Multiple Approaches to Formation Processes: The Pine Spring Site, Southwest Wyoming

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Excavations in 1964 at the Pine Spring site in southwest Wyoming concluded that the site contains three cultural occupation levels; the earliest allegedly dates to the terminal Pleistocene and is associated with megafauna. However, excavations in 1998 and 2000, and analysis of the stratigraphy, AMS dates, micromorphology, and artifact carbonate isotopes, along with debitage refitting, density, orientation, inclination, burning, and trample damage, could not replicate the 1964 findings. A hiatus in deposition accounts for the highest density of artifacts, and the three original occupations are palimpsests. There is no unequivocal association between evidence of human activity and megafaunal remains. © 2006 Wiley Periodicals, Inc.

INTRODUCTION

The Pine Spring site (48SW101) sits at 2329 m (7640 ft) on the north face of Black Mountain in southwest Wyoming (Figure 1). The site encompasses nearly the entire cultural sequence of the region and is an important reference site for southwest Wyoming prehistory (Thompson and Pastor, 1995). Excavated by Floyd Sharrock in 1963 and 1964, Pine Spring contains thousands of artifacts, mostly debitage, and the remains of Pleistocene horse, bison, and camel. Sharrock defined three major episodes of occupation, the earliest of which he dated to circa 10,000 yr B.P. (all dates herein are uncalibrated) and claimed it was associated with megafauna. In this article, we reassess the site's evidence for the three occupations and the association between arti-

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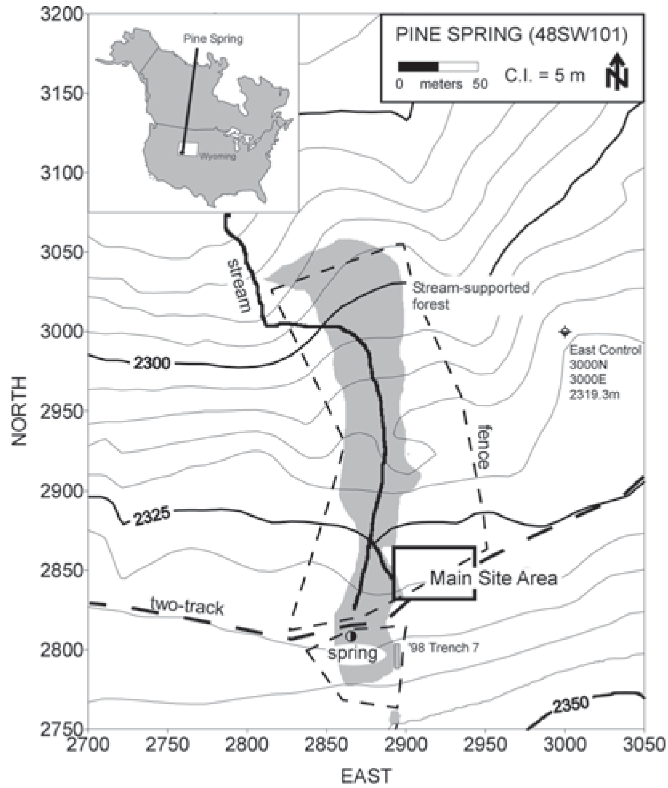

Figure 1. Topographic map of Pine Spring; main site area is portrayed in Figure 3.

facts and Pleistocene fauna through analysis of archaeological and geoarcheological data collected in 1998 and 2000. We employ several methods to examine the site's formation and conclude: (a) that a major hiatus in aggradation accounts for the highest density of artifacts, (b) that the alleged occupations are mixes of artifacts and faunal remains deposited thousands of years apart, and (c) that there is no unequivocal association between evidence of human activity and megafaunal remains.

The regional vegetation of the Pine Spring site is sagebrush desert, but the spring that gives the site its name produces a small, perennial stream that supports a thin but dense strip of meadow, aspen, juniper, cottonwood, mountain mahogany, and spruce (but not pine). The spring has probably run more or less continuously for at least 12,000 years and was undoubtedly what attracted people to the location.

