# THE PALEOINDIAN OCCUPATIONS AT BONNEVILLE ESTATES ROCKSHELTER, DANGER CAVE, AND SMITH CREEK CAVE (EASTERN GREAT BASIN, U.S.A): INTERPRETING THEIR RADIOCARBON CHRONOLOGIES

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*Abstract*. Numerous caves and rockshelters in the Great Basin of western North America contain geological deposits chronicling human adaptive change through the terminal Pleistocene and early Holocene periods. This is especially the case in the western Bonneville basin of Nevada and Utah, where three caves in particular—Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter—have yielded artifacts, faunal remains, floral remains, and hearth features in sealed, stratified contexts. Complex taphonomic histories, however, have led to much confusion in the radiocarbon dating of the caves' cultural deposits. In this paper we review the radiocarbon records of the three sites in detail, analyzing them in the context of site formation processes. Our results suggest that the main Paleoindian occupations of these caves date to between about 10,900 and 9500 radiocarbon years ago (12,850 and 10,650 calendar years ago), and that this corresponds to a cool, wet period in the eastern Great Basin that may relate to the Younger Dryas cooling event in the North Atlantic. In all three caves, Paleoindian occupations are followed by gaps in human occupations of at least 1500 years; these gaps appear to correlate to significant aridification of the Bonneville basin, starting at about 9000 radiocarbon years ago (10,200 calendar years ago).

Keywords: Paleoindian, radiocarbon dating, taphonomy, formation processes, Great Basin

*Resumé*. De nombreuses grottes et abris sous roche dans le Grand Bassin de l'ouest de l'Amérique du Nord contiennent des dépôts géologiques qui témoignent du changement d'adaptation humain pendant les périodes du Pléistocène final et du début de l'Holocène. Ceci est le surtout le cas dans le bassin de Bonneville de l'ouest au Nevada et dans l'Utah, où trois grottes en particulier—la grotte du Danger, la grotte de Smith Creek, et l'abri sous roche de Bonneville Estates—ont dévoilé des objets, des restes fauniques, des restes floraux et des restes de foyer dans des contextes scellés et stratifiés. Cependant, le contexte taphonomique complexe a compliqué la datation par le radiocarbone des dépôts culturels des grottes. Dans cet article nous réexaminons les données radiocarbone des trois sites dans le détail, les analysant dans le contexte des processus de formation de site. Nos résultats suggèrent que les occupations paléoindiennes principales de ces grottes se situent environ entre 10.900 et 9500 années radiocarbone (il y a 12.850 et 10.650 années calendaires), et que ceci correspond à une période froide et humide du Grand Bassin de l'est qui peut se corréler à l'événement du refroidissement du Dryas récent dans le Nord Atlantique. Dans chacune des trois grottes, les occupations paléoindiennes sont suivies par des intervalles sans occupations humaines d’au moins 1500 ans; ces intervalles semblent correspondre à une aridification significative du bassin de Bonneville, commençant il y a environ 9000 années radiocarbone (il y a 10.200 années calendaires).

Mots-clés: Paléoindien, datation radiocarbone, taphonomie, processus de formation, Grand Bassin

The Great Basin is an arid region of the western United States stretching from the Sierra Nevada Mountains in the west to the Rocky Mountains in the east. Like other deserts of the world, geological sedimentation rates in the Great Basin can be very slow to nonexistent, leaving ancient surfaces exposed for thousands of years. In addition, Middle Holocene aridity caused extensive erosion across much the Great Basin, exposing many previously buried early sites (Nials 1999). As a result, Great Basin archaeologists have had a difficult time finding well-buried prehistoric sites. This is especially the case for the period of the terminal Pleistocene and early Holocene (TPEH) (c. 11,000-8000 $^{14}C$ BP). Very few sites $^{14}C$-dated to the TPEH have been found in open-air (i.e., non-cave) geomorphic contexts that are buried, stratified, and sealed. For example, in a recent survey Beck and Jones (1997) reviewed $^{14}C$ age estimates from 35 Great Basin sites. Twenty-four of these are caves or rockshelters, and only 11 are from open sites. Of the open sites, virtually none have yielded expressive stone artifact assemblages, faunal remains, and features that can be shown to unequivocally predate 9000 $^{14}C$ BP. One exception is the extreme northwestern corner of the Great Basin in south-central Oregon, where sealed TPEH sites are relatively common (e.g., Jenkins et al. 2004).

Due to the difficulty in finding open-air sites in stratified, datable contexts, Paleoindian archaeologists in the Great Basin have for decades been drawn to the region’s caves and rockshelters, many of which have been found to contain cultural deposits predating 8000 $^{14}C$ BP (Beck and Jones 1997; Willig and Aikens 1988). Although providing the bulk of information we currently have concerning Great Basin Paleoindian lifeways, this cave-centric perspective has come with a price. First, the cave/rockshelter record tells us only about what early prehistoric foragers were doing within and nearby these permanent features on the landscape, and little about what they did elsewhere. Since these Paleoindians likely practiced relatively high levels of mobility (Elston and Zeanah 2002; Jones et al. 2003), they probably spent much more time away from these natural shelters than they did near them. Second, humans were not the only inhabitants of these shelters; instead, they often shared them with other animals like rodents, carnivores, and raptors (Grayson 1983; Hockett 1991, 1994). The origin of animal and plant remains in these caves and rockshelters, therefore, may be from carnivore predation and gnawing, packrat (*Neotoma* sp.) nesting, or raptor activity, not necessarily from human activities.

This means, then, that archaeological research in the Great Basin's caves and rockshelters must be conducted through a taphonomic perspective that carefully analyzes natural as well as cultural site formation processes. This is the case when interpreting data generated from all materials analyses, whether they be lithic, faunal, floral, or $^{14}$C dating analyses. In this paper, we review the $^{14}$C dating results of three caves/rockshelters located in the eastern Great Basin (Danger Cave, Smith Creek Cave, Bonneville Estates Rockshelter)**,** and show how a taphonomic, site formation approach can assist in interpreting the dates to produce occupational histories of the shelters during the TPEH. We attempt to show that human occupations of the TPEH at these shelters were relatively short but repeated, and that the same pulses of occupation can be found in multiple shelters, suggesting that they may relate to increased use of the region during periods of climatic amelioration (i.e., relatively mesic conditions).

## THE SITES

Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter are located along the border of Nevada and Utah, in the interior of western North America **(Figure 1)**. All three are along the western margin of the Bonneville basin, which during the terminal Pleistocene was filled by a huge, deep lake called Lake Bonneville. Today the western Bonneville basin is dominated by a seasonally dry playa called the Bonneville Salt Flats (1304 m in elevation), which is surrounded by hills and mountains reaching nearly 4000 m in elevation. Great Salt Lake, located to the east of the Bonneville Salt Flats, is a modern remnant of Pleistocene Lake Bonneville.

### *Danger Cave*

Danger Cave is located on the outskirts of Wendover, Utah, and is situated adjacent to the Bonneville Salt Flats (1315 m in elevation), just above the Gilbert Shoreline, which likely formed during the Younger Dryas period, 10,500-10,000 $^{14}$C BP (Oviatt et al. 2001). The cave is an oval chamber about 20 m wide at its mouth and 40 m deep from front to back. Based on a variety of proxy records, Lake Bonneville receded from Danger Cave around 11,500-11,200 $^{14}$C BP (Broughton et al. 2000; Jennings 1957; Oviatt et al. 2005; Rhode et al. 2006).

Archaeological excavation at Danger Cave began in the early 1940s with E. Smith's initial tests and continued in 1949-1953 with J. Jennings' large-scale excavations (Jennings 1957). Jennings and his team unearthed a series of well-stratified and well-preserved cultural layers spanning the Holocene, from more than 10,000 $^{14}$C BP to historic times. Excavation methods used during these early projects were too coarse to permit the tying of specific features, artifacts, and ecofacts to precise strata, and $^{14}$C dating methods were in their infancy so that most of Jennings' first series of dates are now considered ballpark figures at best. Since the late 1960s, excavations in Danger Cave were renewed several times to obtain finer-scaled paleoecological and archaeological data. In the late 1960s Fry (1976; Harper and Alder 1972) excavated a trench in the back of the cave, and in 1986 Madsen and Rhode (1990; Rhode and Madsen 1998) excavated a preserved block of sediment near the mouth of the cave. These excavations led to much new information regarding the Archaic occupations of the cave post-dating about 8500 $^{14}$C BP, but failed to uncover extensive cultural strata predating 9000 $^{14}$C BP. In 2002 and 2004, Madsen and Rhode led a team of researchers again into Danger Cave, this time to re-expose preserved profiles where deposits dating to the TPEH were thought to exist. Their efforts focused on relocating the rear profiles of Jennings' 1949-1953 excavation (called the 143 face) and Fry's 1968 back trench (Rhode et al. 2006).

The TPEH sediments within Danger Cave can be separated into two occupation zones that Jennings (1957) referred to as DI and DII, with DI being the earliest. In Jennings' 143 face, DI is capped by wind-blown sand that is archaeologically sterile (Sand 2), and this is in turn overlain by DII, an occupation zone consisting of three distinct strata. From the bottom-up, these include (1) a layer of charred vegetation (F115), (2) a hardened layer of calcrete, and (3) a layer of well-preserved pickleweed chaff (F117 and F119) (Rhode et al. 2006:222). In the re-exposed back trench profile, Rhode et al. (2006) did not find the DI occupation zone; however, they did identify Sand 2 and DII, represented by a series of stratified features of well-preserved pickleweed chaff and ash.

In contrast to the back trench, Rhode et al. (2006:221) exposed two DI hearth features (called F111 and F112) in the preserved 143 face. These ash lenses are unexcavated portions of hearths that appear in Jennings' stratigraphic profile (Jennings 1957:Figure 54; Rhode et al. 2006:Figure2). For DII, Rhode et al. (2006) exposed a heavily charred layer of bones, vegetal debris, and ungulate and rodent dung (F31), and a pickleweed-rich feature (F30) that most likely represents human processing of seeds.

