each excavation unit varied from 2 to 15 centimeters (0.8 to 5.9 inches), but exceeded 8 centimeters (3.2 inches) at only one site, which also exhibited a small burned stump.

Ceramics recovered from the burned strata exhibited various degrees of sooting, spalling, oxidation, and crackled slips. Flaked stone artifacts exhibited sooting, spalling, crazing, luster changes, and residues. All of the ground stone artifacts affected by the fire were sooted except for one, which was oxidized. The heaviest fire effects recorded for ceramics and flaked stone were observed on artifacts recovered from LA 115152, a site that was moderately burned during the Dome Fire (fig. 7-1). An alligator juniper growing inside the structure at this site was completely consumed by the fire, including the root system. The burning roots allowed the fire to penetrate into subsurface deposits, affecting subsurface archaeological materials deep within the site.

Ecofactual data examined for the SHE study included pollen, faunal, and macrobotanical samples. Examination of pollen samples from burned and unburned contexts indicated that burned samples tend to have higher percentages of degraded pollen compared to unburned samples. A corresponding loss of pollen or a bias to specific pollen types were not apparent, however, in the burned samples. It was not possible to evaluate whether surface pollen was completely consumed by the Dome Fire because the surface pollen samples were collected 1 year after the fire, which allowed sufficient time for natural pollen to accumulate on the surfaces of the tested sites.

Subsurface macrobotanical samples also exhibited fire effects. The introduction of charred modern materials into the archaeological record for macrobotanical materials was the primary effect of both the Dome Fire and the prescribed fire. Samples from burned contexts also exhibited higher frequencies of vitrified charcoal.

Fire-affected samples were primarily recovered from the upper fill of excavation units. Even though more charred remains were found in samples from the upper fill of moderately and heavily burned sites, however, these same samples still yielded fairly high proportions of uncharred remains.

Faunal data were recovered from two of the project sites. One site was unburned and served as the control site. The most severely burned bone in the project assemblage was recovered from the unburned site, and most likely resulted from contact with either burned roof material or a cooking fire.

At the second site (LA 3840), Dome Fire effects were confined to the upper stratigraphic profiles, although the site had been heavily burned. Faunal material was first encountered 16 centimeters (6.3 inches) below the ground surface, well below the levels affected by the fire. Fire effects were noted on faunal materials from this site, but they are attributable to contact with either burned roof material or a cooking fire.



Figure 7-1—Burn-out of stumps leads to subsurface damage on culturally sensitive sites. 1996 Dome Fire, Bandelier National Monument site LA 115152. Heavily burned site due to burn-out of an alligator juniper stump. Effects noted more than 1 meter below ground surface (bgs): artifact damage-smudging, etc., soil matrix oxidized and contaminated with modern charcoal, dating methods compromised, pollen and macrobotanical specimens damaged (Ruscavage-Barz and Oster 1999).

Correlation Between Heating Effects on Archaeological Materials and Visible Changes in the Surrounding Matrix

The matrices surrounding the cultural materials recovered during the SHE study were examined to determine whether observable fire effects could be correlated with effects on associated non-archaeological materials, such as soil and rock. Comparison of burned archaeological and non-archaeological materials

from the tested sites indicated some correlation between the two categories of materials in terms of fire effects. Spalling and cracking of natural rock generally accompanied spalling and cracking of architectural material; fire-affected archaeological materials tended to co-occur with ashy soil, burned vegetation, and charred trees. Such co-occurrence of vegetation and archaeological material damage is common throughout the Southwest (fig. 7-2).



Figure 7-2—Examples of spalling of sandstone due to heating during the 2002 Long Mesa Fire, Mesa Verde National Park, Colorado: (a) panorama, (b) close up (from Buenger 2003).

Subsurface cultural materials and corresponding matrices in the sample investigated for the SHE study generally exhibited fire effects within the first 10 to 15 centimeters (3.9 to 5.9 in.) of fill. Root and stump burnouts were the exception because they allowed the fire to penetrate subsurface deposits and burn deep underground. In these cases, the full range of fire effects were observed, including spalling and sooting of rocks, accumulations of ash deposits in root pipes, and damage to associated archaeological materials.

Correspondence Between SHE Study Fire Effects and Effects Noted in Experimental Fires

The results of the SHE study are consistent with other post-fire studies that have determined that fire effects are rarely found below the first 10 centimeters (3.9 in.) of fill at archaeological sites (Conner and others 1989; Hemry 1996; Lent and others 1996; Thoms 1996; Traylor and others 1990), unless a burned root mass or stump is present. As described above, fire effects were noted on materials within the first 10 to 15 centimeters (3.9 to 5.9 in.) of fill.