Black Mountain's caprock is Oligocene Bishop Conglomerate and is composed of "clasts of red quartzite, gray chert, and limestone in a gray to white tufaceous sandstone matrix" (Love and Christiansen, 1985). Underlying this conglomerate is the Upper Eocene Bridger formation, a "greening-gray, olive-drab, and white tufaceous sandstone and claystone" with "lenticular marlstone and conglomer-

Figure 2. The Pine Spring site, facing southwest. Sharrock's Trench 5 was located on the terrace immediately downslope of the white tent near the trees.

ate" and, just below the spring's elevation, outcrops of Tiger chert (Love and Christiansen, 1985). Pine Spring emanates from the contact between the Bishop and Bridger formations and overlooks several "terraces" that formed during one or more episodes of slumping before the site was occupied; the site sits on one of these terraces (Figure 2).

HISTORY OF RESEARCH

Sharrock sorted most of the excavated artifacts and bone into three "occupations." Occupation 1, the earliest, was ^{14}C-dated using bone collagen from two specimens; one, identified in his catalog as "*Bison bison?*" dated to 9695 ± 195 yr B.P. (GX-0354) and another, identified as "*Bison* sp." dated to 11,830 ± 410 yr B.P. (GX-0355). The Occupation 1 assemblage also contained Agate Basin-like and possible Goshen and Cody Complex points (Frison, 1991; Thompson and Pastor, 1995). Occupation 2 dated to 3650 ± 80 yr B.P. (GX-0356) with a bone collagen date on an *Ovis canadensis* specimen. Sharrock (1966, p. 22) discarded the 11,830 yr B.P. date because the sample "contained too little collagen for a trustworthy count." However, as 1960s bone dates, all three are suspect. Based on projectile point styles and Fremont pottery, Sharrock assigned Occupation 3 to the Late Prehistoric period.

Occupation 1 may be associated with extinct megafauna. Sharrock found four vertebrae (Feature 50; Sharrock's fieldnotes are referenced by feature number and page, e.g., F50:3)[1] lying in anatomical position, which he identified as bison; one vertebra was sacrificed to obtain the 9695 yr B.P. date. Sharrock (1966, p. 22) argued that this animal "was apparently imported after having been partially butchered. . . .a knife associated with the skeleton [45 cm away] was in correct position to have been in the lower thoracic or upper abdominal region of the beast." We re-identified these vertebrae as *Camelops* sp. and re-dated them to 11,180 ± 45 yr B.P.[2] These vertebrae add to other megafaunal remains that Sharrock thought were associated with Occupation 1. Frison (1997) examined all the *Camelops* material from the site and cautiously suggested that spiral green bone breaks on one metapodial might be evidence of human use.

Future use of Sharrock's collection depends, in part, on whether the three occupations are genuine temporal/behavioral units. There is reason, however, to be skeptical.

Using standard techniques for the day, Sharrock's crew of one to six workers excavated five-foot-wide trenches primarily by shovel in 3- and 6-inch levels for a total of 79 days, removing some 140 m^3 of deposit. Sharrock could not recall how extensively he used screens (personal communication, 1998), but a fieldworker we interviewed recalled that 1/4-inch screens were only used towards the end of the excavation, and not consistently. This suggests that the occupations were so distinct that rapid shovel excavation without the aid of screens could uncover them.

However, Sharrock first noted the three occupations on July 23, in Trench 5, halfway through the 1964 season, but also admitted that ". . . in some areas [the occupational surfaces] merge to the point that I'm not always sure I've separated them correctly. . . .The artifact layers are not quite that precise. They vary from 1 to 2 chips wide to approx. 6 in. in thickness" (F27:7). Sharrock recognized that some layers contained a variety of point types, or prehistoric and historic artifacts. The field notes frequently mention krotovina and problems in correlating levels between units (e.g., F32:2). Sharrock's mentor, Jesse Jennings, noted that the southernmost 90 feet of Trench 4 were "roiled" by sheetwash (F1:31). Nonetheless, Sharrock retroactively placed 80% of the excavated material into one of the three occupations.

