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Burned Wood as a Cultural Marker? Ancient Ligneous Landscapes and Firewood Use at Bonneville Estates Rockshelter, Nevada, USA

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Abstract

Plant resources have been widely relied upon by past hunter-gatherer societies; their remains uncovered at archaeological sites can serve as precious archives of the lives of past humans. However, while faunal remains are generally well preserved, botanical materials are usually charred, and less commonly preserved under conditions of desiccation, imbibition or freezing. Bonneville Estates Rockshelter (BER), Nevada, was intermittently occupied by humans from the end of the Pleistocene to recent times and has yielded a rich archaeobotanical corpus consisting of both charred and dessicated remains that have been only partially studied. The present work is an analysis of about 2500 wood charcoal fragments recovered from the PaleoIndigenous (ca. 13 000–10 500 cal. BP) and Early Archaic (ca. 8200–4800 cal. BP) strata of the site. We present the plants selected for firewood during different occupations, question whether this selection is related to cultural and/or environmental factors and compare our results with data on current firewood use by the native populations of the arid American West.

Keywords

anthracology – Bonneville Basin – early Holocene – ethnobotany – late Pleistocene

1 Introduction

Perishable materials were essential to the survival of hunter-gatherer societies (Croes 1997; Hurcombe 2008), and many archaeological disciplines examine these types of remains to better understand past societies. Such studies are particularly diverse in the arid western United States, where numerous archaeological sites are known to contain exceptionally well-preserved plant remains, including pollen, starch, charcoal, seeds, half-burned fleshy fruits, human coprolites, plant — fiber cordage, and basketry. Unsurprisingly, scholars have primarily focused on these types of remains, thus providing valuable information on subsistence pursuits and perishable technologies for ancient populations in western North America (*e.g.*, Kelso 1970; Adovasio, 1970, 1986; Croes 1997; Rhode & Louderback 2007; Geib & Jolie 2008; Rhode 2008; Louderback & Rhode 2009; Blong *et al.* 2020; Coe 2020, 2021; Louderback 2021). However, despite being important sources of information, some macrobotanical lines of evidence have not benefitted from such attention. This is notably the case for wood charcoal, which reflects both the woody environment surrounding human occupations and human choices regarding firewood use (*e.g.*, Chabal *et al.* 1999; Théry-Parisot 2001; Dufraisse *et al.* 2007). Charcoal analysis has the potential to provide significant additional information regarding both paleolandscapes and past human lifeways. In this study, we focus on a question that has been debated for a long time: To what extent is anthracology able to provide paleoethnological information? In other words, can burned wood be considered a cultural marker in the same manner as other biocultural remains?

We explore this question using charcoal analyses of the remains present at the Bonneville Estates Rockshelter (BER) archaeological site in eastern Nevada. Specifically, we aim to provide new knowledge on the use of woody resources by the Late Pleistocene and Early Holocene Native peoples of the Great Basin by demonstrating that: (1) firewood is not just a reflection of natural vegetation; (2) significant disparities exist between the management of fuel by PaleoIndigenous and Early Archaic groups; and (3) the uses and customs of woody plants persist among the present-day native peoples of the Bonneville Basin.

2 Paleoenvironmental and Archaeological Context

2.1 *Holocene Warming in the Bonneville Basin*

The Bonneville Basin is located in the eastern part of the Great Basin, mainly in what is now the state of Utah. Although the Great Basin is currently one of the driest regions in the United States, this was not always the case. During the Last Glacial Maximum, the basin was home to a large paleolake called Lake Bonneville, which covered 52 000 km² (Oviatt & Shroder 2016). In the following millennia, this paleolake gradually dried up, becoming practically empty by approximately 13,000 cal BP. (Oviatt 2015). The various stages of high water levels carved numerous caves and rockshelters into the shorelines, including BER. The cave was originally formed by waves from the Pleistocene Lake Bonneville, which reached its maximum at approximately 18 700 cal BP. It is one of the oldest rockshelters in the region and has remained mostly dry since its creation. As the lake had dried up by approximately 15 000 cal BP, wide areas of saline playas and marshland were exposed in the valleys (Gilbert 1980; Currey *et al.* 1983; Oviatt *et al.* 1992; Benson *et al.* 2011; Oviatt 2015; Thompson *et al.* 2016; Palacios-Fest *et al.* 2022). Not long after, these areas were frequented by PaleoIndigenous people, with the oldest known traces of occupation of the Bonneville Basin dating to the time of the Clovis culture (approximately 13 000 cal BP) in the Smith Creek Cave (Bryan 1977; see also Goebel & Keene 2014; Lynch *et al.* 2024) and in BER itself (Goebel *et al.* 2021).

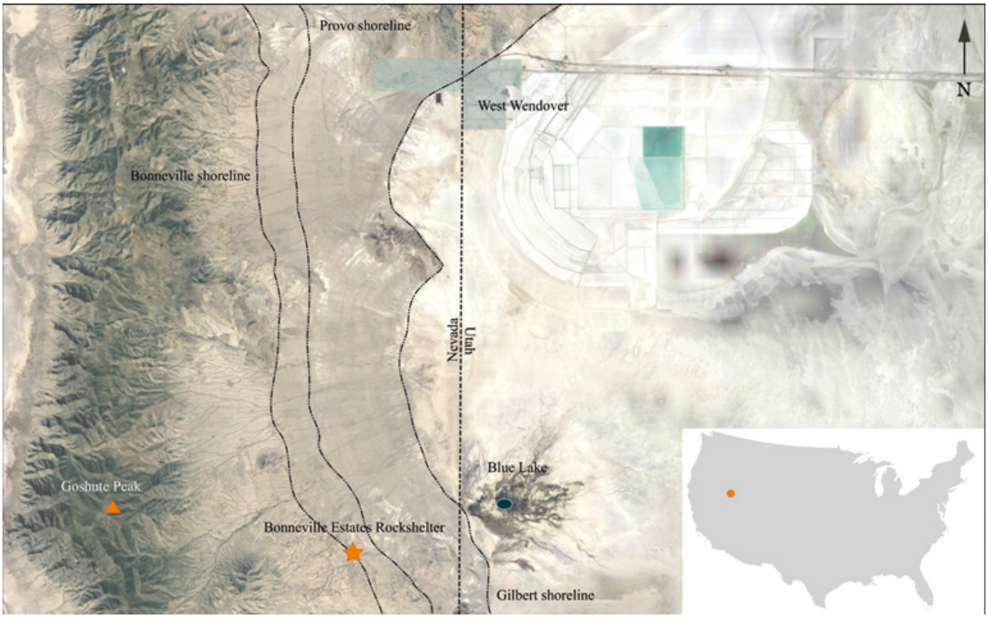

FIGURE 1 Location of Bonneville Estates Rockshelter. Map background © GOOGLE EARTH

The process of aridification of the basin accelerated at the very beginning of the Holocene (ca. 11 700 cal BP), resulting in a shift from a mosaic environment of open pine woodland and sagebrush shrubland in the Younger Dryas[1] to the present desert shrubland at the beginning of the Holocene, where numerous Amaranthaceae, sagebrush (*Artemisia*), horsebrush (*Tetradymia*), and other shrubs grow side by side (Rhode & Madsen 1995; Rhode 2000a,b; Madsen *et al.* 2001; Louderback & Rhode 2009; Goebel *et al.* 2011; Thompson *et al.* 2016).