The DI and DII features appear to have resulted from different kinds of activities, some human and some non-human. For DI, Jennings (1957) described six hearth features, as follows:

> These little hearths were in no sense modeled or fabricated fire-places. They were simply areas of blackened or faintly reddened sand where fires of sticks or twigs had been built upon the flat surface. A thin lens of ash or ash and charcoal covered the discolored zone. The diameter of each was approximately 2 feet. In cross-section the sand beneath the fire might be discolored in a lenticular or crescentic pattern from 1 to 3 inches deep at the center, where the heat was greatest, thinning to finally pinch out at the surface at the periphery (1957:54).

Apparently, no such hearth features were encountered in DII (Jennings 1957:64), but Jennings did describe a small pit feature and an extensive deposit of charred remains that appears to have burned naturally.

TPEH human occupations at Danger Cave span from approximately 10,300 to 8300 $^{14}$C BP (Rhode et al. 2007). No diagnostic artifacts were recovered during Rhode et al.'s (2006) most recent field studies, so assemblage characterizations must rely on Jennings' (1957) original descriptions. Early excavations of DI produced a small assemblage of cultural remains including one lanceolate-shaped point (that may be a stemmed point) and several scrapers, possible ground-stone artifact fragments, and knotted pieces of twine. DII yielded a much more extensive assemblage primarily consisting of large side-notched and corner-notched points, a variety of flake tools, ground-stone artifacts, basket fragments, twine fragments, and chewed quids. DII also produced human coprolites filled with pickleweed seeds (Fry 1976; Rhode et al. 2006).

*Smith Creek Cave*

Smith Creek Cave is located about 30 km north of the town of Baker, Nevada. It is situated at an elevation of about 2040 m above sea level, 460 m above the high shoreline of Pleistocene Lake Bonneville. Smith Creek Cave has a large, southeast-facing mouth that is roughly 18 m high and 50 m wide. Its depth from front to back is about 30 m. Although high above the Bonneville shoreline, the cave would have been visible to humans traveling along the lakeshore during the TPEH (Bryan 1979). Bryan directed controlled archaeological excavations at Smith Creek Cave in 1968, 1971, and 1974. Detailed descriptions of the findings of these excavations can be found in two reports (Bryan 1979, 1988).

Artifact-bearing deposits of TPEH age occur in two discernible stratigraphic layers, a grey ash and silt stratum overlain by a deposit of dung, rubble, and silt (Bryan 1979:183-184). The grey ash and silt stratum is more specifically described as a “compact layer, no more than about 12 cm thick, of grey ash, twigs, other plant remains often wadded together with balls of hair, charcoal, silt, and dung in a fine rubble matrix” (Bryan 1979:184). Across the cave the grey ash grades into a deposit of loose rubble and pink silt that also contains artifacts but appears to be significantly reworked. The grey ash and presumably the silt are thought to be aeolian in origin (Bryan 1979:183). The overlying dung, rubble, and silt stratum is “finely stratified,” compact, and up to 16 cm thick (Bryan 1979:184-185). Its contents include sheep dung, charcoal, juniper twigs and berries, bone fragments, and artifacts; Bryan (1979) interprets these as representing alternating sheep and human occupations.

Bryan (1979) recovered stone artifacts from both the grey ash and silt stratum and dung, rubble, and silt stratum, and he called them the “Mt. Moriah occupation zones.” These include stemmed bifacial points, bifaces, flake tools, fragments of twine, chewed quids, and some worked pieces of bone. Associated faunal remains that appear to be the result of human activity include mountain sheep and pronghorn, but jackrabbits, hares, and rodents also occur, as do isolated bird, fish, and reptile bones (Bryan 1979:185-186).

At least eight charred features interpreted as hearths are described by Bryan (1979:187-190) **(Figure 2).** Most of these originated stratigraphically from the dung, rubble, and silt zone and penetrated downward into the grey ash and silt zone. These features were typically unlined concentrations of ash, charcoal, charred bone, and sometimes charred dung. Some of them, like Hearth 7, also contained uncharred plant remains or uncharred perishable artifacts.

*Bonneville Estates Rockshelter*

Bonneville Estates Rockshelter is located about 50 km south of the town of West Wendover, Nevada, and is situated upon the high shoreline complex of Pleistocene Lake Bonneville (1580 m in elevation). Bonneville Estates is an open shelter that has a southeast-facing mouth reaching 10 m high and 25 m wide. From front to back, it is about 15 m deep at its deepest point. The lake receded from its high shoreline around 14,500 $^{14}$C BP, so at that time the rockshelter became “high and dry” and open for human and animal use.

Initial excavations at Bonneville Estates were carried out in 1988 by P-III Associates, an archaeological consulting firm from Utah (Schroedl and Coulam 1989). Our team began full-scale excavations in 2000 and continued to excavate the rockshelter’s sediments through 2006 (Goebel et al. 2003; Graf 2007; Rhode et al. 2005). TPEH cultural deposits have been uncovered in two excavation areas that are called the west block and east block. Details on the site’s stratigraphy and dating, lithic artifact assemblages, faunal assemblages, and paleobotanical assemblages can be found in Graf (2007), Goebel (2007), Hockett (2007), and Rhode and Louderback (2007).

Briefly, the sediments within Bonneville Estates Rockshelter consist of a series of silt-and-rubble deposits interdigitated with well-preserved organic layers. The organic layers appear to be the result of a variety of depositional agents: some are clearly the result of human activities, some are the result of animal activities, and some are the result of a combination of the two. Cultural deposits throughout the profile contain not just stone artifacts, but also well-preserved faunal remains (many with cutmarks and other recognizable signs of having been butchered by humans), hearths with charred plant macrofossils, and perishable artifacts like basket fragments, cordage fragments, bone awls and needles, beads and pendants. Through our excavations, we have discerned six cultural components that range in age from the terminal Pleistocene to historic times (i.e., the 20th Century AD).

TPEH occupations at Bonneville Estates Rockshelter span from approximately 11,000 to 9,500 $^{14}$C BP (although a single hearth feature with no associated diagnostic artifacts has been $^{14}$C dated to 8800 $^{14}$C BP) (Graf 2007). In the west block we have identified three stratigraphically distinct cultural layers, and in the east block we have identified a corresponding series of hearths in a set of loose silt-and-rubble deposits. Assemblages for the west block and east block contain diagnostic Great Basin stemmed points and point fragments, side and end scrapers, gravers, bone awl/needle fragments, and fragments of cordage (Goebel 2007). Associated faunal remains that can be attributed to human activity include artiodactyls (pronghorn, deer, and mountain sheep), sage grouse, hare, black bear, and grasshopper (Hockett 2007). Through 2006, we had excavated more than 14 hearth features that predate 8800 $^{14}$C BP; typically these are unlined oval-shaped hearths (50-80 cm in diameter) that have shallow basins and are filled with wood charcoal and ash underlain by reddened silt and rubble (or unintentionally charred organics of an earlier event) **(Figure 3)**. Their sizes, shapes, and contents fit Jennings' (1957) descriptions of TPEH hearths at Danger Cave. Charred plant macrofossils found within the Bonneville Estates hearths are the result of using plants for fuel; however, Rhode and Louderback (2007) suggest that some charred seeds found in the hearths could be evidence of human consumption (although no ground-stone artifacts have been found in the TPEH deposits at Bonneville Estates).

## THE RADIOCARBON DATES

Tables 1-3 present reported $^{14}$C dates for Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter. Although 98 $^{14}$C dates are listed in these tables, only about half can be reliably used to estimate ages of the TPEH cultural occupations in these sites. For this reason, detailed taphonomic reviews of the $^{14}$C chronologies for the three sites are required here.

*Danger Cave*

Forty-six $^{14}$C dates have been reported for the lower strata at Danger Cave. In **Table 1** and the discussion below, these are presented by cultural component. We argue that the DI cultural occupation dates to some brief interval between 10,350-10,000 $^{14}$C BP, lower DII dates to about 10,100-10,000 $^{14}$C BP, and middle/upper DII dates to less than 8600 $^{14}$C BP.

Twenty $^{14}$C dates come from samples ascribed stratigraphically to DI; however, some are unreliable and some are of natural, not cultural, origin. The two oldest dates (C-609 and C-610) are unreliable solid carbon dates (not gas dates) and rejected here, following Rhode and Madsen (1990). A third date (M-204) is on naturally deposited sheep dung collected from below the DI occupation surface (situated at the top of Sand 1) (Jennings 1957). Additionally, five samples (M-118, M-119, Beta-19611, Tx-89, and Tx-88) are from Sand 2, above the DI occupation surface (Jennings 1957:60), and provide age estimates for naturally occurring materials (either sheep dung or uncharred twigs and sticks) but not the cultural occupation. This leaves 12 samples that either come from the DI occupation surface or are clearly the product of human activities (i.e., they are human coprolites). Even among these samples, though, there is a major discrepancy between dates obtained from hearth charcoal and dates obtained from other materials. The hearth charcoal (M-202, Beta-168656, Beta-158549) and dispersed charcoal (Tx-87) dates all overlap at one standard deviation and suggest an age of occupation bracketed between 10,350-10,000 $^{14}$C BP for the DI occupation surface. Associated uncharred twigs are either significantly older (10,600 ± 200 $^{14}$C BP [Tx-85]) or younger (8970 ± 150 $^{14}$C BP [Tx-86]), and the five human coprolites attributed to DI yielded $^{14}$C ages range from 8680 ± 50 to 3020 ± 59 $^{14}$C BP. As Rhode et al. (2006) suggest, these coprolites are aberrantly young and likely redeposited from later-aged sediments. A single AMS $^{14}$C date of 10,600 ± 250 (AA-

20859) on jackrabbit bone collagen also seems too old; this sample may be the result of some non-human agent. Lastly, more information is needed for the sample that produced the $^{14}C$ date of 9780 ± 210 (Beta-19336) to evaluate whether it relates to the DI cultural occupation.