In addition, Sharrock drew attention to the "remarkably consistent correlation of each of three site occupation levels with the three soil horizons," finding that in "over 80% of the excavated area, Occupation 1 . . . was completely within the C horizon, Occupation 2 completely within the B horizon, and Occupation 3 completely within the A horizon" (1966, p. 16–17). But Sharrock did not use soil horizons to define the occupations; in fact, he thought it fortuitous that the cultural stratigraphy paralleled the soil horizonation (1966, p. 17). Still, this is an all-too-comfortable correlation. The site's

[1] Sharrock used Jesse Jennings' feature system, in which all excavation units, regardless of their size, shape, or origin, were numbered consecutively as features. Thus, the site is F1; the first excavation unit is F2; a discernible stratum might be F3; a hearth in that stratum, F4; an unusual aggregation of bone, F5, and so on. These features are relabeled in the report (e.g., F27 is Trench 5).

[2] In a May 5, 1965 letter to Sharrock, Stanley Olsen identified these lumbar vertebrae as "large camel or *Symbos*." However, catalog notes indicate that Stephen Durrant, a small-mammal specialist in the University of Utah's Biology Department, also identified the remains. Apparently, his identifications were taken over those of Olsen. We showed the F50 remains to seven qualified individuals, six of whom were certain that they were not bison and probably camel. The remains compare very well with camel remains from the Casper site in Wyoming.

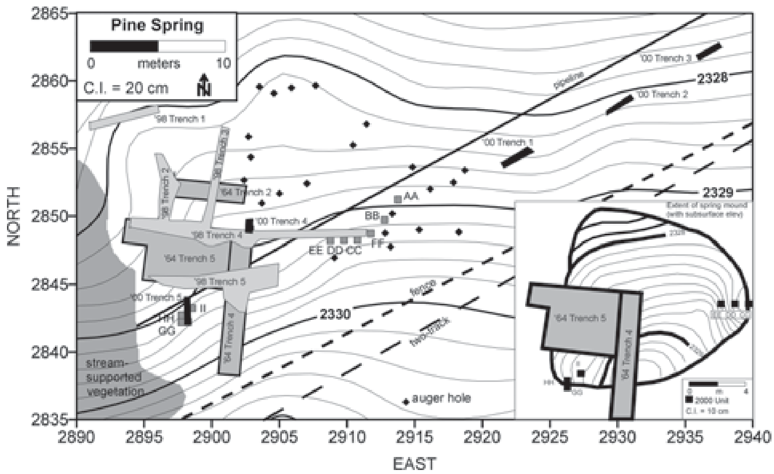

Figure 3. Map of the main excavation area showing some of the 1964 trenches and the University of Wyoming 1998 and 2000 excavation units and backhoe trenches; inset shows subsurface map of spring mound.

stratigraphy merits a reexamination: (a) given that the deposits range from a few centimeters to 1.5 m in thickness, containing artifacts suggesting an occupational range of some 10,000 years; (b) were excavated quickly, largely by shovel without screens, and (c) bear evidence of bioturbation and redeposition.

SITE STRATIGRAPHY

Equipped with Sharrock's fieldnotes and photos, Kelly located the old excavation units with backhoe trenches in 1998. Locals stated that the excavations remained open until the BLM filled them with heavy equipment. In the interim, looters destroyed the profiles; the BLM then put a pipeline through the site in the 1970s. Although he located Trenches 4 and 5, Kelly did not find a single intact midden profile. With exploratory trenches, he located two areas of "intact" deposits, one to the east and one to the south of Sharrock's Trench 5. In 2000, we placed six 0.5 × 0.5 m units (AA through FF) in the former area and three 0.5 × 0.5 m units (GG, HH, and II) in the latter area (Figure 3).

The units were excavated in 5-cm levels following natural strata where possible; all items found *in situ* and larger than 3 cm in maximum dimension were piece plotted with a total station, and their orientation, inclination, length, side up, and presence of carbonates noted. Deposits were screened through 1/8-inch mesh, avoiding krotovinas; sediment weight was recorded to calculate artifact densities. Water screening on-site was not possible, but sediment samples were collected in nearly all levels and processed later.