2.2 Bonneville Estates Rockshelter (BER)

BER is a large, dry shelter measuring approximately 25 m long and 10 m wide (Graf 2007). Situated in the Lead Mine Hills, approximately 50 km south of West Wendover, Nevada (40 °28′29.67″N 114 °7′17.04″E), the site is located on the Bonneville shoreline at an altitude of around 1550 m above mean sea level (AMSL) (Figure 1). The roof, which is now slightly collapsed, rises to a height of 15 m in the center of the shelter. This shelter cover, in addition to the arid climate, has resulted in the remarkable preservation of organic remains (*e.g.*,

1 We place the Younger Dryas between 12 800–11 600 cal BP, in accordance with the chronozone chosen in Goebel *et al.* (2011) and in agreement with the results of Rasmussen (2014).

burned and unburned seeds, unburned wood and herbaceous plants, charcoals, and coprolites) and even artifacts made of perishable materials, including fragments of baskets and twine.

In 2000, a team of researchers conducted excavations on behalf of the U.S. Bureau of Land Management. Almost 55 m^2 was excavated over the next nine years, and the oldest archaeological layers at the site were found to date back to 13,000 cal BP (Goebel *et al.* 2021; Graf 2007).

Several archaeological components have been identified in BER, including two main components of the Pleistocene-Holocene transition. The stratigraphy is well preserved, and a multitude of hearths have been identified, enabling one of the largest dating campaigns in the Northern Hemisphere (Goebel *et al.* 2021). The earliest archaeological traces at BER correspond to component VIII, which comprises two material-poor strata: 20 and 19 (Table 1 and Figure 2). Its associated lithic industry was provisionally attributed to the pre-Clovis techno-complex (Goebel *et al.* 2021), but in view of the absence of combustion features and a very small assemblage of only non-diagnostic remains, the original investigators considered this attribution to be equivocal. The next three strata (18b, 18a and 17b′) correspond to component VII. Its lithic technology was assigned to the PaleoIndigenous techno-complex referred to as the Western Stemmed Tradition, and the strata date from the late Allerød through the Younger Dryas. Following Goebel *et al.* (2021), we combined these three strata into a single PaleoIndigenous component. Component VI consists of a single intermediate stratum, 17b, with a limited assemblage of material attributed to the Earliest Archaic dating to the beginning of the Holocene (Goebel *et al.* 2021).

Finally, the last component included in this study, component V, comprises strata 17a, 16, 15, 14c, 14b (sometimes divided into lower and upper parts), 14a (also sometimes divided into lower and upper parts) and 13. These strata date back to the Middle Holocene and are attached to the Early Archaic techno-complex.

2.3 Cultural Phases at Bonneville Estates Rockshelter (BER)

At BER, organic remains (bone and plant material), lithic pieces, and human-produced hearths make it possible to validate the stratigraphic position of most assemblages (Goebel *et al.* 2011). The first well-attested assemblage is the PaleoIndigenous assemblage. The diagnostic lithic material consists of stemmed points composed of obsidian or other volcanic rocks, a few bifacial pieces, several unifacial scrapers, and some marginally worked flakes. Given the scarcity of cortical fragments and other early stage stone tool manufacturing debris, it seems that tool preforms arrive at the site, with only final shaping

TABLE 1 Bonneville Estates Rockshelter chronostratigraphy of levels studied for this paper

Component	Phase	Strata	Date range (cal BP, oxcal20)	Techno-complex
VIII	Pre-Clovis	20, 19	14 516±182 13 397±45	Pre-Clovis
VII	Dry Gulch	18b, 18a, 17b′	12 941±71 10 531±85	PaleoIndigenous
VI	Wendover	17b	10 021±105 8 581±53	Earliest Archaic
V	Pie Creek	17a, 16, 15, 14c, 14b lower, 14b upper, 14a part 2, 14a part 1, 13	8 257±50 4 792±70	Early Archaic

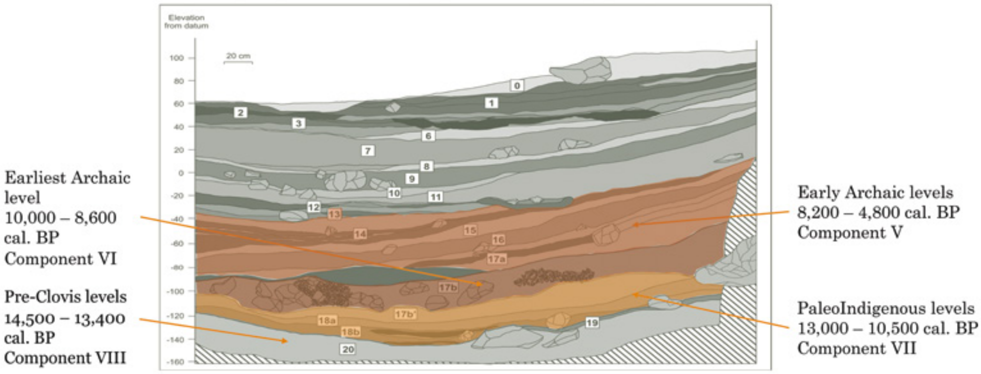

FIGURE 2 West block stratigraphy of Bonneville Estates Rockshelter (after Goebel *et al.* 2021)

or retouching being carried out *in situ* (Goebel 2007; Goebel *et al.* 2011, 2018). Moreover, most materials used for knapping come from distant locations (over 100 km away) (Goebel *et al.* 2007, 2011). The range of prey hunted by PaleoIndigenous groups, although broad, consisted mainly of artiodactyls, sage grouse (*Centrocercus urophasianus*), rabbits (*Sylvilagus*/*Brachylagus*), hares (*Lepus* sp.), and even katydids (*Capnotes occidentalis*) (Hockett 2015). From the seasonality data obtained on sage grouse, it appears that the PaleoIndigenous groups occupied the site on several occasions during the spring (Goebel *et al.* 2011). These data indicate that PaleoIndigenous occupations were of short duration and integrated into a system of high mobility in terms of both time and space (Goebel *et al.* 2011).

Archaeological materials at BER are most abundant in the Early Archaic layers as the site was intensively used during this period. The Early Archaic industry was characterized by significant production of side-notched bifacial points (Goebel *et al.* 2018). The presence of numerous cortical flakes indicates that unprocessed blocks of lithic raw material arrived at the site and all stages of knapping activities occurred there, with most of the material coming from local sources. However, some Early Archaic materials came from more distant sources, up to approximately 300 km away, which is even farther than those exploited by PaleoIndigenous populations (Goebel 2007; Goebel *et al.* 2018). From a dietary perspective, the faunal assemblage of the Early Archaic was less diverse than the PaleoIndigenous ones, with the bulk of the hunting economy concentrated on artiodactyls and hares. During this period, other small game (mainly rabbit and sage grouse) declined significantly, and insects completely disappeared from the faunal spectrum. This may have resulted from environmental changes associated with landscape aridification (Hockett 2015; Goebel *et al.* 2018). At BER, the Early Archaic also saw the beginning of the intensive use of small seeds and other plant parts (Poaceae, Amaranthaceae and Cactaceae). Seeds have also been identified in PaleoIndigenous strata, but in much smaller quantities (Rhode & Louderback 2007). While the presence of collecting packrats (notably *Neotoma* spp. in the PaleoIndigenous levels has raised questions about the anthropogenic origin of these seeds (Rhode & Louderback 2007), the presence of grinding tools at the Early Archaic levels confirms the anthropogenic processing of at least some of them. Finally, the Early Archaic levels are characterized by the presence of numerous remains of basketry, which once again suggests more permanent occupations and activity diversification (Goebel *et al.* 2018; Coe 2020).

These data undoubtedly indicate a reduction in mobility from the PaleoIndigenous to the Early Archaic periods and suggest a shift from a mobile residential system during the PaleoIndigenous period to a logistical system during the Early Archaic period.