Only five $^{14}C$ samples can be attributed to lower DII **(Table 1)**. One of these is a solid carbon date (C-640) and cannot be trusted, and two (GaK-1895, GaK-1899) are on naturally occurring twigs, ash, and dung that produced disparate ages of 10,130 ± 250 and 6960 ± 210 $^{14}C$ BP. Given that these two were bulk samples of natural materials, they do not provide specific age estimates and should be disregarded (Rhode et al. 2006). This leaves just two $^{14}C$ dates to use to establish the age of the lower DII cultural occupation: 10,080 ± 130 and 10,050 ± 50 $^{14}C$ BP. The 10,050 age estimate is on charcoal from a heavily charred deposit, and the 10,080 age estimate overlaps it at one standard deviation (although its sample material has not been reported [Madsen and Rhode 1990]).

The middle and upper parts of DII are more securely dated. Disregarding a solid carbon date (C-611) and two pickleweed chaff dates (GaK-1900 and GaK-1896), which according to Rhode et al. (2006) are bulk samples that cannot be used to specifically date this stratum, all of the remaining $^{14}C$ samples post-date 8600 $^{14}C$ BP. Of the ten human coprolites sampled, seven fall between about 8400 and 8100 $^{14}C$ BP, while three are significantly younger (6020 ± 50, 5060 ± 40, and 5030 ± 40 $^{14}C$ BP). These younger coprolites are probably redeposited from above-lying DIII or DIV (which have been shown to date to roughly 6000-3000 $^{14}C$ BP [Madsen and Rhode 1990]). The rest of the $^{14}C$ dates conform with the bulk of the coprolite dates, indicating that middle and upper DII probably reflect human use of Danger Cave from about 8600 to 7400 $^{14}C$ BP.

*Smith Creek Cave*

Sixteen $^{14}C$ dates have been reported for the Pre-Archaic, “Mt. Moriah” component in Smith Creek Cave **(Table 2)**. These range from 14,220 ± 650 to 9280 ± 160 $^{14}C$ BP, but most cluster between about 11,000 and 10,000 $^{14}C$ BP.

Bryan (1979) dismissed the oldest and youngest dates as aberrant. The date of 14,220 ± 650 $^{14}C$ BP was on artiodactyl hair and is inconsistent with dates from the cultural component as well as an underlying layer of bristlecone pine needles $^{14}C$ dated to about 13,000-12,500 $^{14}C$ BP (Bryan 1988:67). The young dates of 9280 ± 160 and 9800 ± 190 $^{14}C$ BP were not properly pretreated at the Gakushuin University laboratory (GaK) in Japan; re-dating of the latter charcoal sample at the Birmingham laboratory (Birm) produced a date of 10,740 ± 130 $^{14}C$ BP (Bryan 1979:186). By deleting these obviously discordant dates, Bryan concluded that the Mt. Moriah component at Smith Creek Cave began by 12,000 $^{14}C$ BP, “before the earliest evidence for Clovis on the High Plains” (1988:70).

This interpretation, however, does not hold up against closer scrutiny of the remaining $^{14}C$ age estimates, especially when considering the context of the finds and the variety of $^{14}C$-dated materials. In his reports, Bryan notes several times that the grey ash zone and its features were mixed. Most telling is the following statement: “The range of dates, combined with the fact that so many perishables were preserved in the completely burned wood ash (burning must have preceded deposition of the perishables), as well as the evidence for intrusive hearths and sheep beds, all show that considerable bioturbation had occurred after the ash layer started to accumulate” (Bryan 1988:68). This certainly explains the aberrantly old date of 14,220 ± 650 $^{14}C$ BP, and it helps explain how a piece of uncharred cordage dated to 10,420 ± 100 $^{14}C$ BP could occur in the grey ash and silt layer, which underlies the dung, rubble, and silt layer thought to date to as early as 11,140 ± 200 $^{14}C$ BP. To us, these inconsistencies in the dates as well as the evidence for extensive bioturbation in the grey ash and silt calls into question the primary association of the features, artifacts, and $^{14}C$-dated ecofacts from this layer. The only $^{14}C$ dates that should be used to define the age of the cultural component are dates on wood charcoal from hearths or direct dates on perishable artifacts (i.e., the S-twist cordage).

When considered in this way, there are nine $^{14}C$ dates from six features and one artifact that provide an accurate representation of the age of the Mt. Moriah component at Smith Creek Cave. These range from 11,140 ± 200 to 9940 ± 160 $^{14}C$ BP, and probably reflect repeated shortterm visits to the cave by Paleoindians. The first of these events may have occurred around 11,140 $^{14}$C BP; however, this date does not conform with five other dates ranging from 10,660 ± 220 to 10,570 ± 160 $^{14}$C BP from the same hearth complex (excavated in TP8). Confirmation of this early $^{14}$C date should be sought either by dating additional charcoal from this particular concentration or by dating the yucca quid that Bryan (1979:188) reportedly found within it. Until this happens, we conclude that the Mt. Moriah component at Smith Creek Cave unequivocally dates to about 10,700-9900 $^{14}$C BP, but could date to as early as 11,200 $^{14}$C BP.

*Bonneville Estates Rockshelter*

Thirty-six $^{14}$C dates have been reported for the TPEH strata at Bonneville Estates Rockshelter **(Table 3)**. These are presented in Table 3, first by excavation (west block and east block) and second by stratigraphic layer.

West block TPEH deposits are divided into four strata, 19, 18b, 18a, and 17b'. Stratum 19 is the deepest stratum to have produced stone artifacts and burn features interpreted as hearths; however, these occur in an area where the stratum is unsealed from upper-lying stratum 18b. Age estimates for stratum 19 range from 15,240 ± 50 to 10,640 ± 60 $^{14}$C BP. The dates of 15,240 and 11,960 $^{14}$C BP were obtained from bones not associated with any lithic artifacts or features; they are probably paleontological (Graf 2007). The remaining ten dates are from wood charcoal or bone samples from two hearth features. Six of these dates range from 12,390 ± 40 to 10,970 ± 60 $^{14}$C BP, while the other five range from 10,900 ± 50 to 10,640 ± 60 $^{14}$C BP. We agree with Graf (2007) that the earlier set of dates likely represents the time that stratum 19 was deposited by natural agents like woodrats (*Neotoma* sp.), raptors, and carnivores, and that the later set of dates likely represents the time that humans occupied the surface of stratum 19, lighting one or two fires (features 03.16/04.13 and 03.17) and discarding a few pieces of stone debitage. The wood charcoal samples that produced the older dates are probably natural fragments of dried vegetation that became incorporated into the humans' fires. Feature 04.13b, for example, is stratigraphically within stratum 19 and likely represents burning of natural vegetation when the upper hearth (03.16/04.13) was dug into it and burned. Given this interpretation, we conclude that all of the feature 04.13b dates are of natural, not cultural, origin. We tentatively conclude that stratum 19 is essentially a natural deposit of organics, and that human activities occurred only on or near its surface. The timing of these activities is best represented by the young $^{14}C$ dates from features 03.16/04.13 and 03.17; together they indicate an age of 10,900-10,600 $^{14}C$ BP.

Strata 18b, 18a, and 17b’ are more securely $^{14}C$ dated **(Table 3)**. For stratum 18b we have four hearth features that range in age from 11,010 ± 40 to 10,405 ± 50 $^{14}C$ BP. The hearth dated to 11,010 $^{14}C$ BP came from an area of the west block where stratum 19 was not deposited, thereby explaining the apparent reversal in dates. For stratum 18a we have one hearth feature with three dates ranging from 10,130 ± 60 to 10,040 ± 70 $^{14}C$ BP. For stratum 17b’ we have two hearth features that range from 9580 ± 40 to 9430 ± 50 $^{14}C$ BP. The single ages on the hearths from strata 18b and 17b’ (especially the oldest one at 11,010 $^{14}C$ BP) need to be confirmed with additional analyses.

East block strata dating to the TPEH (strata 12, 10, and 9) were loose and more massively bedded than west block strata, making it difficult to distinguish individual cultural occupations. Seven hearth features, however, were identified during the excavation, and $^{14}C$ dates on these features generally conform with their stratigraphic positions. The lowest two hearths, found in the silts of stratum 12, yielded $^{14}C$ dates that range from 10,380 ± 40 to 10,250 ± 50 $^{14}C$ BP. Immediately above these were three hearths likely dating to between 10,050 ± 50 and 9990 ± 50 $^{14}C$ BP; dates of 10,560 ± 50 and 10,380 ± 60 $^{14}C$ BP on two of these hearths are probably too old given their stratigraphic position above the lowest pair of hearths (Graf 2007). Although undoubtedly TPEH in age, it is possible that the use of old pine wood in these latter two hearths accounts for the dates that appear “too old” in comparison with the other dates that are consistently several centuries younger. The two hearths from stratum 10 date to between 9580 ± 40 and 9440 ± 80 $^{14}C$ BP, and the hearth feature recovered from the lower part of stratum 9 dates to 8830 ± 60 $^{14}C$ BP.