Three major strata are evident at the site (Figure 4). Stratum I, the lowest and oldest, is a poorly sorted, loosely packed, pink to gray mottled, dark yellowish-brown, single-grained, gravelly sandy loam. It appears to be a slump or landslide deposit. The

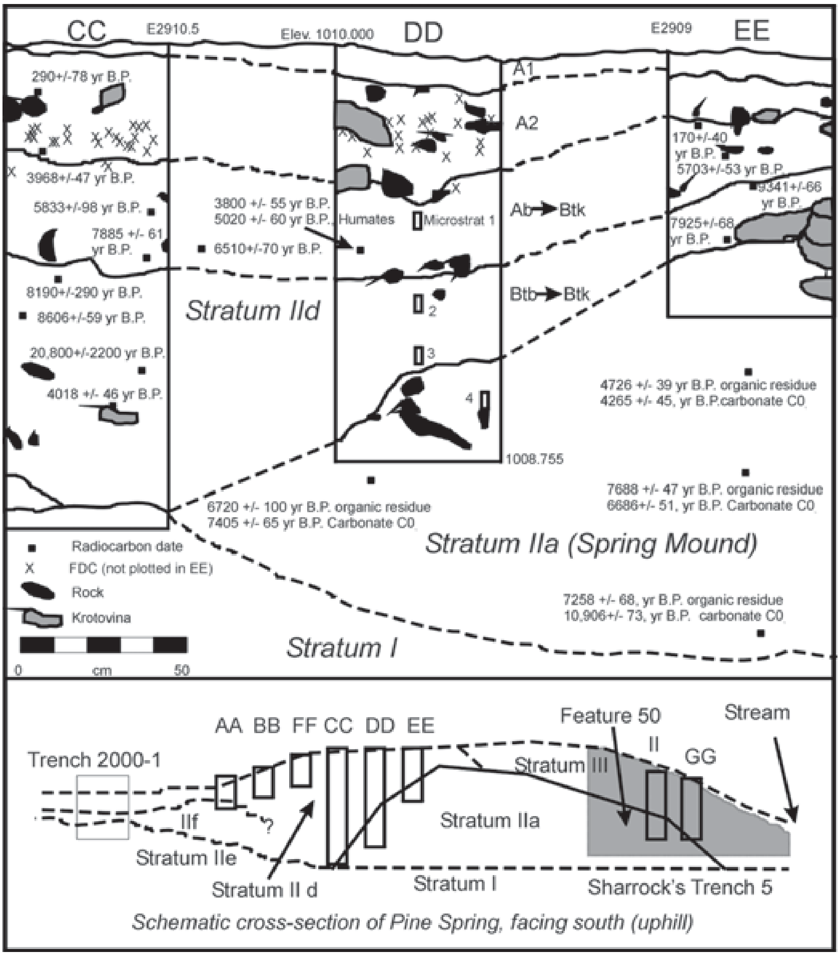

Figure 4. Stratigraphy of excavation units CC, DD, and EE, facing south (upslope), with radiocarbon dates; at bottom is a schematic diagram showing location of 2000 excavation units and Sharrock's Trench 5 relative to schematic site stratigraphy.

cobbles in this stratum are subangular to subrounded. No bedding was observed in it. Pedogenic features include gleying and *in situ* clay weathering, such as the dissolution of clay from bedrock clasts and the possible production of clay from primary minerals. Stratum I has reddish hues and textural characteristics identical to the Bishop conglomerate upslope of the site. To the west, near the perennial creek, the Bishop's reddish hues are modified to grays and rust colors (moist colors: 7.5YR 8/4, 10YR 5/1, 10YR 4/4), and the matrix is more clayey, probably the result of long-term groundwater through-flow that favored carbonate dissolution, resulting in the liberation of detrital clay from the carbonate rock. Stratum I is of an unknown thickness but may be on the order of tens of meters.

Overlying Stratum I is Stratum II, a loosely to moderately packed, poorly sorted, light gray, massive, calcareous, trace to slightly pebbly clayey silt; in places, it contains tufa-infiltrated slope wash and/or evaporative phreatogenic carbonates. Stratum II is divided into several substrata.