3 Materials and Methods

3.1 *Charcoal Assemblages*

The charcoal fragments analyzed in this study were obtained from two different contexts. Some were derived from two sediment columns from which the entire sediment was recovered as a bulk sediment sample. Other samples were recovered judgmentally (*i.e.*, as grab sediment samples) during excavation, particularly when areas with a high concentration of charcoal were exposed

(Figure 3). Most of the charcoal was recovered by dry-sieving the sediment samples using different sieve openings (1/4″, 1/8″ and 1/16″), with the analyzed charcoal from the <1/4″ fraction. To date, only 50 charcoal fragments have been analyzed from a well-identified hearth in square N3W14 of PaleoIndigenous level 18b. The hearth-charcoal assemblages are snapshots of the last fire. When we speak of hearths, we are generally talking about combustion structures that have been reused several times. The charcoal produced during previous fires was destroyed and reduced to ash when new combustion occurred. For this reason, charcoal from hearths is generally not studied as a priority but rather as a supplement to scattered charcoal (*i.e.*, moved from combustion features during cleaning or other activities), as only the last species used will be recorded in hearth deposits (Chabal 1992; Chabal *et al.* 1999).

Moreover, as scattered charcoal is not uniformly present in the stratigraphic layers of the site, we assume that its occurrence did not result from surface runoff (which would have been rare due to the region's low rainfall levels). The absence of a layer of charcoal covering the entire surface of the rockshelter, burned sediment, and artifacts also rules out the intervention of a wildfire that spread into the rockshelter. In contrast, the presence of circumscribed spaces with burned sediment and charcoal in various layers of the site leads us to

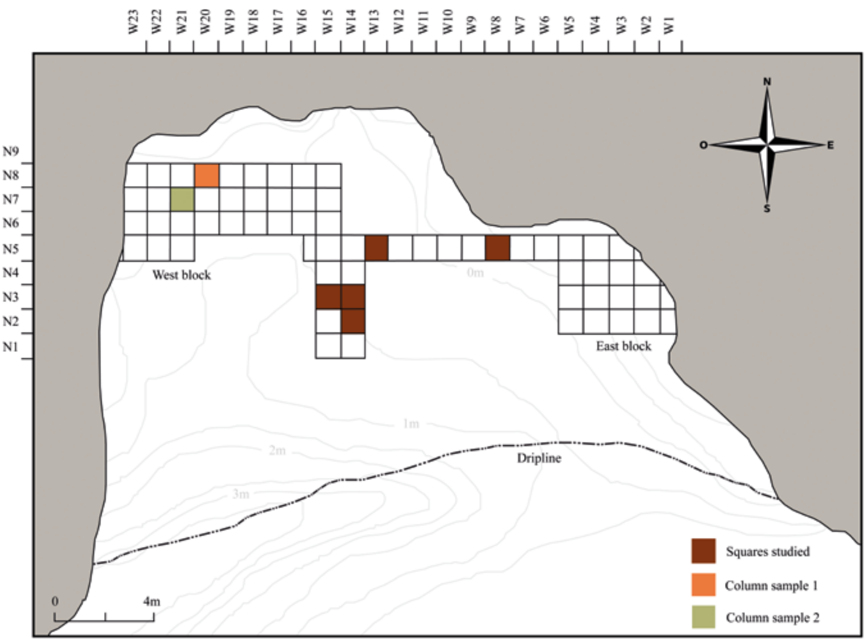

FIGURE 3 Map of the Bonneville Estates Rockshelter excavations between 2000 and 2009 (after Graf 2007)

believe that various small-scale combustions, similar to controlled hearths, occurred throughout BER's occupation. In this context, scattered charcoal samples have traditionally been identified in anthracology as resulting from the dispersal of hearth contents (Chabal 1992; Chabal *et al.* 1999). These areas may be more or less circumscribed, and scattering may be voluntary (emptying) or involuntary (in this case, trampling or other taphonomical agents).

3.2 *Charcoal Analysis*

Archaeological charcoals were identified under a reflected light microscope (mainly Leica DM2700) at different magnifications (between 50× and 1000×) and under different light conditions (bright and dark fields) with no prior treatment. The charcoal was fractured manually according to three anatomical sections of wood (transverse, radial longitudinal, and tangential longitudinal) to obtain fresh sections. The anatomy of the archaeological charcoal was then compared with that of modern specimens in the reference collection of the CEPAM (Cultures Environnements, Préhistoire-Antiquité-Moyen Âge) laboratory (Nice, France) to identify the family, genus, or, more rarely, species level. Other reference resources were also occasionally consulted, notably the wood anatomy site InsideWood (Wheeler 2011; Wheeler *et al.* 2020; available online at http://insidewood.lib.ncsu.edu/search). Our results are presented in the form of an anthracological diagram, created using the Excel macro "ACACIA" (Nourissier *et al.* 2019; available online at https://dendrac.mnhn.fr/spip.php?rubrique69). Finally, for illustrative purposes, scanning electron microscope (SEM) microphotographs were taken of a selection of charcoal specimens (Tescan Vega3 XMU from the CCMA de Valrose, Université Côte d'Azur and the Hitachi TM4000 benchtop SEM from the Desert Research Institute, Reno, NV, USA).

4 Results

To date, almost 2500 archaeological charcoal fragments have been identified (Table 2, Figure 4). The preservation of the charcoal is excellent, as reflected by the very low number of unidentified taxa (7). Although some charcoal fragments could not be identified at the genus or family level, they retained sufficient anatomical characteristics to be identified as "Angiosperm". Some non-woody plants were encountered and labelled "non-woody plant". Finally, some fragments showed completely altered or destroyed anatomy, making them impossible to identify. Therefore, they were labelled "unidentifiable" (Table 2).

TABLE 2 Charcoal Analysis Results by Component and Strata

	PaleoIndigenous							
	20	**19**	**18b**	**18a**	**18/17b**	**17b'**	**17b**	**17a**
Amaranthaceae			10	2	2	12		1
Amelanchier (Serviceberry)								
Artemisia sp. (Sagebrush)	39	10	88	32	48	80	32	25
Brickellia (*Brickellbush*)								
Ephedra sp. (Jointfir)						39		
Ericameria (*Rabbitbrush*)					1			
Ericameria/Gutierrezia								
Gutierrezia (*Snakeweed*)								
Pinus (fenestriform pits)		1			3			
Pinus (pinoid pits)								
Populus/Salix								
Prunus (Plum)								
Purshia (Bitterbrush)								
Ribes (Currant)								
Sarcobataceae (Greasewood)	2		1	22	6	33		5
Symphoricarpos (Snowberry)			1	1				
Tetradymia (Horsebrush)								
cf. Amaranthaceae								
cf. *Artemisia*								
cf. *Ephedra*								
cf. *Ericameria*								
cf. *Gutierrezia*								
cf. *Purshia*								
cf. *Tetradymia*								
Angiosperm	3					5		
Non-woody plant								
Unidentifiable			1	1		1		
Total	44	11	101	58	60	170	32	31

Early Archaic									Total
16	15	14c	14b lower	14b upper	14a part 2	14a part 1	14/13	13	
14	4	3	2	35	30	45	11	92	263
							6		6
24	22	71	32	64	21	61	22	276	947
						4		3	7
16	26	28	14	137	95	209	16	203	783
		1		10		5	9	24	50
								8	8
		7		13	5	26	3	8	62
						5			9
				1		2			3
								1	1
						3	2		5
					1				1
								1	1
2		3	6	13	20	46	13	48	220
				1					3
				14	2	5		8	29
								1	1
						1			1
				1					1
			2				1	4	7
1				4		3		5	13
3									3
						1			1
1	1	3	7	8		11	2	5	46
								6	6
						2	1	1	7
61	53	116	63	301	174	429	86	694	2484