## CALIBRATION AND ANALYSIS OF THE $^{14}$C CHRONOLOGIES OF DANGER CAVE, SMITH CREEK CAVE, AND BONNEVILLE ESTATES ROCKSHELTER

Of the 98 $^{14}$C dates reviewed above, only about half are appropriate for interpreting the ages of the TPEH cultural occupations preserved in Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter **(Table 4)**. These are the dates from cultural features, artifacts, and ecofacts that are consistent with other $^{14}$C dates and stratigraphic position. Interpreting these "good" dates nonetheless is a complex procedure. As Bryan (1988) has pointed out, we cannot simply average all of the dates from a single cultural stratum to determine the age of that stratum; nor can we count every date from a cultural stratum as representing an individual occupation event, since some features, ecofacts, or artifacts may have multiple dates. Here we use "occupation event" as a unit of observation, calculating a single $^{14}$C-BP age for each feature, perishable artifact, or human coprolite dated. When a feature or artifact had multiple $^{14}$C dates, we averaged those that are considered accurate, deleting from the analysis any dates recognized in the discussion above as being discordant or incorrect **(Tables 1-3)**. We then calibrated the resulting dates (at one sigma) using the Calpal Online Radiocarbon Calibration program, interpreting an age for each event in calendar years before present (cal BP) **(Figure 3)**.

Danger Cave appears to have had two major pulses of human occupation. The first (the brief DI and lower DII occupations, separated by a few decades to centuries) probably began no earlier than 12,200 cal BP and ended 11,400 cal BP. After a hiatus of about 1500 years, a second period of occupation (middle-upper DII) occurred from about 9450 cal BP to 9000 cal BP. Human use of Danger Cave continued through the middle Holocene (Madsen and Rhode 1990; Rhode and Madsen 1998).

Humans used Smith Creek Cave most intensively from 12,800 to 12,100 cal BP. One hearth, however, may date to earlier than this (13,200-12,900 cal BP), and another hearth dates to later (11,800-11,300 cal BP). The early hearth needs to be re-dated to confirm its presumed age. Human occupation ceased entirely by 11,300 cal BP, until Fremont foragers began to use the cave during the late Holocene (Bryan 1979).

Human occupation of Bonneville Estates Rockshelter may have begun by 13,050 cal BP, but as in the case of Smith Creek Cave, the single $^{14}C$ date on the earliest hearth needs confirmation. After this, humans appear to have repeatedly visited Bonneville Estates from 12,850 to 11,350 cal BP, lighting small fires, butchering carcasses of artiodactyls, sage grouse, and other animals, repairing nets, and resharpening stone tools (Goebel 2007; Hockett 2007). Humans may have used the rockshelter less frequently from 12,150 to 11,850 cal BP, and not at all from 11,350 to 11,100 cal BP. A second pulse of activity occurred from 11,100 to 10,650 cal BP. Cultural remains of this later occupation are virtually identical to those of the earlier occupation, suggesting that human activities in and around the rockshelter remained unchanged. One last hearth feature chronicles a possible human occupation of Bonneville Estates about 10,150-9800 cal BP. No artifacts or faunal remains were found in or around this hearth, so if humans did use the rockshelter during this time, their stay must have been brief and ephemeral. Besides this, we can find no evidence to show that humans used Bonneville Estates Rockshelter between 10,650 and 8380 cal BP (Graf 2007), a lengthy hiatus of at least 2200 years. When they re-entered the rockshelter after 8380 cal BP, they were making large side-notched points to hunt artiodactyls and grinding up lots of small seeds with ground-stone artifacts.

## DISCUSSION AND CONCLUSIONS

Based on the results of this analysis, the following conclusions can be made concerning the human populations of the eastern Great Basin during the terminal Pleistocene and early Holocene.

*1. Initial human occupation of the western Bonneville basin occurred as early as 12,850 cal BP and possibly earlier.* Humans certainly used Bonneville Estates Rockshelter by 12,850 cal BP, Smith Creek Cave by 12,800 cal BP, and Danger Cave by 12,250 cal BP. At Smith Creek Cave and Bonneville Estates, older hearths have been $^{14}C$ dated to 13,200-12,900 cal BP and 13,050-12,800 cal BP, respectively. These dates, however, need to be confirmed with additional analyses. Confirmation of these two dates would suggest that humans first used these two caves at a time coeval with the Clovis occupation of other regions of North America.

*2. In the western Bonneville basin from 12,850 to 10,650 cal BP, humans exclusively made and used Great Basin stemmed points.* Stemmed points have been found associated with the early hearths at Smith Creek Cave and Bonneville Estates Rockshelter, and a possible stemmed point came from the DI cultural occupation at Danger Cave (Jennings 1957:109; Jennings 1978:39, Figure 20). The age of fluted points in the western Bonneville basin is more difficult to establish. E. Smith is rumored to have found two concave-based, possibly fluted points from the lower layers at Danger Cave; however, these points were lost, one was "re-discovered" at the Utah Museum of Natural History, and neither had precise provenience information (Holmer 1986:94-95; Jennings 1957:47), making the dating of them impossible. At Bonneville Estates, no diagnostic bifacial points have been found associated with the earliest, potentially Clovis-age hearth (13,260-12,856). Since fluted and unfluted concave-based points have not been found in a primary context in any of the region's caves or rockshelters, while stemmed points repeatedly have been found to post-date 12,850 cal BP, we conclude for now that fluted forms could have been produced before, but not after, 12,850 cal BP in the eastern Great Basin. This observation lends support to the interpretation that Clovis fluted points pre-date stemmed points in the eastern Great Basin and are contemporaneous with Clovis points elsewhere in western North America.

3. *The strong pulse of early human use of Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter, 12,850-10,560 cal BP, coincided with a period of cool, possibly wet climate.* Multiple proxy records suggest that the western Bonneville basin was well-watered during this time. Lake Bonneville transgressed to an elevation of about of about 1288 m (4250 ft.) and constructed the Gilbert shoreline 12,350-11,950 cal BP (Oviatt et al. 2001). Although lake levels fell shortly after this time (Broughton et al. 2000), water continued to flow into the western Bonneville basin for another 2000 years, primarily from the south along the Old River Bed (Oviatt et al. 2003). A similar hydrologic record exists for the Sunshine Well site (located in Long Valley west of the Bonneville basin, central Nevada), which was well-watered during the TPEH until about 9650-9550 cal BP. Paleobotanical data suggest that the continued flow of

water in the region was as much a consequence of cooler temperatures as it was increased summer precipitation (Madsen et al. 2001; Rhode 2000). The presence of sage grouse, marmot, and black bear in the TPEH deposits at Bonneville Estates conforms to these other proxy data as well (Hockett 2007). This period of relatively cool, wet climate has been attributed to the Younger Dryas (Madsen 2002; Oviatt et al. 2003), but clearly these conditions as well as the prolonged use of the region's caves persisted for some centuries after the close of this climatic period (11,500 cal BP).

4. *All three sites record a significant hiatus in human occupation during the early Holocene.* Early human use of the caves ceased by 11,350 cal BP, except at Bonneville Estates where it continued until 10,650 cal BP. Danger Cave does not appear to have been occupied again until 9450 cal BP, Bonneville Estates Rockshelter does not appear to have been occupied again until 8380 cal BP (with the exception of a possible ephemeral event around 10,000 cal BP), and Smith Creek Cave was not re-occupied until the late Holocene. Given that all three caves appear to have been abandoned, and that other caves in the region (e.g., Hogup Cave and Camels Back Cave) were not occupied at all until after 9450 cal BP (Aikens 1970; Schmitt and Madsen 2005), we conclude that this hiatus represents a region-wide human demographic event. Multiple lines of evidence suggest that the eastern Great Basin became very hot and dry by 10,200 cal BP. The Old River Bed dried up completely by 10,100-10,000 cal BP (Oviatt et al. 2001), marshes dried up in the small basins to the west of the Bonneville basin by 9500 cal BP (Huckleberry et al. 2001; Thompson 1992), and xeric-adapted small mammals replaced montane-and-mesic-adapted small mammals between 10,000 and 9200 cal BP at places like Bonneville Estates, Homestead Cave, and Camels Back Cave (Grayson 1998; Hockett 2007; Schmitt et al. 2002). Perhaps humans opted not to adapt to the marked increase in aridity and instead moved from the area, so that there was no resident population in the western Bonneville basin from 10,650 to 9450 cal BP.

*5. Human occupations of Danger Cave and Bonneville Estates Rockshelter resumed during the early-middle Holocene; at Danger Cave this occurred by 9450 cal BP and at*

*Bonneville Estates by 8250 cal BP*. Danger Cave was probably re-occupied at such an early time because of its location adjacent to a productive marsh, where pickleweed seeds and other marsh-adapted plants and animals could be intensively collected, even during the driest times. When humans re-appeared there, they certainly were taking full advantage of these resources (Rhode et al. 2006). The lack of a nearby spring or marsh likely precluded use of Bonneville Estates in this fashion. Instead, re-occupation of Bonneville Estates may correlate to a wet period that occurred 8200-8000 cal BP (Hockett 2007). This may relate to the so-called “8.2-k” event, a 160-year-long period of cooling in the North Atlantic that may have led to significant climate change world-wide (Alley and Ágústsdóttir 2005; Schmidt and LeGrande 2005; Thomas et al. 2007). As Graf (2007) and Hockett (2007) have pointed out, from this time onward through the middle Holocene, intensity of human use of Bonneville Estates Rockshelter seems to have kept pulse with fluctuating climate. Increased periods of summer rainfall that may have occurred in the Great Basin during the 8.2-k event probably led to abundant grasses and sagebrush on the hillslopes flanking the western Bonneville basin. These would have attracted artiodactyls including pronghorn and even bison, in turn leading to a greater human presence at places like Bonneville Estates Rockshelter, despite the immediate unavailability of water (Hockett 2007). Another middle Holocene occupation at Bonneville Estates dating to about 7200-6800 cal BP (Graf 2007) may correspond to yet another “anomalously” wet period indicated by regional paleobotanical records (Rhode 2000; see also Madsen et al. 2001).