Most of what Sharrock called F26 we label Stratum IIa. Sharrock believed F26 to be a dislocated block of Bridger clay (1966, p. 20; Eardley, 1966, pp. 198–199), but it is a spring-mound deposit. Spring mounds form where spring-supported plant material traps eolian sediment, often creating a round or doughnut-shaped mound with an outlet for the spring's flow. In the western United States, they tend to have high carbonate content from eolian input (Haynes, 1967), degassing of carbonate-saturated water, and from evaporation of carbonate-enriched waters. Stratum IIa has high carbonate content, is white to buff-colored (10Y/R 7/2), and has a "cottage-cheese" structure (the Bridger formation is almost entirely clay and has a smooth texture). From its exposure in our backhoe trenches, Sharrock's fieldnotes, and bucket augering, we determined the extent of the buried spring mound and revealed its somewhat round shape (Figure 3). The southern portion of Stratum IIa contains discrete pebble lines and buried lenses of organic matter and is not as impregnated by carbonates; pebble content is up to 10%. The northern half of the stratum shows a fining upwards sequence, with 5% pebbles at its base to less than 1% near its top. Surface soil formation is stronger over the northern portion of the unit. At its westernmost occurrence, near the stream, gleying (Btg and AB(t)→Bk; see Birkeland, 1999, for notation of polygenetic [overprinted or engulfed] soil horizons) and *in situ* clay weathering occur. In places, this stratum is broken down into substratum based on color and pebble content. Moist colors vary from the stratum's upper to lower portions: 10YR 7/2, 10YR 5/2,10YR 5/2, 10YR 3/2.

Further evidence that Stratum IIa is a spring mound comes from gastropods that Mead extracted from three sediment samples. Shells from the base of stratum IIa were too fragmented for identification, but *Pupilla* sp. and *Vallonia* sp. occur in a sample from the stratum's middle, and specimens from a sample near the stratum's top included *Catinella* sp., *Pupilla muscorum*, *Pupilla* sp., *Vertigo* cf. *modesta*, and Hydrobiidae (poorly preserved; however, they are consistent in shape with *Amnicola* sp. or *Fontelicella* sp.). All these taxa live in Wyoming today, and all except the hydrobiids are pulmonate snails that live under leaf litter or logs in moist to semiarid areas, such as Pine Spring's wooded microenvironment. The hydrobiids, however, are gill-breathers and indicate the presence of an open, perennial pond.

A thin section of Stratum IIa examined by Goldberg (sample 4; see below) revealed its massive, calcareous nature. The presence of root voids and phytoliths support an interpretation of a spring mound. Stratum IIa's abundant clay could have been deposited as slopewash or as an eolian deposit, caught by quiet water or by surrounding vegetation. Uncommon, however, are secondary pedofeatures, such as calcareous hypocoatings (Bullock et al., 1985); this is surprising in light of the supposedly evaporative nature of these deposits.

Stratum IId overlies IIa and in the area of units CC, DD, and EE, a distinctive surface soil (Argiboroll) is present (Figure 4). The sequence of soil horizons is: A1, A2, Ab→Btk, Btb→Btk, C. The A horizon (0–40 cm bs [below surface]) has a silt loam texture, and is the zone's most recent humus accumulation. Below the A is horizon

Ab→Btk (40–70 cm bs), a zone of humus accumulation with a silty clay loam texture and clay illuviation. Analysis of three samples from this horizon (Davis, 1999) confirmed Paul Martin's earlier conclusion that pollen preservation at the site is very poor (personal communication to Sharrock, January 22, 1965).

The underlying Btb→Btk horizon (70–101 cm bs) is a silty clay loam with Stage I+ calcium carbonate that is violently effervescent. These sediments are designated Stratum IId to differentiate them from Stratum III; relatively unmodified Stratum IIa underlies the Btb→Btk horizon in the area of units CC–EE and extends to Stratum I gravel (101–200 cm bs). Stratum IId continues to the east, where it is exposed in backhoe trenches 2000-1, -2, and -3 (Figures 3 and 5) and becomes progressively thinner as the land surface slopes up to the east.