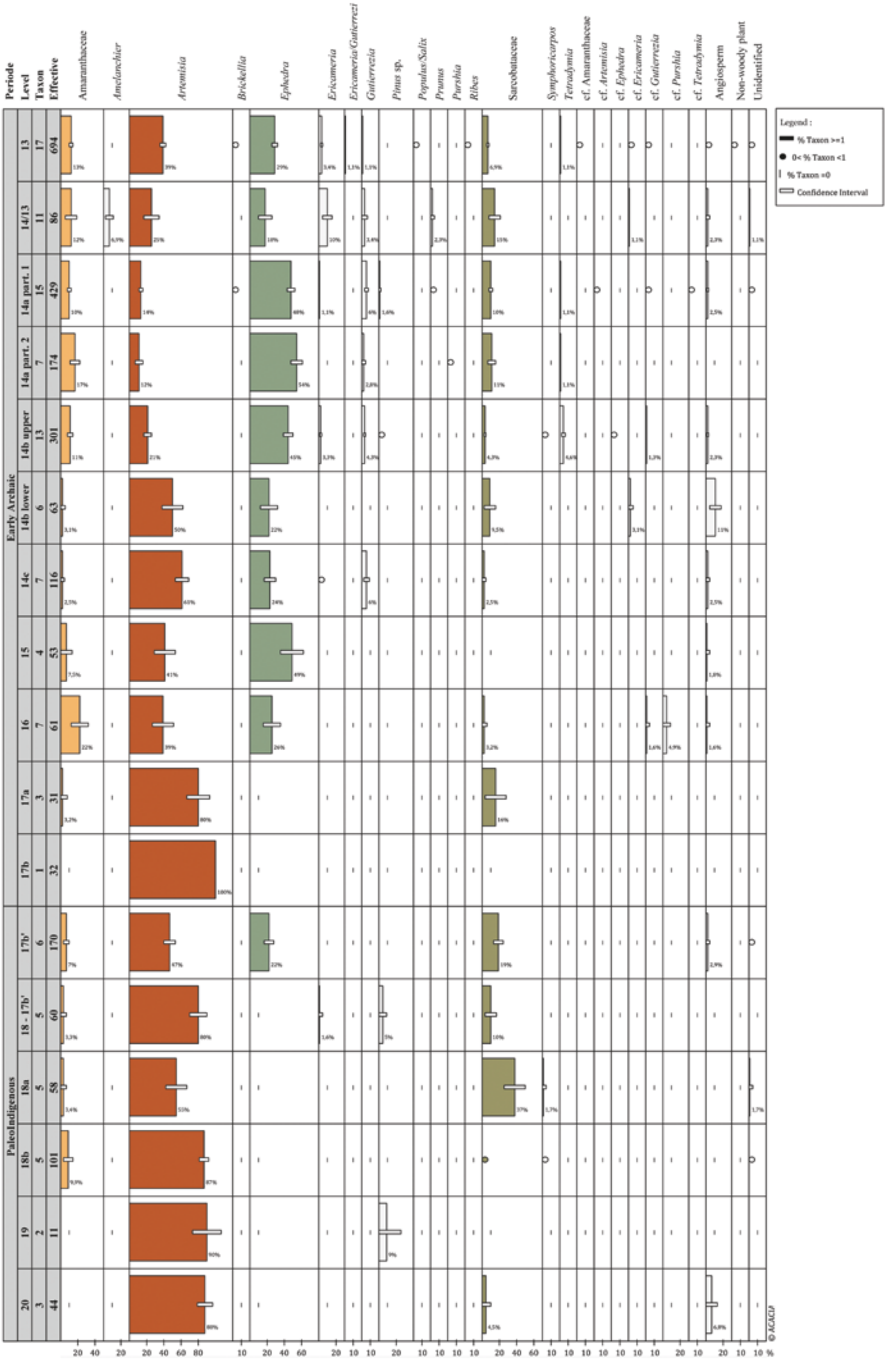

FIGURE 4 Archaeological charcoal identification diagram

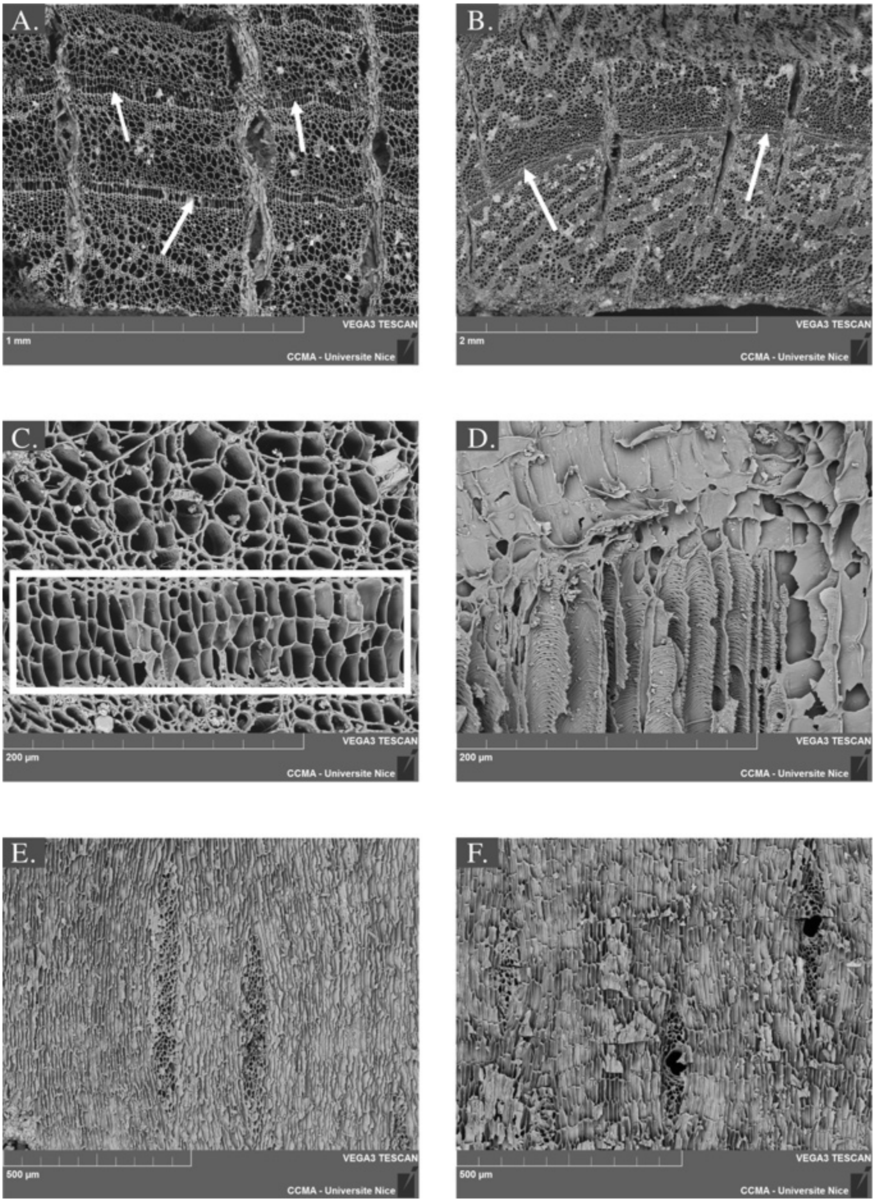

FIGURE 5 Scanning electron micrographs — Artemisia. Arrows and box mark interxylary cork lines