One site, LA 115152, proved the exception because the root system of an alligator juniper burned into a structure during the Dome Fire (fig. 7-3). Fire effects on natural and archaeological materials were noted throughout the structure, with the burned root system and ashy soil continuing well below the limits of the excavation. The site (LA 118345) affected by the prescribed fire, described in more detail below, also provided evidence of deep subsurface penetration by fire, again due to the fact that an alligator juniper provided a conduit.

Very few fire-affected artifacts were observed overall, with most found on the surface. Most of the burned subsurface artifacts from the SHE sites cannot attribute their alteration to the Dome Fire because they were recovered from levels too far below the ground surface to be impacted by natural or prescribed fires. Instead, these artifacts probably attained their burned appearance as a result of contact with burned roof materials or hearths.

Alteration of Datable Materials

Four different dating methods were tested for this project: archeomagnetism, dendrochronology, radiocarbon, and obsidian hydration. The results obtained from these methods were compared with the ceramic data to determine whether the dates obtained from the various methods are accurate or have been affected by the Dome Fire (or other post-depositional processes).



Figure 7-3—LA 118345, Bandelier National Monument site LA 115152. Site burned during a prescribed fire (Ruscavage-Barz and Oster 1999).

The only samples for archeomagnetic dating were obtained from a hearth at LA 3840, located approximately 1.11 meters (3.6 feet) below the ground surface. Since the Dome Fire was evident only in the first 5 centimeters (2 in.) of fill for this site, any anomalies in the archeomagnetic dates were not attributable to the Dome Fire.

Wood samples were collected from two sites for dendrochronology. Two wood samples from one site were recovered from deep levels unaffected by the Dome Fire. The samples from the other site, located outside the Dome Fire perimeter but affected by a low-intensity prescribed burn, were recovered from the lower fill of the structure and, likewise, were not impacted by the prescribed fire.

Radiocarbon (^{14}C) dates were obtained for four of the project sites. The radiocarbon dates from three sites were somewhat consistent with the ceramic dates, and were thus considered to provide reliable indications of the approximate dates that the sites were occupied. The remaining site did not yield any ceramics, thus the reliability of the radiocarbon dates could not be

assessed. Most significant, even where modern charcoal had been mixed with archaeological deposits inside of a structure, the radiocarbon dates did not appear to have been compromised.

Twenty obsidian artifacts were submitted for obsidian hydration (OH). Although no chronometric dates were obtained from the samples, the widths of the hydration bands were compared to site dates obtained from ceramics and ^{14}C assays to determine whether hydration band width was consistent with site dates. The OH results are somewhat ambiguous and in most cases do not agree with site ages based on other chronological data. Band widths obtained for the samples range from 1.1 to 8.9 microns, which is a very wide range considering that most of the sites date to the A.D. 1300s and 1400s.

Band widths greater than five microns for obsidian artifacts from three of the sites suggested that the flaked edges of the samples were manufactured thousands, not hundreds, of years ago (Thomas Origer, personal communication 1998). If the obsidian samples were affected by the Dome Fire, band widths should have been thinner rather than thicker or the hydration bands would be missing (Green 1997; Skinner and others 1997; Trembour 1990).

Results obtained from dateable samples from the project sites indicated very little impact to these materials from the Dome Fire. Reliable dates, with the exception of obsidian hydration, were obtained from most samples, including those derived from extremely disturbed contexts. Thus the Dome Fire did not compromise the various dating methods employed, because most of the samples came from subsurface contexts that were below the zone of effect for the Dome Fire.

Potential for Detecting Ancient Fires, and Correspondence of Surface and Subsurface Burn Severity Data

To address the issue of detecting ancient fires in archaeological excavations, a structural site (LA 118345) located in an area for which a 200-year fire history was available was included in the SHE study sample. This site had been burned over during a prescribed fire in 1994.

The stratigraphic profile of LA 118345 was examined for evidence of earlier fires. No evidence of previous fires was apparent in either of the test units outside the structure. Within the structure, however, an oxidized soil layer containing burned duff below a level of clean unburned fill was encountered. This burned layer was encountered 20-26 centimeters (7.9-10.2 in.) below the ground surface, while the effects attributable to the prescribed fire effects ended 7 centimeters (2.8 in.) below the ground surface. The lower burned layer was therefore assumed to represent an earlier

fire event. Two ^{14}C samples were collected from the earlier burned layer, producing calibrated dates of A.D. 1025-1290 and A.D. 1290-1425, respectively. These dates indicated that the fire event was not part of the 200-year sequence already known but instead represented a much earlier fire event.