Stratum IIe is also exposed in backhoe trenches 2000-1 (Figure 5), -2, and -3 and contains two gravel lenses, labeled IIb and IIc. Stratum IIe is less bedded than IIa and contains slopewash-redeposited Bridger Formation clays with inclusions of Bishop Conglomerate. It is less calcareous, and has fewer voids, suggesting less vegetation than in IIa. Eardley's and Sharrock's original interpretation, (i.e., slope-reworked Bridger Formation material) is accurate for this stratum. In the backhoe trenches and unit AA, Stratum IIe is overlain by Stratum IIf, a brown (7.5YR 5/4), massive, matrix-supported, pebbly to cobbly mud that suggests slope wash and minor debris flows.

A soil exhibiting strong, medium-sized prismatic structure is formed into the surface of IIe, and we believe this is the same buried soil exposed in units CC, DD, and EE (Ab→Btb and Btb→Bk horizons). We return to the relevance of this soil below.

Stratum III is the uppermost sediment covering Sharrock's Trench 5 area. It is poorly sorted, moderately packed, light gray mottled to very dark grayish-brown (moist colors: 10YR 7/2 to 10YR 3/2), massive, trace pebbly clayey silt. The texture and geologic associations suggest it is largely slopewash with some possible intermittent alluvial beds. It is turbated by rodent activity, excavation, and looting.

Excavation on the east side of the spring mound revealed two related differences from Sharrock's excavation. Sharrock found that Occupation 1 was "limited to the upper few inches of [the spring mound] soil" in Trench 5 (F34:1), but we recovered no archaeological material from stratum IIa on the mound's east side. In addition, units CC, DD, and EE revealed a thicker B horizon than that depicted in Sharrock's field profiles, photos, and notes.

We considered the possibility that the B horizon, containing some artifacts, had developed down into the eastern spring mound and hence masked the presence of artifacts in the mound's upper reaches. To test this idea, Goldberg examined thin sections (27 × 46 mm) of four microstratigraphic samples (see Figure 4) from the Ab→Btk horizon, the upper and lower Btb→Btk horizons, and upper Stratum IIa of Unit DD using established procedures (Courty et al., 1989). The spring-mound sample revealed a calcareous clay, similar to a marl, consisting predominantly of clayey matrix with inclusions of silt-sized grains of quartz and feldspar (~1–3%); sand-sized angular pieces of chert and rounded quartz (traces = tr.); and sand-sized angular pieces of sparitic calcite with quartz silt (tr.). The matrix is massive, but punctuated with numerous cracks, and rounded to elliptical vughs, vesicles, and chambers. Some of the latter three void types contain remnants of roots.

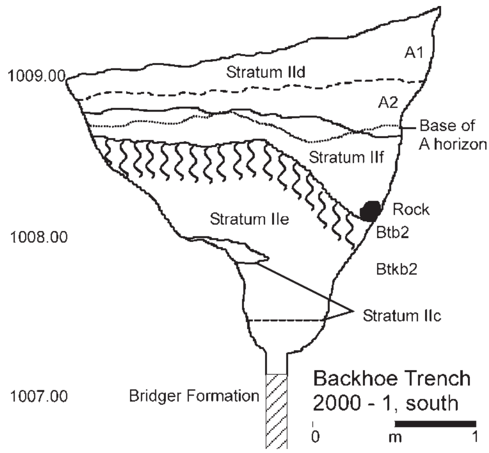

Figure 5. South (upslope) profile of backhoe trench 2000-1 (see location in Figures 3 and 4).

The samples from the Btb→Btk horizon, however, consist of generally noncalcareous sandy, silty clay, with inclusions of the underlying marl, as well as fresh granular-size grains of sparitic limestone, fine sandstone, tuffaceous sandstone, and partially etched grains of sparite. The sample is pale yellow to white, suggestive of iron depletion associated with gleying; individualized impregnations and some coatings of iron and manganese are localized throughout. Other secondary features include diffuse clay coatings and intercalations; these are not present as void coatings. Furthermore, to judge from what appear to be remains of much larger calcareous domains, much of the calcite within the matrix appears to be undergoing dissolution. The structure is angular blocky to prismatic, with intrapedal vesicles and irregular vughs.

This loamy material was possibly deposited through slopewash, and has been influenced by postdepositional translocation of clay, decalcification, and mobilization of iron and manganese. The sample is clearly from part of a soil horizon, as is reflected in the well-developed blocky structure. The presence of grains and irregular domains of the underlying calcareous marl may have been worked into this sediment by bioturbation or localized colluviation. In any case, the lithologic and pedogenic contrast of this sample with the underlying calcareous clay is clear, and two distinct types of sedimentation are definitely present.