4.1 *Floristics Results*

4.1.1 PaleoIndigenous Layers

In the PaleoIndigenous strata, including strata 20 through 17b′, 444 charcoal fragments were identified and eight taxa (minimum number of taxa (MNT): 7) were identified. Only 11 fragments (approximately 2.5%) could not be identified, at least at the family level (Table 2). Almost all of the identified taxa are meso-and xerophilous shrubs that thrive today in the lowlands and hills surrounding the site (±900–1600 msl). Sagebrush (*Artemisia*), a member of the Asteraceae family, can easily identified by its distinctive anatomy with interxylary cork lines and strongly dominates the assemblage. According to Carlquist (2001), "The phenomenon of interxylary corks is not easily referred to in any secondary xylem category. It is related to growth ring activity, but even in genera such as *Artemisia*, in which interxylary cork is conspicuous […], it occurs in only a few species" (Carlquist 2001: p. 179), including *Artemisia tridentata* (Diettert 1938), which is currently one of the main *Artemisia* species in the Bonneville Basin. Sarcobataceae, represented by greasewood (*Sarcobatus vermiculatus*), the only species currently present in this region, also occurs throughout the PaleoIndigenous sequence in varying proportions, similar to Amaranthaceae. Amaranthaceae are woods with phloem inclusions, which makes them considerably more fragile than taxa composed entirely of xylem, and their anatomy, which very similar among the various genera, is no longer sufficiently well preserved after combustion to allow accurate identification of genus or species. The genera and species of this family are numerous and do not all have the same environmental requirements. Nevertheless, based on charcoal vessel patterns viewed in cross-section, it is probable that the genus *Atriplex* is the most common among the identifiable Amaranthaceae, while a few individuals point toward the presence of the genus *Grayia*.[2] Indeed, this taxon appears to have a cross-section with pores arranged more regularly in a tangential band.

At the same time, one taxon appeared in significant proportions in stratum 17b' alone, namely jointfir (*Ephedra*), a gnetophyte that is particularly well adapted to arid environments. Finally, pine (*Pinus* with fenestriform cross-field

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2 Some botanists have recently modified *Grayia's* phylogeny and integrated it into the genus *Atriplex*. However, as this decision is not unanimous, we refer to the U.S. Department of Agriculture website (plants.usda.gov, last consulted on 16 April 2024) and the World Flora Online website (worldfloraonline.org, last consulted on 16 April 2024) and consider *Grayia* a genus in its own right.

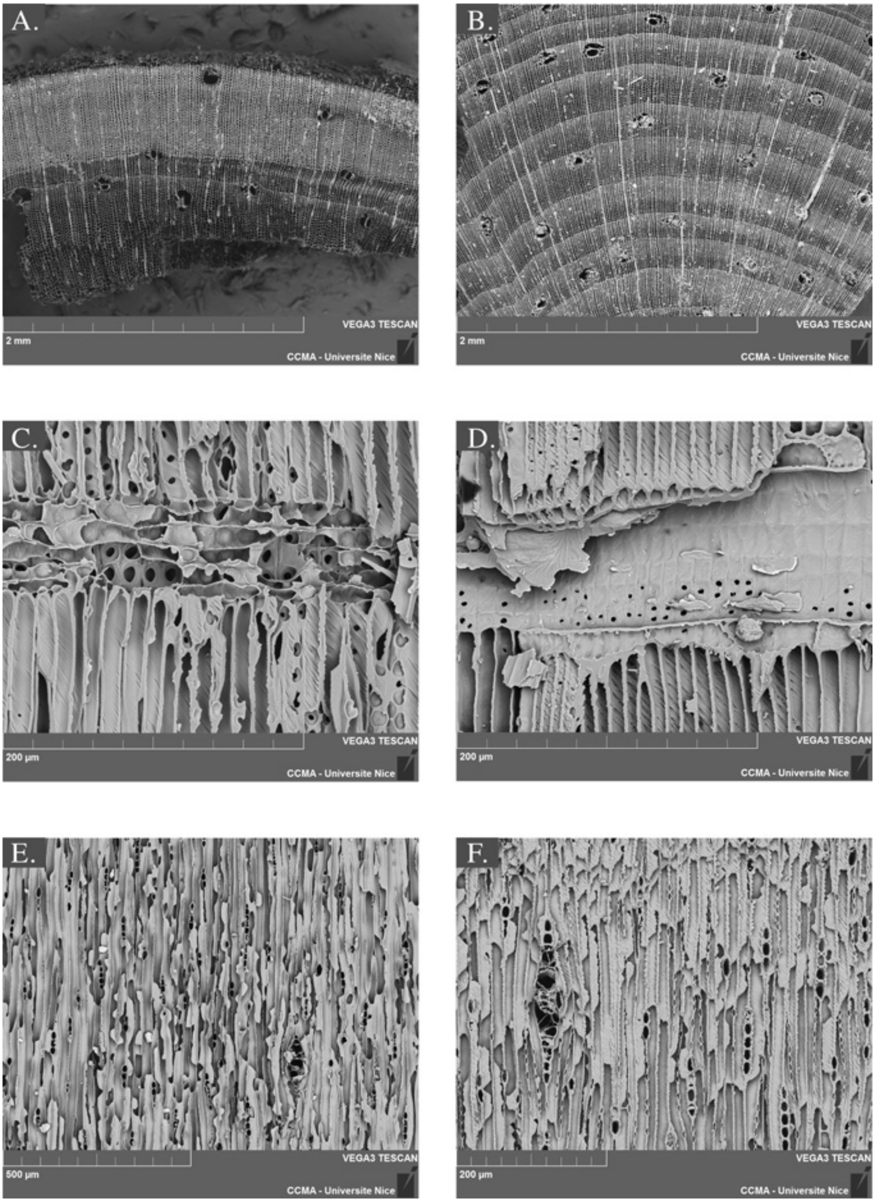

FIGURE 6 Microphotographs of modern specimens. (A, C, E) *Pinus flexilis*; (B, D, F) *Pinus monophylla*

pitting; Figure 6C), perhaps limber pine (*Pinus flexilis*),[3] the only arboreal taxon, and snowberry (*Symphoricarpos*) were also present. These currently grow at much higher altitudes, but during the Late Pleistocene they would have grown very close to the rockshelter (Rhode & Madsen 1995; Rhode 2000a,b).

The taxa in the PaleoIndigenous levels suggest an open, dry landscape on lower slopes and slightly less arid conditions higher in the hills, allowing for more developed plant cover.

4.1.2 Early Archaic Layers

In total 2040 charcoal fragments were identified in the Early Archaic strata. The lower Early Archaic strata (17b, 17a, 16 and 15), on the one hand, have a floristic composition very similar to that of the PaleoIndigenous strata. On the other hand, the most recent strata (14's various sub-strata and 13) were distinguished by greater taxonomic richness, with up to 12 taxa (MNT=11) in strata 14b upper and 13 (Table 2). The Early Archaic charcoal fragments were also well preserved, with only 2% of the assemblage categorized as unidentifiable, non-woody plants, or angiosperms.

Similar to the PaleoIndigenous layers, sagebrush is abundant and ubiquitous in the Early Archaic layers. However, in some Early Archaic layers, it is no longer sagebrush that dominates but jointfir. The proportions of these two taxa are negatively correlated over time (Figure 7).