Based on the stratigraphic position discussed above, the fire event appeared to have occurred after the structure collapsed. This interpretation conflicted somewhat with the radiocarbon dates because the dates from the fire event pre-dated radiocarbon dates obtained from materials near the structure floor below the roof fall level. The later fire event was not visible in the stratigraphic profile, and no other fire events were evidenced above the level of the roof fall.

The limited data from the SHE study suggested that ancient fires are difficult to detect from archaeological contexts. No ancient fires were detected either during excavation or in stratigraphic profiles at the other study sites, and perhaps the only ancient fires potentially recognizable in archaeological contexts would be catastrophic wildland fires rather than low intensity periodic fires like those believed to have characterized the landscape prior to the late A.D. 1800s.

The second question considers whether the level of burn severity determined by surface observations is reflected in subsurface deposits. The answer is no. The depths of penetration are similar at all sites, whether lightly or heavily burned. The only exceptions are attributable to the root burnout that occurred within one structure, and near another.

At LA 115152, there was no clear break between Dome Fire debris (e.g., ash, charcoal, burned organic materials) and archaeological sediments. This condition was a direct result of the burning root system, which carried the fire underground. If the root system had not ignited, then it is likely that only the surface of the site would have been impacted, similar to another SHE site (LA 3840) that was heavily burned on the surface but did not exhibit any fire damage to the structure interior. The evidence from LA 3840 indicates that surface burn severity is not reflected in subsurface archaeological contexts absent a root burnout.

Summary and Conclusions

One of the important lessons of the SHE study is that a significant difference exists between potential fire effects to surface versus subsurface materials. The effects that fire can have on surface archaeological materials ranges from negligible to extreme depending on the severity and residence time of the fire on the site. This contrasts sharply with the range of fire effects on subsurface deposits, which appear to be relatively protected from fire effects below the first few centimeters except when a burning stump and/or

root system provide a conduit for heat penetration to subsurface cultural deposits.

The potential for damage caused by such “burnouts” was exhibited at two of the Bandelier SHE study sites impacted by wildland fire and prescribed fire, respectively. In both cases, the stumps and roots of large junipers ignited and burned underground causing significant damage to subsurface deposits. An alligator juniper growing in a structure at LA 115152 was totally consumed during the Dome Fire. The burning stump carried the fire into the root system inside the structure, heavily impacting the structure fill. Most of the root system was completely consumed, leaving root cavities lined with ash and charcoal that later collapsed, resulting in mixing of archaeological fill and modern ash/charcoal.

A less severe root burnout resulting from a prescribed fire occurred at LA 118345. The root system of a cut juniper stump ignited, even though the stump had been cut to minimize fire effects to the site. The root cavity extended well below the level of the structure floor. Fortunately, the stump was adjacent to the exterior structure wall and, when it burned, did not impact the structure interior. The evidence from this site demonstrated that prescribed fires, as well as wildland fires, can significantly impact subsurface archaeological contexts. Even though the stump had been cut to minimize potential fire impacts, it had been left as a “stub” rather than being flush-cut and/or treated to prevent ignition (for example, by covering with soil).

The evidence from the SHE study, and other fire effects studies discussed here, has significant implications for the interpretation of archaeological data from

sites suspected to have been burned over in the past, as well as the management of cultural resources. Depending on the kinds of cultural materials and fuels present at a given site—as well as the specific characteristics of the fire or fires that have passed over it—not only the integrity of the site but the information potential of its contents may be destroyed or altered. Given the right conditions, severe fire effects may include heavy damage to subsurface deposits, long thought to be insulated from thermal and other fire-caused alteration.

The accumulations of fuels on contemporary landscapes have reached historically unprecedented levels, thanks to decades of aggressive fire suppression and exclusion. The potential for fires to destroy or seriously compromise the interpretation of the archaeological record has correspondingly increased. Cultural resources managers and field archaeologists would be well advised to include consideration of regional fire histories in environmental reconstructions, and data analyses. Understanding the role of fire as a site formation process is essential for every cultural resources specialist working in landscapes that have been touched by fire.

Postscript

These studies will be more than a decade old by the anticipated publication date of this volume. We believe that the results of this work stand the test of time quite well. We are proud of this pioneering effort. We hope it will be useful to future “pyroarchaeologists.”