These data indicate that the B horizon developed in sediments deposited on top of the spring mound rather than in the spring mound itself. The thicker B horizon on the east side of the spring mound does not explain why Sharrock found artifacts and bones in its upper reaches while we did not.

Possibly, Sharrock recovered artifacts because he excavated a much larger sample, but how abundant was archaeological material in the upper spring mound? In fact, Sharrock believed that F26 was sterile until he recovered F50, mentioned above, in Trench 5 with only 16 days left in the excavation (F27:18). But F50 contained only

Table I. Radiocarbon dates from the Pine Spring site.

Catalog number	Lab number	Location	Material	Age (yr B.P.)	Age calibrated (BC unless noted) 95% interval	Comments
FS 845	SR-5893	'64 Trench 5, Unit DDD, 'occupation 1'	Camel metapodial	11,260 ± 50	11,550–11,050	Frison (1991) suggests might be humanly fractured
UW 013	SR-5894	'64 Trench 5, 'occupation 1'	Bison radius	10,510 ± 50	10,950–10,150	
FS 777-84	SR-5895	'64 Trench 5, Unit FF, 'occupation 1'	Ovis Canadensis, long bone frag	3,980 ± 80	2900–2200	
UW 010	SR-5896	'64 Trench 5, Unit BB, Feature 50 'occupation 1'	Equus? Pelves	11,530 ± 50	11,900–11,200	
FS 736	SR-5897	'64 Trench 5, Unit BB, Feature 50 'occupation 1'	Camel? Vertebrae	11,180 ± 45	11,472–11,033	
SW101/1520	AA41607	Middle of spring mound, below unit EE	Soil, carbonate CO_2	6686 ± 51	5669–5512	
			Soil, organic residue	7688 ± 47	6594–6440	
SW101/1518	AA41608	Top of spring mound, below Unit EE	Soil, carbonate CO_2	4265 ± 45	2935–2857, 2813–2696	
			Soil, organic residue	4726 ± 39	3635–3376	$\delta^{13}C = -13.4$, possible carbonate contamination
SW101/1519	AA41609	Bottom of spring mound, below Unit EE	Soil, Carbonate CO_2	10,906 ± 74	11,192–10,867	
			Soil, organic residue	7258 ± 68	6231–5992	
12PS98 (Haynes)	AA30464	Near top of spring mound, below Unit DD	Soil, carbonate CO_2	7465 ± 65	6441–6216	Sample taken by V. Haynes, 1998
	AA30463		Soil, organic residue	6720 ±100	5788–5478	
14PS98 (Haynes)	AA30461	Near base of A horizon, Unit DD	Carbon, organic residue	3800 ± 55	2407–2125	Sample taken by V. Haynes, 1998
	AA30462		Humates of soil enveloping	5020 ± 60	3958–3697	
SW101/450	Beta-122583	Top of spring mound, unit N2842 E2898	Carbon	10,110 ± 60	10,164–9388	From 1998 excavation
9PS98 (Haynes)	Beta-122584	Near base of A horizon, bet. units CC and DD	Carbon	6510 ± 70	5560–5338	Sample taken by V. Haynes, 1998
SW101/1340	AA41610	EE, Base of B horizon, on top of spring mound	Carbon	7925 ± 59	7039–6652	$\delta^{13}C$ is –11.1, possible carbonate contamination; sample not re-run
SW101/847	AA41628	EE, top of B horizon	Carbon	9341 ± 66	8751—8379	
SW101/1335	AA41629	EE, middle of A horizon	Carbon	5703 ± 53	4691–4448	