3 The pines with fenestriform cross-field pitting (Figure 6C) from the Bonneville Basin region are from the soft pine group (sub-genus *Strobus*, section *Quinquefolia*, sub-section *Strobus*) (Baas *et al.* 2004; Gernandt *et al.* 2005). The corresponding species are *Pinus flexilis* and *Pinus albicaulis* (Woods *et al.* 2001; Bryce *et al.* 2003; Van Buren *et al.* 2011). Since the latter is not currently present in the area close to BER, and since *P. flexilis* is much more widespread in the Bonneville Basin, we assume that the archaeological fenestriform cross-field pitting pine corresponds to *Pinus flexilis*. This type contrasts with pinoids cross-field pitting pine (Figure 6D) represented in the Bonneville Basin by pinyon pines (sub-genus *Strobus*, section *Parrya*, sub-section *Cembroides* and *Balfourianae*) and hard pines (sub-genus *Pinus*, section *Trifoliae*, sub-section *Ponderosae* and *Contorta*) (Baas *et al.* 2004; Gernandt *et al.* 2005). In the Bonneville Basin, the corresponding species are *Pinus monophylla*, *P. edulis*, and *P. longaeva* for the section *Parrya* and *Pinus ponderosa* and *P. contorta* for the section *Trifoliae* (Woods *et al.* 2001; Bryce *et al.* 2003; Van Buren *et al.* 2011;). The singleleaf pinyon pine, *Pinus monophyla*, is the other most common pine in the Bonneville Basin region. It migrated into the BER area after approx. 8000 cal BP (Madsen & Rhode 1990). We therefore assume that the cross-field pinoid pines identified from the Early Archaic levels are probably *Pinus monophylla*.

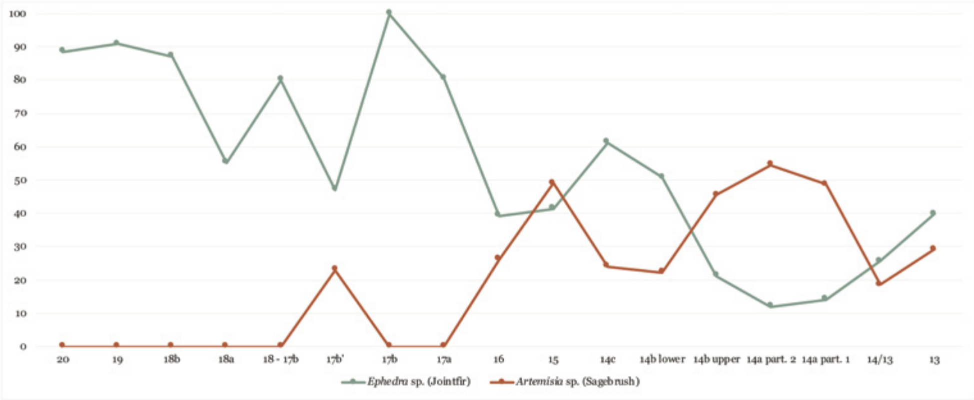

FIGURE 7 Curves of sagebrush (*Artemisia*) and jointfir (*Ephedra*) occurrences by level

Sarcobataceae and Amaranthaceae were present in almost all of the levels. Most of the other identified species were shrubs from the Asteraceae family. These taxa, such as rabbitbrush (*Ericameria*), horsebrush (*Tetradymia*), snakeweed (*Gutierrezia*), and brickellbush (*Brickellia*) are xerophytic. A few Rosaceae were sporadically present, including the genera *Amelanchier*, *Prunus* and *Purshia*. While *Purshia* can be found among xerophilous vegetation, this is not the case for serviceberries (*Amelanchier*) and plums/cherries (*Prunus*), which are less resistant to drought but prefer upland open rocky slopes and outcrops or riparian wash areas. Other arboreal taxa were occasionally identified, such as *Populus*/*Salix* (we use this alternative name because these two genera are very similar from a microanatomical viewpoint), soft pine (*Pinus* with fenestriform cross-field pitting), pinyon pine (*Pinus* with pinoid cross-field pitting; Figure 6D), and perhaps single-leaf pinyon pine (*Pinus monophylla*). Finally, small mesophilous shrubs and lianas, such as snowberries or currants (*Ribes*) were rarely identified.

Charcoal data from the Early Archaic strata revealed an environment relatively similar to that of the PaleoIndigenous strata but dryer and more open. Owing to the greater number of samples, which allowed for the identification of secondary species, we were able to provide a much more precise portrayal of the environment with a more complete shrub community in the low and middle slopes (Amaranthaceae, *Artemisia*, *Brickellia*, *Gutierrezia*, *Ericameria*, *Ephedra*, *Purshia*, *Prunus*, *Sarcobatus*, *Tetradymia*) as well as a developed woody cover of the higher montane zone (*Amelanchier*, *Pinus*, *Populus*/*Salix*, *Ribes*, *Symphoricarpos*).

5 Discussion

5.1 *Fuel Wood Selection*

5.1.1 PaleoIndigenous Strata

The anthracological results from the PaleoIndigenous strata showed that sagebrush was used intensively. Therefore, the question of overrepresentation on the site is legitimate. Palynological studies conducted near BER indicate that during the Younger Dryas and earliest Holocene, the site environment was an open shrubland/woodland mosaic composed mainly of sagebrush and some pine (Louderback & Rhode 2009). Packrat middens are good local paleoenvironmental indicators as the nests of rats of the genus *Neotoma* are built from various plant macroremains collected by the rats in a relatively small territory. These packrat middens are numerous in the region, and one was located in a rock recess only a few meters away from BER. The results of the analysis of plant macroremains that make up these packrat middens provide a more detailed picture of the vegetation (Rhode 2000a; Madsen *et al.* 2001), indicating once again that the landscape was dominated by pine, juniper and sagebrush, although secondary species were more visible. The packrat middens near BER ceased to be built between 13 095 and 12 836 cal BP, *i.e.*, at the beginning of the Younger Dryas. In addition to lowland woody species (*Artemisia*, *Atriplex*, *Ericameria*, *Glossopetalon*, *Gutierrezia*, *Symphoricarpos* and *Tetradymia*), conifers were well represented (Rhode 2000a). These packrat middens also supplied fragments of Engelmann spruce (*Picea engelmannii*), a taxon completely absent from the BER area today, which is associated with the limber pine (*Pinus flexilis*) and common juniper (*Juniperus communis*) (Rhode 2000a). Since pine was very poorly represented in the archaeological charcoal assemblages of BER during this period, the preferential use of sagebrush could be the result of technical or cultural choices made by the site's inhabitants. Nevertheless, the pine identified during this period was of the limber type (*Pinus* type *flexilis*), and currently this species only very rarely descends below an altitude of 1800 m. Furthermore, packrat middens near BER yielded five pine fragments (between 13 781–13 582 and 13 091–12 822 cal BP) representing 11% of the woody plant remains identified during this period in this packrat midden (Rhode 2000a). Therefore, it is more likely that pines did not thrive in the immediate vicinity of the site, with only a few specimens collected until the beginning of the Younger Dryas, and that the choice of sagebrush was purely practical. Targeting sagebrush, therefore, appears to be a pragmatic choice, suggesting that this species was sufficiently abundant at the site and did not require regular recourse to other species (*e.g.*, *Atriplex*, *Ericameria*, *Glossopetalon*, *Gutierrezia*, *Symphoricarpos* and *Tetradymia*) and was likely well suited to the pyrotechnological needs of the PaleoIndigenous inhabitants.