Without doubt, the caves and rockshelters of the Great Basin have provided and will continue to provide an important resource to archaeologists studying the region’s terminal Pleistocene and early Holocene archaeological record. Cultural chronologies are based largely on evidence from these enclosed sites, and virtually everything we know about early subsistence behavior has been gleaned from the well-preserved faunal and floral remains that they contain. Given the relative importance of the cave record in this part of the world, it is especially important that we always interpret their contents through a taphonomic perspective focusing on natural as well as cultural formation processes. A broad array of taphonomic agents are known to have contributed to the deposition of the materials found in these natural shelters, making it especially difficult to interpret resulting $^{14}C$ ages. Chronologies of cultural events must be developed through the dating of materials clearly relevant to those cultural events. Every dated sample needs to be carefully evaluated in terms of its origin, potential for redeposition, and potential for contamination. By focusing just on $^{14}C$ ages from samples clearly of human origin (i.e., charcoal from hearths, perishable artifacts, human coprolites), we can build accurate chronologies of human occupations in these sites, and can more precisely relate these to climatic events and better understand the evolution of human adaptations.

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## REFERENCES

AIKENS, C. M. (1970) *Hogup Cave*. University of Utah Anthropological Papers No. 93. Salt Lake City.

ALLEY, R. B.; ÁGÚSTSDÓTTIR, A. M. (2005) The 8k Event: Cause and Consequences of a Major Holocene Abrupt Climate Change. *Quaternary Science Reviews* 24:1123-1149.

BECK, C.; JONES, G. T. (1997) Pleistocene/Early Holocene Archaeology of the Great Basin. *Journal of World Prehistory* 11:161-236.

BROUGHTON, J. M.; MADSEN, D. B.; QUADE, J. (2000) Fish Remains from Homestead Cave and Levels of the Past 13,000 Years in the Bonneville Basin. *Quaternary Research* 53:392-401.

BRYAN, A. L. (1979) Smith Creek Cave. In TUOHY, D. R.; RENDALL, D. L., eds. *The Archaeology of Smith Creek Canyon*, pp. 164-251. Nevada State Museum Anthropological Papers No. 17. Carson City.

BRYAN, A. L. (1988) The Relationship of the Stemmed Point and Fluted Point Traditions in the Great Basin. In WILLIG, J. A.; AIKENS, C. M.; FAGAN, J. L., eds. *Early Human Occupation* *in Far Western North America: The Clovis-Archaic Interface*, pp. 53-74. Nevada State Museum Anthropological Papers No. 21. Carson City.

ELSTON, R. G.; ZEANAH, D. W. (2002) Thinking Outside the Box: a New Perspective on Diet Breadth and Sexual Division of Labor in the Prearchaic. *World Archaeology* 34:103-130.

FRY, G. (1976) *Analysis of Prehistoric Coprolites from Utah*. University of Utah Anthropological Papers No. 97. Salt Lake City.

GOEBEL, T. (2007) Pre-Archaic and Early Archaic Technological Activities at Bonneville Estates Rockshelter: A First Look at the Lithic Artifact Record. In GRAF, K.; SCHMITT, D., eds. *Paleoindian or Paleoarchaic? Great Basin Human Ecology at the Pleistocene-Holocene Transition*, in press. University of Utah Press, Salt Lake City.

GOEBEL, T.; GRAF, K. E.; HOCKETT, B. S.; RHODE, D. (2004) Late Pleistocene Humans at Bonneville Estates Rockshelter, Eastern Nevada. *Current Research in the Pleistocene* 20:20-23.

GRAF, K. E. (2007) Stratigraphy and Chronology of the Pleistocene to Holocene Transition at Bonneville Estates Rockshelter, Eastern Nevada. In GRAF, K. E.; SCHMITT, D., eds. *Paleoindian or Paleoarchaic? Great Basin Human Ecology at the Pleistocene-Holocene Transition*, in press. University of Utah Press, Salt Lake City.

GRAYSON, D. K. (1983) The Paleontology of Gatecliff Shelter: Small Mammals. In THOMAS, D. H., ed. *The Archaeology of Monitor Valle*y: 2. Gatecliff Shelter, pp. 98-126. Anthropological Papers Vol. 59, pt. 1. Amerian Museum of Natural History, New York.

GRAYSON, D. K. (1998) Moisture History and Small Mammal Community Richness during the Latest Pleistocene and Holocene, Northern Bonneville Basin, Utah. *Quaternary Research* 49:330-334.

HARPER, K. T.; ALDER, G. M. (1972) Paleoclimatic Inferences Concerning the Last 10,000 Years from a Resampling of Danger Cave, Utah. In FOWLER, D. D., ed. *Great Basin Cultural Ecology: A Symposium*, pp. 13-23. Desert Research Institute Publications in the Social Sciences No. 8. Reno.

HOCKETT, B. (1991) Toward Distinguishing Human and Raptor Patterning on Leporid Bones. *American Antiquity* 56:667-679.

HOCKETT, B. (1994) A Descriptive Reanalysis of the Leporid Bones from Hogup Cave, Utah. *Journal of California and Great Basin Anthropology* 16:106-117.

HOCKETT, B. (2007) Nutritional Ecology of Late Pleistocene-to-Middle Holocene Subsistence in the Great Basin: Zooarchaeological Evidence from Bonneville Estates Rockshelter. In GRAF, K. E.; SCHMITT, D., eds. *Paleoindian or Paleoarchaic? Great Basin Human Ecology at the Pleistocene-Holocene Transition*, in press. University of Utah Press, Salt Lake City.

HOLMER, R. N. (1986) Common Projectile Points of the Intermountain West. In CONDIE, C. J.; FOWLER, D., eds. *Anthropology of the Desert West: Papers in Honor of Jesse D. Jennings*, pp. 91-115. University of Utah Anthropological Papers No. 110. Salt Lake City.

HUCKLEBERRY, G.; BECK, C.; JONES, G. T.; HOLMES, A.; CANNON, M.; LIVINGSTON, S.; BROUGHTON, J. M. (2001) Terminal Pleistocene/Early Holocene Environmental Change at the Sunshine Locality, North-Central Nevada, U.S.A. *Quaternary Research* 55:303-312.

JENKINS, D.; CONNOLLY, T.; AIKENS, C. M. (2004) *Early and Middle Holocene Archaeology of the Northern Great Basin*. Anthropological Papers of the University of Oregon No. 62. Eugene.

JENNINGS, J. D. (1957) *Danger Cave*. Anthropological Papers of the University of Utah No. 27. Salt Lake City.

JENNINGS, J. D. (1978) Prehistory of Utah and the Eastern Great Basin. Anthropological Papers of the University of Utah No. 98. Salt Lake City.

JONES, G. T.; BECK, C.; JONES, E. E.; HUGHES R. E. (2003) Lithic Source Use and Paleoarchaic Foraging Territories in the Great Basin. *American Antiquity* 68(1):5-38.

MADSEN, D. B. (2002) Great Basin Peoples and Late Quaternary Aquatic History. In HERSHELER, R.; CURREY, D. R.; MADSEN, D. B., eds. *Great Basin Aquatic Systems History*, pp. 387-405. Smithsonian Institution Press, Washington DC.

MADSEN, D. B.; RHODE, D. (1990) Early Holocene Pinyon (*Pinus monophylla*) in the Northeastern Great Basin. *Quaternary Research* 33:94-101.

MADSEN, D. B., RHODE, D.; GRAYSON, D. K.; BROUGHTON, J. M.; LIVINGSTON, S. D.; HUNT, J.; QUADE, J.; SCHMITT, D. N.; SHAVER, M. W. III (2001) Late Quaternary Environmental Change in the Bonneville Basin, Western USA. *Palaeogeography, Palaeoclimatology, Palaeoecology* 167:243-271.

MULLEN, C. O. (1997) *Mammalian Response to Pleistocene/Holocene Environmental Change in the Great Basin: the Jackrabbit's Tale*. Ph.D. Dissertation, University of Nevada, Reno.

NIALS, F. (1999) *Geomorphic Systems and Stratigraphy in Internally-Drained Watersheds of the Northern Great Basin: Implications for Archaeological Studies*. Technical Papers of the University of Nevada Sundance Archaeological Research Fund No. 5. Reno.

OVIATT, C. G.; MILLDER, D. M.; ZACHARY, C.; MCGEEHIN, J. (2001) Refining the Age of the Lake Transgression to the Gilbert Shoreline in the Lake Bonneville Basin, Utah, USA. *EOS, Transactions*. *American Geophysical Union Fall Meeting Supplement* 82:F755.

OVIATT, C. G.; MADSEN, D. B.; SCHMITT, D. N. (2003) Late Pleistocene and Early Holocene Rivers and Wetlands in the Bonneville Basin of Western North America. *Quaternary Research* 60:200-210.

OVIATT, C. G.; MILLER, D. M.; MCGEEHIN, J. P.; ZACHARY, C.; MAHAN, S. (2005) The Younger Dryas Phase of Great Salt Lake, Utah, USA. *Palaeogeography, Palaeoclimatology, and Palaeoecology* 219:263-284.

RHODE, D. (2000) Holocene Vegetation History in the Bonneville Basin. In MADSEN, D. B., ed. *Late Quaternary Paleoecology in the Bonneville Basin,* pp. 149-163. Utah Geological Survey Bulletin 130, Salt Lake City.

RHODE, D.; LOUDERBACK, L. (2007) What is the Evidence for Dietary Plant Use in the Bonneville Basin during the Pleistocene/Holocene Transition? In GRAF, K. E.; SCHMITT, D., ed. *Paleoindian or Paleoarchaic? Great Basin Human Ecology at the Pleistocene-Holocene Transition*, in press. University of Utah Press, Salt Lake City.

RHODE, D.; MADSEN, D. B. (1998) Pine Nut Use in the Early Holocene and Beyond: The Danger Cave Archaeobotanical Record. *Journal of Archaeological Science* 25:1199-1210.

RHODE, D.; GOEBEL, T.; GRAF, K.; HOCKETT, B.; JONES, K. T.; MADSEN, D. B.; OVIATT, C. G.; SCHMITT, D. N. (2005) Latest Pleistocene-Early Holocene Human Occupation and Paleoenvironmental Change in the Bonneville Basin, Utah-Nevada. In PEDERSON, J.; DEHLER, C., ed. *Interior Western United States*, pp. 211-230. Geological Society of America Field Guide 6. Boulder, Colorado.

RHODE, D., MADSEN, D. B.; JONES, K. T. (2006) Antiquity of Early Holocene Small-Seed Consumption and Processing at Danger Cave. *Antiquity* 80(308):328-339.

SCHMIDT, G. A.; LEGRANDE, A. N. (2005) The Goldilocks Abrupt Climate Change Event. *Quaternary Science Reviews* 24:1109-1110.

SCHMITT, D. N.; MADSEN, D. B. (2005) *Camels Back Cave*. University of Utah Anthropological Papers No. 125. Salt Lake City.

SCHMITT, D. N.; MADSEN, D. B.; LUPO, K. D. (2002) Small-Mammal Data on Early and Middle Holocene Climates and Biotic Communities in the Bonneville Basin, USA. *Quaternary Research* 58:255-260.

THOMAS, E. R.; WOLFF, E. W.; MULVANEY, R.P.; STEFFENSEN, J. P.; JOHNSEN, S. J.; ARROWSMITH, C.; WHITE, J. W. C.; VAUGHN, B.; POPP, T. (2007) The 8.2ka Event from Greenland Ice Cores. *Quaternary Science Reviews* 26:70-81.

THOMPSON, R. S. (1992) Late Quaternary Environments in Ruby Valley, Nevada. *Quaternary Research* 37:1-15.

WILLIG, J. A.; AIKENS, C. M. (1988) The Clovis-Archaic Interface in Far Western North America. In WILLIG, J. A.; AIKENS, C. M.; FAGAN, J. L., eds. *Early Human Occupation in Far Western North America: The Clovis-Archaic Interface*, pp. 1-40. Nevada State Museum Anthropological Papers No. 21. Carson City.

Table 1. Radiocarbon Dates for the Terminal Pleistocene and Early Holocene Deposits at Danger Cave.

| Material Dated | $^{14}C$ Age | Sample Number | Reference | Stratigraphic context |
|---|---|---|---|---|
| *DI* | | | | |
| Sheep dung | 11,453 ± 600 | C-609[1] | Jennings 1957:60 | Sand 2 [split sample with M-118] |
| Uncharred plant stem | 11,151 ± 570 | C-610[1] | Jennings 1957:54 | Top of Sand 1; DI occupation surface |
| Sheep dung | 11,000 ± 700 | M-118[2] | Jennings 1957 | Sand 2 |
| Lepus bone collagen | 10,600 ± 250 | AA-20859 | Mullen 1997 | DI |
| Twigs, F108[3] | 10,600 ± 200 | Tx-85 | Tamers et al. 1964 | Top of Sand 1; DI occupation surface |
| Charcoal, F108 | 10,270 ± 650 | M-202 | Jennings 1957 | Top of Sand 1; DI occupation surface |
| Uncharred twigs | 10,400 ± 700 | M-119 | Jennings 1957 | Sand 2 |
| Charcoal, F111 | 10,310 ± 40 | Beta-168656 | Rhode et al. 2006 | Top of Sand 1; DI occupation surface |
| Charcoal, F112 | 10,270 ± 50 | Beta-158549 | Rhode et al. 2006 | Top of Sand 1; DI occupation surface |
| Charred sheep dung | 10,270 ± 650 | M-204 | Jennings 1957 | Sand 1, below cultural occupation |
| Charcoal, vegetal debris | 10,150 ± 170 | Tx-87 | Tamers et al. 1964 | Top of Sand 1; DI occupation surface |
| Sheep dung | 9920 ± 185 | Beta-19611 | Madsen and Rhode 1990 | Stratum 3 (1986 excavation); equivalent to Sand 2 |
| Not reported[4] | 9780 ± 210 | Beta-19336 | Madsen and Rhode 1990 | Stratum 2 (1986 excavation); equivalent to surface of Sand 1 |
| Twigs and sticks | 9740 ± 210 | Tx-89 | Tamers et al. 1964 | Lower Sand 2 |
| Sheep pellets | 9050 ± 180 | Tx-88 | Tamers et al. 1964 | Lower Sand 2 |
| Charred dung, twigs | 8970 ± 150 | Tx-86 | Tamers et al. 1964 | Contact between Sand 1 and Sand 2—D1 occupation surface |
| Human coprolite | 8680 ± 50 | Beta-187446 | Rhode et al. 2006 | DI |
| Human coprolite | 3310 ± 60 | Beta-97898 | Rhode et al. 2006 | DI |
| Human coprolite | 3270 ± 40 | Beta-187444 | Rhode et al. 2006 | DI |
| Human coprolite | 3030 ± 40 | Beta-187083 | Rhode et al. 2006 | DI |
| Human coprolite | 3020 ± 50 | Beta-187445 | Rhode et al. 2006 | DI |
| *Lower DII* | | | | |
| Twigs, ash, and dung | 10,130 ± 250 | GaK-1899 | Harper and Alder 1972 | Lower DII |
| Not reported[4] | 10,080 ± 130 | Beta-19333 | Madsen and Rhode 1990 | Stratum 5 (1986 excavation); equivalent to lower DII |
| Charcoal, F115[5] | 10,050 ± 50 | Beta-169848 | Rhode et al. 2005 | Lower DII |
| Charred rat dung | 8960 ± 340 | C-640[1] | Jennings 1957 | Top of Sand 2 |
| Twigs and ash | 6960 ± 210 | GaK-1895 | Harper and Alder 1972 | Lower DII |
| *Middle/Upper DII* | | | | |

| | | | | |
|---|---|---|---|---|
| Pickleweed chaff | 9900 ± 400 | GaK-1900 | Harper and Alder 1972 | Fry's layer F12; Upper DII |
| Pit feature, charcoal | 9789 ± 630 | C-611[1] | Jennings 1957:64 | Middle of DII |
| Pickleweed chaff | 9590 ± 160 | GaK-1896 | Harper and Alder 1972 | Layer F12 (1968 excavation); Upper DII |
| Pickleweed chaff | 8570 ± 40 | Beta-193123 | Rhode et al. 2006 | Stratum 04-11 (2004 excavation); equivalent to Fry's Layer F12; Middle DII |
| Not reported[4] | 8440 ± 50 | Beta-190887 | Rhode et al. 2006 | Stratum 6 (1986 excavation); equivalent to middle DII |
| Not reported[4] | 8410 ± 50 | NSRL-11436 | Rhode et al. 2006 | Stratum 8 (1986 excavation); equivalent to upper DII |
| Pickleweed chaff | 8380 ± 60 | Beta-193124 | Rhode et al. 2006 | Stratum 04-10 (2004 excavation); equivalent to Fry's Layer F12; Middle DII |
| Human coprolite | 8380 ± 40 | Beta-187449 | Rhode et al. 2006 | DII |
| Human coprolite | 8300 ± 40 | Beta-187450 | Rhode et al. 2006 | DII |
| Charcoal, F119[6] | 8270 ± 40 | Beta-168857 | Rhode et al. 2006 | Upper DII |
| Not reported | 8200 ± 50 | Beta-190866 | Rhode et al. 2006 | Stratum 7 (1986 excavation); equivalent to middle/upper DII |
| Human coprolite | 8190 ± 50 | Beta-187448 | Rhode et al. 2006 | DII |
| Human coprolite | 8160 ± 40 | Beta-189084 | Rhode et al. 2006 | DI |
| Human coprolite | 8130 ± 50 | Beta-187447 | Rhode et al. 2006 | DII |
| Human coprolite | 8100 ± 40 | Beta-187453 | Rhode et al. 2006 | DII |
| Human coprolite | 8100 ± 40 | Beta-187454 | Rhode et al. 2006 | DII |
| Not reported | 7920 ± 80 | Beta-23653 | Rhode et al. 2006 | Stratum 9 (1986 excavation); equivalent to upper DII |
| Pine nut hull | 7410 ± 120 | AA-3623 | Madsen and Rhode 1990 | Stratum 10 (1986 excavation); equivalent to upper DII |
| Human coprolite | 6020 ± 50 | Beta-187452 | Rhode et al. 2006 | DII |
| Human coprolite | 5060 ± 40 | Beta-189085 | Rhode et al. 2006 | DII |
| Human coprolite | 5030 ± 40 | Beta-187451 | Rhode et al. 2006 | DII |

[1]Solid carbon date that is unreliable (Madsen and Rhode 1990:96).
[2]Cited as M-116 in Jennings (1957:60).
[3]Sample split with M-202 (Rhode et al. 2006).
[4]Probably charcoal (D. Madsen, pers. commun., 2007).
[5]F31 in Jennings (1957).
[6]F30 in Jennings (1957).