5.1.2 Early Archaic Groups

During the Early Archaic occupation, the taxonomic diversity of charcoal assemblages increased. This could be linked to the duration of occupation, which, according to previously acquired multidisciplinary results, has increased (Goebel *et al.* 2018). Thus, it seems that more intensive harvesting of fuelwood over the long term resulted in a broader range of selected taxa, in accordance with one of the main postulates of anthracology (Chabal 1992, 1994, 1997; Shackleton & Prins 1992; Kelly 1995; Théry-Parisot 2002), whether it is a question of more exhaustive wood gathering, new collection territories, or plant formations. Sagebrush also continued to be used extensively, extending to craftwork, as illustrated by a study on the remains of wickerwork made from sagebrush bark (Coe 2020). The use of jointfir, which is almost absent from the region's pollen spectra (<1%) (Thompson *et al.* 2016), also seems to reflect pronounced taxonomic choices made by the inhabitants of the site. Most *Ephedra* are wind pollinated and produce pollen that can be preserved, which is why they are frequently found in pollen spectra worldwide (Maher Jr. 1964; Girard & Renault-Miskovsky 1979; De Beaulieu *et al.* 1985; Rydin *et al.* 2006; Naughton *et al.* 2007; Torres *et al.* 2008; Louderback & Rhode 2009; Zhang *et al.* 2013; Bolinder *et al.* 2015; Qin *et al.* 2015;Cubizolle *et al.* 2022). Furthermore, *Ephedra* has been identified as one of the main contributors to Miocene vegetation in the Bonneville Basin region (Thompson *et al.* 2016), proving that the edaphic conditions of the region allow for the conservation of pollen from this taxon, just as jointfir can be the main contributor to plant formation. Ephedra was also absent from all of the packrat middens dating before 8000 cal BP in the Bonneville Basin and remains uncommon even after this date (Rhode & Madsen 1995; Rhode 2000b; Madsen *et al.* 2001). Thus, its near absence around the Pleistocene-Holocene transition does not appear to be due to taphonomic and/or analytical biases but rather to the fact that this taxon was not abundant in the landscape. Today, it is not a dominant species. Together, these factors allowed us to put forward the hypothesis that *Ephedra* wood was selected as soon as it reappeared in the environment at the beginning of the Holocene. In contrast, although juniper (*Juniperus*) pollen was identified in the Bonneville Basin during the Late Pleistocene/Early Holocene, this taxon was absent from the charcoal analysis spectrum. However, it is interesting to note that this taxon was used by the occupants of the Early Archaic layers (stratum 14) to create basketry from its bark (Coe 2020). Therefore, this taxon seems to be present in the BER environment but does not appear to have been used as a fuel resource.

Finally, while many species identified as firewood at BER are edible or produce edible fruits, only Amaranthaceae and pine type *monophylla*, whose pine nut seeds were consumed in the Early Archaic strata, were used for both firewood and food (Rhode 2008).

5.1 *Gathering Territories*

5.2.1 PaleoIndigenous Groups

The low floristic diversity and relative absence of pine in the PaleoIndigenous layers seem to indicate that the BER's wood collection area was restricted to the immediate vicinity of the rockshelter (Figure 8). Sagebrush and Amaranthaceae dominate, and Sarcobataceae is common; today they grow on the Bonneville and Provo Lake margin terraces. The identification of very rare fragments of pine and snowberry could be evidence of some collection at higher elevations. However, it is also possible that during the Younger Dryas some of these plants still grew in the direct vicinity of the site, such as some of today's snowberry bushes present in rocky outcrops around BER. This is confirmed by the Bonneville Estates packrat midden data, which identify these taxa at elevations of less than 1800 m between 12 900 and 11 500 cal BP (Rhode & Madsen 1995; Rhode 2000a; Madsen *et al.* 2001).

5.2.2 Early Archaic Groups

In view of the substantially more abundant floristic diversity of the Early Archaic strata, groups appear to have extended their collection area in conjunction with the longer duration of occupations. The precise source of the jointfir gatherings is open to question. Today, jointfir is clearly not the most abundant taxon around the rockshelter, but it can be found there, and important jointfir stands are located approximately 30 km north of the site (along U.S. Route 93 Alternate toward West Wendover; personal observations). Moreover, jointfir appears to have been rare in the past. In addition to its

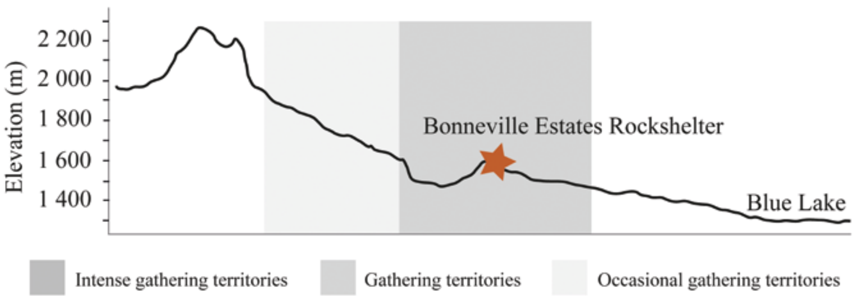

FIGURE 8 PaleoIndigenous gathering territories (after Goebel *et al.* 2021)

absence in the pollen spectra discussed above, it is uncommon in the botanical assemblages of packrat middens in the region. It is possible that a few rare stands existed in the past; however, they must have been relatively remote and modest. As the identification of Amaranthaceae species is difficult and most are fairly ubiquitous, it is difficult to draw any inferences about the collection area. Nevertheless, the identification of numerous seeds of *Allenrolfea occidentalis*, a more halophilic Amaranthaceae, and cattail (*Typha* spp.) fluff (used to light fires) in the latest Early Archaic layers (strata 14 and 13), as well as the appearance of numerous basketry elements made from tule bulrush (*Schoenoplectus* sp. or *Scirpus* sp.), reed, or cane (*Phragmites* sp.), and cattail (*Typha* sp.) fibers testifies to a close tie with the Blue Lake marshes (Rhode & Louderback 2007; Rhode 2008; Coe 2020, 2021). This exploitation of the marsh margin could also be linked to an increase in Amaranthaceae in the charcoal. More likely, however, it resulted from the shift from sagebrush to a more xeric landscape dominated by saltbush, greasewood, and horsebrush (*Tetradymia*). Moreover, in the charcoal assemblage, the appearance of new low-elevation taxa (*e.g.*, *Tetradymia*, *Brickellia* and *Prunus*) in the same strata (14's various sub-strata and 13) seems to indicate an intensification of wood collection and lowland exploitation in the direct vicinity of the site during the periods when the rockshelter experienced the greatest occupation (Figure 9). The fact that occupations became more intense, as suggested by our anthracological results, is supported by multiple lines of archaeological evidence (Goebel *et al.* 2021). This territory was exploited from the very beginning of the Late Pleistocene occupation, but the appearance of new taxa and secondary species leads us to hypothesize that the collection of wood and exploitation of the lowlands intensified during the Early Archaic. Finally, the sporadic appearance of various additional mesophilous or riparian taxa (*Amelanchier*, *Pinus*, *Populus*/*Salix*, *Prunus*, *Ribes*, *Symphoricarpos*) could indicate occasional excursions to higher, more forested areas or wet washes. The nearest place one can encounter this

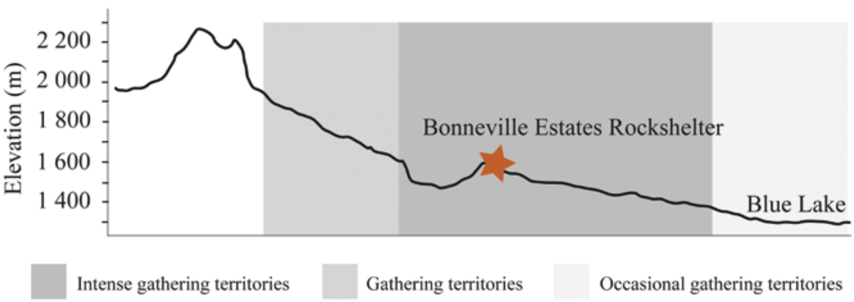

FIGURE 9 Early Archaic gathering territories (after Goebel *et al.* 2021)

type of vegetation is to the west, particularly toward the Goshute Mountains (about a four-hour walk, round trip). Early Archaic bifacial points similar to those from BER have been found around upland springs in these mountains, and more recently (after 4000 cal BP), there are numerous open-air sites in the pinyon-juniper zone, focusing on the collection of pine nuts (Malinky 2005).