Table 2. Radiocarbon Dates for the Terminal Pleistocene and Early Holocene Deposits at Smith Creek Cave.

| Material Dated | $^{14}C$ Age | Sample Number | Reference | Stratigraphic context |
|---|---|---|---|---|
| Artiodactyl hair | 14,220 ± 650[1] | RIDDL-796 | Bryan 1988 | Grey ash and silt |
| Wood twigs | 12,150 ± 120[2] | Birm-752 | Bryan 1988 | Grey ash and silt |
| Camelid hair | 12,060 ± 450 | RIDDL-797 | Bryan 1988 | Grey ash and silt |
| Scattered charcoal | 11,680 ± 160 | Tx-1421 | Bryan 1979 | Grey ash and silt |
| Charcoal, TP-8 1st hearth | 11,140 ± 200 | Tx-1637 | Bryan 1988:71 | Dung, rubble, and silt; dug into grey ash |
| Bovid hair | 10,840 ± 250 | RIDDL-795 | Bryan 1988 | Grey ash and silt |
| Charcoal, TP-8 2nd hearth | 10,660 ± 220 | GaK-5442 | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |
| Charcoal, TP-8 3rd hearth | 10,630 ± 190 | GaK-5443 | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |
| Charcoal, TP-8 3rd hearth | 10,570 ± 160 | GaK-5445 | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |
| *Average of two* | *10,590 ± 122* | | | |
| Charcoal, TP-8 3rd hearth | 9280 ± 160[3] | GaK-5446 | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |
| Charcoal, TP-8 4th hearth | 10,740 ± 130 | Birm-702 | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |
| Charcoal, TP-8 4th hearth | 10,460 ± 260 | GaK-5444b[4] | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |
| *Average of two* | *10,647 ± 116* | | | |
| Wood (cellulose) | 10,700 ± 180 | Birm-917 | Bryan 1979 | Grey ash and silt |
| S-twist cordage | 10,420 ± 100 | TO-1173 | Bryan 1988 | Grey ash and silt |
| Charcoal, TP-6 hearth 12[5] | 10,330 ± 190 | Tx-1638 | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |
| Charcoal, TP-6 hearth 9 | 9940 ± 160 | Tx-1420 | Bryan 1979 | Dung, rubble, and silt; dug into grey ash |

[1]Bryan (1988) argues that this date must be aberrant since it is older than dates of about 13,000 BP recovered from lower-lying bristlecone pine needle layer.
[2]This age estimate was incorrectly reported as 12,200 ± 300 in Figure 5 of Bryan (1979:187).
[3]Bryan (1979) interprets this as aberrantly too old (sample was not pretreated correctly).
[4]This sample was re-run from earlier sample dated to only 9800 ± 160 (GaK-5444); Bryan (1979) attributed discrepancy to lack of alkaline pretreatment in earlier run.
[5]This hearth was called hearth 7 in Figure 5a of Bryan (1979:188).

Table 3. Radiocarbon Dates for the Terminal Pleistocene and Early Holocene Deposits at Bonneville Estates Rockshelter.

| Material Dated | $^{14}C$ Age | Sample Number | Reference | Stratigraphic context |
|---|---|---|---|---|
| *West Block* | | | | |
| Bone | 15,240 ± 50 | UCIAMS-22180 | Graf 2007 | Stratum 19 |
| Bone | 11,960 ± 60 | Beta-209265 | Graf 2007 | Stratum 19 |
| Charcoal, F04.13b[1] | 12,390 ± 40 | Beta-195045 | Graf 2007 | Stratum 19 |
| Charcoal, F04.13b | 12,330 ± 40 | Beta-195046 | Graf 2007 | Stratum 19 |
| Bone, F04.13b | 11,530 ± 40 | Beta-209265 | Graf 2007 | Stratum 19 |
| Charcoal, F0413b | 10,970 ± 60 | Beta-200874 | Graf 2007 | Stratum 19 |
| Charcoal, F03.16/04.13 | 12,270 ± 60 | AA-58595 | Graf 2007 | Stratum 19/18b |
| Charcoal, F03.16/04.13 | 10,690 ± 70 | AA-58590 | Graf 2007 | Stratum 19/18b |
| Charcoal, F03.17 | 12,180 ± 60 | AA-58587 | Graf 2007 | Stratum 19 |
| Bone, F03.17 | 10,900 ± 50 | UCIAMS-22176 | Graf 2007 | Stratum 19 |
| Bone, F03.17 | 10,830 ± 40 | Beta-210524 | Graf 2007 | Stratum 19 |
| Charcoal, F03.17 | 10,640 ± 60 | Beta-200875 | Graf 2007 | Stratum 19 |
| *Average of three* | *10,821 ± 31* | | | |
| Charcoal, F05.06 | 11,010 ± 40 | Beta-207009 | Graf 2007 | Stratum 18b |
| Charcoal, F03.15a | 10,800 ± 60 | AA-58594 | Graf 2007 | Stratum 18b |
| Charcoal, F03.15a | 10,760 ± 70 | AA-58592 | Graf 2007 | Stratum 18b |
| *Average of two* | *10,773 ± 46* | | | |
| Charcoal, F04.14 | 10,540 ± 40 | Beta-195047 | Graf 2007 | Stratum 18b |
| Charcoal, F03.14 | 10,405 ± 50 | AA-58593 | Graf 2007 | Stratum 18b |
| Charcoal, F01.01 | 10,130 ± 60 | Beta-170444 | Graf 2007 | Stratum 18a |
| Charcoal, F01.01 | 10,080 ± 50 | Beta-164229 | Graf 2007 | Stratum 18a |
| Charcoal, F01.01 | 10,040 ± 70 | Beta-170443 | Graf 2007 | Stratum 18a |
| *Average of three* | *10,090 ± 34* | | | |
| Charcoal, F05.02 | 9580 ± 40 | Beta-207010 | Graf 2007 | Stratum 17b' |
| Charcoal, F03.13 | 9440 ± 50 | AA-58589 | Graf 2007 | Stratum 17b' |
| Charcoal, F03.13 | 9430 ± 50 | AA-58588 | Graf 2007 | Stratum 17b' |
| *Average of two* | *9435 ± 35* | | | |
| *East Block* | | | | |
| Charcoal, E4-12-C5/D3-10-C10[2] | 10,380 ± 40 | Beta-195013 | Graf 2007 | Stratum 12 |
| Charcoal, E4-12-C5/D3-10-C10 | 10,340 ± 60 | Beta-203504 | Graf 2007 | Stratum 12 |
| *Average of two* | *10,367 ± 33* | | | |
| Charcoal, E3-13-C4 | 10,250 ± 50 | Beta-206278 | Graf 2007 | Stratum 12 |

| | | | | |
|---|---|---|---|---|
| Charcoal, D5-10-C8a/C8d | 10,380 ± 60 | AA-58600 | Graf 2007 | Stratum 12 |
| Charcoal, D5-10-C8a/C8d | 10,050 ± 50 | Beta-182935 | Graf 2007 | Stratum 12 |
| Charcoal, D4-12-C9b | 10,030 ± 50 | Beta-182934 | Graf 2007 | Stratum 12 |
| Charcoal, D4-10-C8/C7b | 10,560 ± 50 | Beta-182931 | Graf 2007 | Stratum 12 |
| Charcoal, D4-10-C8/C7b | 9990 ± 50 | AA-58598 | Graf 2007 | Stratum 12 |
| Charcoal, E4-10-C3/E5-10-C7 | 9580 ± 40 | Beta-195042 | Graf 2007 | Stratum 10 |
| Charcoal, E4-10-C3/E5-9-C5b | 9570 ± 40 | Beta-195044 | Graf 2007 | Stratum 10 |
| *Average of two* | *9595 ± 48* | | | |
| Charcoal, E6-10-C10 | 9520 ± 60 | Beta-161891 | Graf 2007 | Stratum 10 |
| Charcoal, E6-10-C10 | 9440 ± 80 | AA-58599 | Graf 2007 | Stratum 10 |
| *Average of two* | *9493 ± 48* | | | |
| Charcoal, A4-9-C1 | 8830 ± 60 | Beta-203507 | Graf 2007 | Stratum 9 |

[1]Hearth feature designation for west block.
[2]Hearth feature designation for east block.

Table 4. Reliable $^{14}C$ ages dating cultural occupation events at Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter.

| Danger Cave | | Smith Creek Cave | | Bonneville Estates Rockshelter | |
|---|---|---|---|---|---|
| $^{14}C$ BP | Cal BP | $^{14}C$ BP | Cal BP | $^{14}C$ Age | Cal BP |
| 10,310 ± 40 | 12,360-12,014 | 11,140 ± 200 | 13,260-12,856 | 11,010 ± 40 | 13,018-12,818 |
| 10,270 ± 650 | 12,679-10,966 | 10,660 ± 220 | 12,788-12,177 | 10,821 ± 31* | 12,852-12,722 |
| 10,270 ± 50 | 12,268-11,872 | 10,647 ± 116* | 12,721-12,366 | 10,773 ± 46* | 12,803-12,700 |
| 10,150 ± 170 | 12,185-11,469 | 10,590 ± 122* | 12,679-12,260 | 10,690 ± 70 | 12,739-12,607 |
| 10,080 ± 130 | 11,950-11,413 | 10,420 ± 100 | 12,539-12,121 | 10,540 ± 40 | 12,648-12,363 |
| 10,050 ± 50 | 11,750-11,419 | 10,330 ± 190 | 12,483-11,741 | 10,405 ± 50 | 12,511-12,161 |
| 8570 ± 40 | 9552-9523 | 9940 ± 160 | 11,772-11,262 | 10,367 ± 33* | 12,474-12,124 |
| 8440 ± 50 | 9509-9435 | | | 10,250 ± 50 | 12,172-11,842 |
| 8410 ± 50 | 9485-9361 | | | 10,090 ± 34* | 11,832-11,489 |
| 8380 ± 60 | 9465-9324 | | | 10,050 ± 50 | 11,750-11,419 |
| 8380 ± 40 | 9460-9340 | | | 10,030 ± 50 | 11,710-11,392 |
| 8300 ± 40 | 9396-9264 | | | 9990 ± 50 | 11,593-11,346 |
| 8270 ± 40 | 9368-9172 | | | 9595 ± 48* | 11,079-10,822 |
| 8200 ± 50 | 9249-9077 | | | 9580 ± 40 | 11,056-10,814 |
| 8190 ± 50 | 9240-9066 | | | 9493 ± 48* | 11,008-10,698 |
| 8160 ± 40 | 9191-9045 | | | 9435 ± 35* | 10,710-10,613 |
| 8130 ± 50 | 9151-9028 | | | 8830 ± 60 | 10,091-9774 |
| 8100 ± 40 | 9091-9011 | | | | |
| 8100 ± 40 | 9091-9011 | | | | |
| 7920 ± 80 | 8932-8655 | | | | |
| 7410 ± 120 | 8340-8090 | | | | |

*Average dates of hearths or bones with multiple $^{14}C$ dates.