5.3 *Ethnobotanical Data on Native Uses of Woody Plants*

Assessing the cultural value of perishable materials (*e.g.*, wood) in the daily economy of hunter-gatherer groups is particularly difficult in archaeology. The possibility of conducting comparative studies on the uses and habits of current populations is a rare opportunity that should be seized. Several indigenous groups currently reside in BER, notably the Gosiute and the Western Shoshone. Therefore, a comparison between the woody plants identified in anthracology and their use or non-use by native people was considered.

As far as food is concerned, *Atriplex* seeds, especially *A. confertifolia* (Gosiute: *ka'-nûm-pi*), and *Pinus monophylla* (Gosiute: *ti'-ba-wa-ra*; Shoshone: *wah-pee*), or pinyons (Gosiute: *ti'-ba*), are main sources of food for the Gosiutes (Chamberlin 1911; Rhode 2002). Other species identified in archaeological charcoal are also consumed, such as the fruits of *Amelanchier alnifolia* (Gosiute: *ti'-ûm-pi*; Shoshone: *ti'ampi*), *Ribes aureum* (Gosiute: *kai'-i-ûmp*; Shoshone: *ohapogombi*) and *Prunus virginiana* (Gosiute: *to'-o-nûmp*) (Chamberlin 1911; Mozingo 1987; Rhode 2002). The leaves of *Artemisia tridentata* (Gosiute: *po'-ho-bi*; Shoshone: *pohovi*) are often used to coat berries for preservation among the Gosiute and used as seasoning among the Shoshone (Chamberlin 1911; Steward 1938; Rhode 2002). The Shoshone produce chewing gum from *Ericameria nauseosa* (Shoshone: *sipümb*) roots (Rhode 2002).

Domestic objects (*e.g.*, baskets, bowls, or jugs) can be made from willow wood (Gosiute: *si'-o-pi*; Shoshone: *coo-see see-bup*) (Chamberlin 1911; Train *et al.* 1941; Stoffle *et al.* 1989), and baskets are sometimes reinforced with *Amelanchier* stems. Among the Western Shoshone, *Amelanchier* and *Sarcobatus vermiculatus* (Shoshone: *tovini*) are used to make objects requiring dense wood, such as digging sticks and arrows (Steward 1941; Rhode 2002). None of the species identified in the charcoal appeared to have been used for the architecture of Gosiute dwellings, whereas *Salix exigua* (Shoshone: *kwishisuuvi*) was used for brush houses by the Shoshone (Stoffle *et al.* 1989; Rhode 2002).

In medicine, sagebrush is undoubtedly one of the most versatile plants, being used in teas and poultices to treat fever, rheumatism, and colds (Chamberlin 1911). The Shoshone also use it to treat worms and eye troubles (Train *et al.* 1941). Similarly, the Shoshone use the leaves of *Gutierrezia sarothrae* (Shoshone: *tavishepi*) and prepare a tea from *Ericameria nauseosa* (Train *et al.* 1941; Stoffle *et al.* 1989). The Gosiutes use gum made from *Pinus monophylla* to ease suffering from intestinal parasites and employ decoctions of *Prunus virginiana* bark for blood disorders, notably nosebleeds. This plant is also used to treat intestinal disorders, particularly in children and infants (Chamberlin 1911). Among the Shoshone, *Amelanchier* bark is boiled to clean the eyes and soothe them in cases of burns from the sun's reflection on the snow (Train *et al.* 1941). The Shoshone also use *Salix exigua* bark (chewed or boiled) to treat a variety of pain, thanks to the willow's aspirin-like active ingredients (Rhode 2002; Train *et al.* 1941; Stoffle *et al.* 1989). *Ephedra viridis* tea (Shoshone: *tutumbi*) is also utilized as a remedy to treat numerous disorders (*e.g.*, pain and intestinal and blood issues) (Rhode 2002; Train *et al.* 1941; Stoffle *et al.* 1989). The Shoshone use *Kraschenninikovia lanata* (Shoshone: *shee-shup*), an Amaranthaceae, to produce shampoos and prevent hair loss (Train *et al.* 1941). Finally, Shoshone infants regularly bathe in sagebrush-infused baths, and sagebrush-leaf fumigation is regularly performed to purify spirits or spaces (Stoffle *et al.* 1989).

This overview of the uses and customs associated with woody plants identified in archaeological charcoal assemblages shows that while certain taxa appear to be deliberately chosen for firewood, many woody species are used for other purposes, including within the ritual sphere. This also leads us to think that archaeological charcoal is a potent tool for identifying people's fuel of choice, although the occasional contribution of other species may be linked to non-firewood uses of certain taxa.

5.4 *The Cultural Persistence of the Fuelwood Economy among Present-day Native People of the Great Basin*

In addition to its food, craft, medicinal virtues, and ritual uses, sagebrush is still used as a fuel of choice by contemporary indigenous peoples, especially in desert areas (Rhode 2002). It regularly produces seasoned wood ideal for starting fires, both as a fuel and as a friction tool (Chamberlin 1911; Zigmond 1981; Rhode 2002). Ethnological surveys have not revealed any particular use of jointfir for firewood (Steward 1938; Kelly 1939); however, Zigmond (1981) observed that jointfir charcoal is suitable for tattooing. Theoretically, researchers estimate that firewood collection by hunter-gatherer groups rarely extended beyond a radius of 5 km (Roper 1979; Kelly 1995, 1999, 2013; Théry-Parisot & Meignen 2000; Lebreton *et al.* 2017). As jointfir rarely grows in the Bonneville Estates area, it is possible that this taxon was collected specifically to obtain charcoal, perhaps for tattooing. While this hypothesis is difficult to sustain, our experimental results demonstrate that this species burns much longer than sagebrush, which can combust entirely within seconds. It takes an average of 1.10 minutes to burn 1 cg of sagebrush, compared with 2.09 min to burn 1 cg of jointfir, *i.e.*, twice as long (observation based on 18 experimental burns, publication forthcoming). In the context where wood is a relatively scarce resource, wood that produces flames and, by extension, heat for an extended time was probably sought. Despite being rare, Early Archaic people could have collected jointfir during daily foraging excursions from the rockshelter, supplementing the more regular use of locally abundant sagebrush fuel. Finally, for Amaranthaceae and Sarcobataceae, the last taxonomic groups used extensively by prehistoric populations for firewood, it appears that shadscales (*Atriplex* spp.) are still used. Sarcobataceae, however, are not burned by contemporary populations but are instead used to make tools (Stoffle *et al.* 1989).

6 Conclusion

The study of archaeological charcoal from the PaleoIndigenous and Early Archaic strata at BER highlights the different ways early native peoples harvested firewood between these two major periods. Indeed, taxonomic selection and the territories covered diverged, and comparisons of anthracological and palynological data suggest that variation in firewood use was the result of environmental pressures linked to aridification during the Early Holocene as the site's inhabitants made conscious choices. The most common taxa (sagebrush, shadscales, and greasewood) persist throughout the chronological sequence. However, during the Early Archaic, the regular use of jointfir suggests that this taxon may have been intentionally sought for its longer-lasting combustion, a quality that is no longer cited regarding jointfir by Gosiute and Shoshone. Likewise, during the Early Archaic period, the BER's occupants occasionally supplied the rockshelter with wood from uplands more than 10 km away. These findings demonstrate the ability of charcoal to provide data complementary to those delivered by other archaeological and paleobotanical lines of evidence, thereby contributing to both environmental and societal reconstructions. Future studies should be continued at this site, integrating more data and, in particular, studying more charcoal fragments from hearths, as well as at other sites, which would provide a more general picture of the uses and customs associated with firewood in the early populations of the Bonneville Basin. Finally, despite the particular difficulty in approaching the cultural aspect of perishable materials in archaeology, as they are often invisible, ethnological examples remind us that these ecofacts, firewood in particular, are culturally charged as other materials that are more easily conversed with and better known to archaeologists.

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