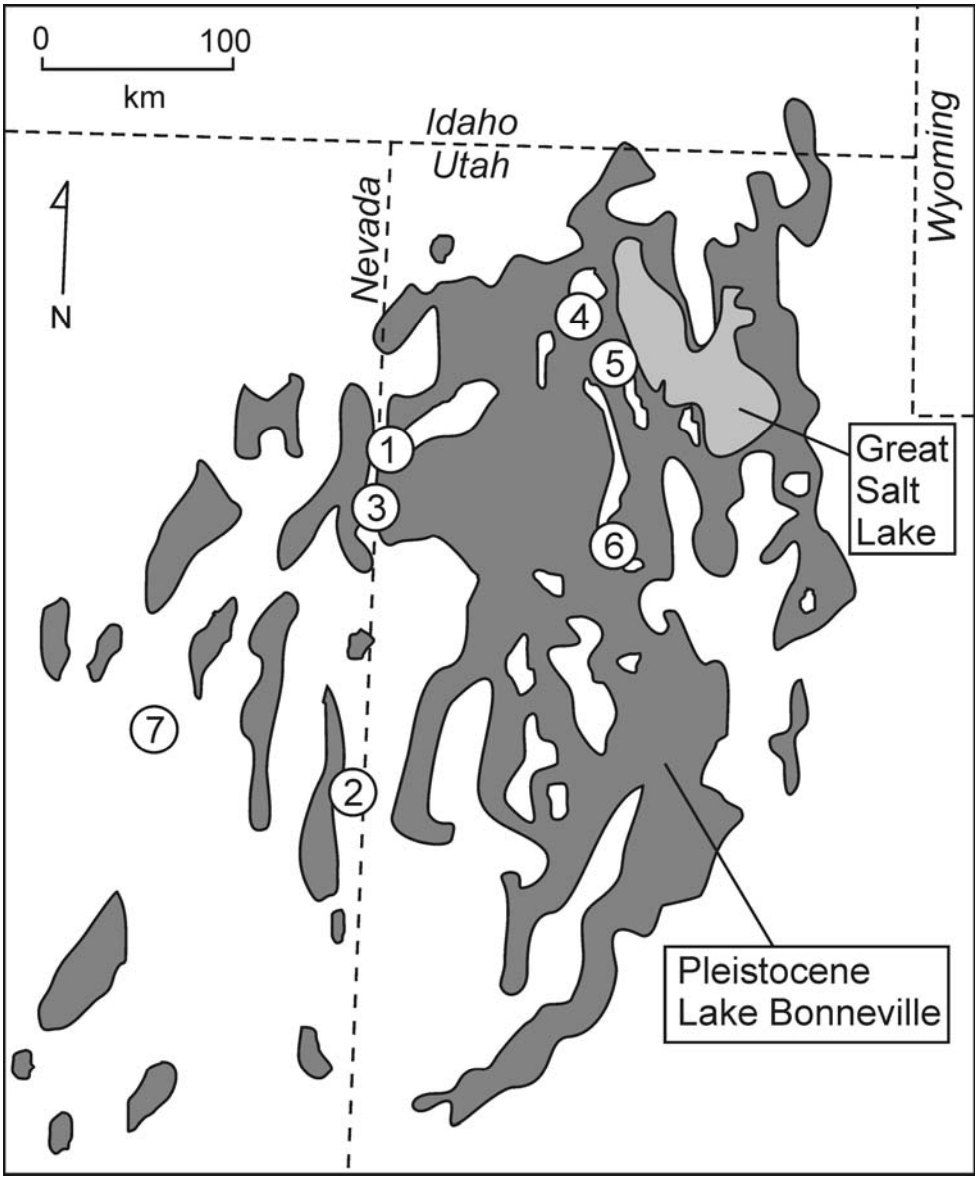
Figure Captions

Figure 1. Map showing location of archaeological sites mentioned in text (1, Danger Cave; 2, Smith Creek Cave; 3, Bonneville Estates Rockshelter; 4, Hogup Cave; 5, Homestead Cave; 6, Camels Back Cave; 7, Sunshine Well), greatest extent of Lake Bonneville during the late Pleistocene, and other late Pleistocene lakes.

Figure 2. A view of the Smith Creek Cave excavation, along the west side of the cave at its mouth, where the main Mt. Moriah occupation zones occurred. The grey ash and silt stratum is exposed around the excavator's shadow (photo courtesy of Alan Bryan).

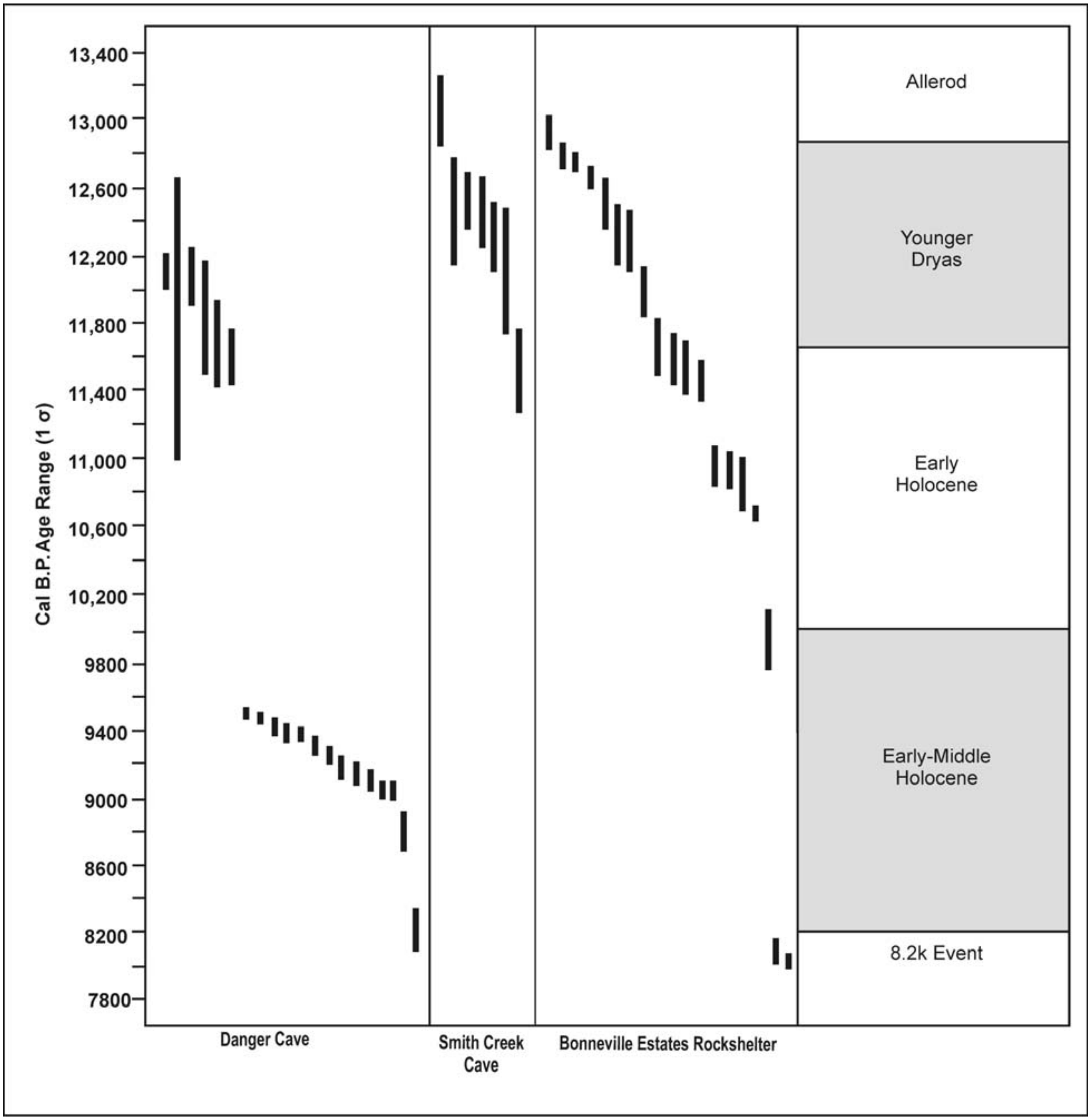
Figure 3. Hearth feature 03.15 (stratum 18b), one of the oldest $^{14}C$-dated hearths at Bonneville Estates Rockshelter (photo by Bryan Hockett).

Figure 4. Calibrated $^{14}C$ ages that accurately measure the ages of the early cultural occupations at Danger Cave, Smith Creek Cave, and Bonneville Estates Rockshelter (from Table 4). According to multiple proxy records, during the Younger Dryas period the western Bonneville basin filled with water, forming the Gilbert shoreline. Gradual drying occurred during the early Holocene, followed by extremely hot and arid conditions during the early-middle Holocene. During the "8.2k" event, climate was more mesic than during the previous 1500 years.



0
100
km
N
Idaho
Utah
Nevada
Wyoming
1
2
3
4
5
6
7
Great Salt Lake
Pleistocene Lake Bonneville

BER
Stratum 18b, Spit 1
Feature 03.15
-18cm bd
Unit N8 W20
9/26/03
B. Hockett


13,400
13,000
12,600
12,200
11,800
11,400
11,000
10,600
10,200
9800
9400
9000
8600
8200
7800
Cal B.P. Age Range (1 σ)
Danger Cave
Smith Creek Cave
Bonneville Estates Rockshelter
Allerod
Younger Dryas
Early Holocene
Early-Middle Holocene
8.2k Event