SW101/809	AA41630	EE, A1/A2 contact	Carbon	170 ± 40	A.D. 1656–1950	
SW101/1940	AA41612	CC, lowest date in unit, near krotovina	Carbon	4140 ± 110	9223–8450	Large standard deviation encouraged re-run of sample
				9480 ± 140	2671–2455	$\delta^{13}C$ is –20.6, possible carbonate contamination; very small sample, .16 mg
				4018 ± 46	2925–2455	SW101/1940 after removal of carbonates
SW101/1935	AA41617	CC, in B horizon	Carbon	15,290 ± 160	16,989–15,697	$\delta^{13}C$ is –4.8, possible carbonate contamination
SW101/1935	AA41617	CC, in B horizon	Carbon	20,800 ± 2200		Re-run with carbonates removed, $\delta^{13}C = -23.3$
SW101/1921	AA41613	CC, near top of B horizon	Carbon	8606 ± 59	7789–7535	
SW1011420	AA41614	CC, near top of B horizon	Carbon	8190 ± 290	7801–6455	Very small sample, .07 mg
SW101/1383	AA41616	CC, near bottom of A horizon	Carbon	10,422 ± 82	10,743–9998	$\delta^{13}C$ is –13, possible carbonate contamination
				7885 ±61	7036–6636	SW101/1383 after removal of carbonates
SW101/2004	AA41618	CC, near bottom of A horizon	Carbon	5833 ± 98	4859–4459	
SW101/2002	AA41627	CC, middle of A horizon	Carbon	3968 ± 47	2581–2331	
SW101/2001	AA41615	CC, near top of A horizon	Carbon	290 ± 78	A.D. 1439–1812	
SW101/1966	AA41611	HH, contact bet. Midden and spring mound	Carbon	10,190 ± 73	10,387–9602	
SW101/1953	AA41620	HH, near bottom of B horizon	Carbon	625 ± 31	A.D. 1297–1398	
SW101/1819	AA41623	HH, middle of B horizon	Carbon	408 ± 34	A.D. 1430–1625	
SW101/1768	AA41619	HH, middle of A horizon	Carbon	1288 ± 40	A.D. 657–818	
				1305 ± 43	A.D. 647–783	
SW101/1595	AA41624	HH, in A1 horizon	Carbon	684 ± 44	A.D. 1265–1395	
SW101/1552	AA41622	HH, top of A horizon	Carbon	177 ± 34	A.D. 1655–1949	
SW101/1550	AA41621	HH, near top of unit	Carbon	617 ± 35	A.D. 1299–1399	
FS752	AA41625	Sharrock's Feature 52 (hearth), 'occupation 2'	Carbon	2887 ± 66	1264–900	
FS576	AA41626	Sharrock's Feature 29 (hearth), 'occupation 2'	Carbon	2528 ± 43	801–513	
SW101/1526	AA41631	2000 Trench 5, in top of spring mound	Carbon	1294 ± 41	A.D. 655–813	
SW101/1530	AA41632	2000 Trench 5, in top of spring mound	Carbon	2007 ± 57	162–A.D. 87	
SW101/1698	Beta 190120	II, level 7	Bone (vertebra)	1180 ± 40	A.D. 770– 70	Bighorn sheep, $\delta^{13}C = -18.0$

Note. SR = Stafford Research labs, AA = University of Arizona, Beta = Beta Analytic. Dates were calibrated using Calib 4.0. (Available at http://radiocarbon.pa.qub.ac.uk/calib).

one artifact, and only two other projectile points were found in F26 (F34:2). We recovered only a few flakes from the upper portion of the spring mound in Unit II and suspect that all artifacts in the spring mound were bioturbated downward.

Radiocarbon Dates

Forty-six new radiocarbon dates were obtained on 37 samples (Table I). Two dates were obtained on each of four samples of spring-mound deposits, one on each sample's carbonate CO_2, and a second on each sample's organic residue. These dates suggest that the lower spring mound is Early Holocene in age (Figure 4). But these dates are difficult to interpret because the lower Stratum IIa sample and one of the middle samples have carbonate CO_2 ages that are *older* than the organic residue ages, while the other middle Stratum IIa sample and the upper sample have carbonate ages that are *younger* than the organic residue ages. The fact that the carbonate CO_2 ages generally fall outside the two-sigma range of their corresponding organic residue ages suggests that some ionic exchange may have occurred between the sediment carbonates and groundwater in the lower deposits, and between the sediments and vadose water in the upper sediments.

In addition, we dated several bone specimens collected by Sharrock, including one of the *Camelops* vertebrae from F50 and one of two *Equus* innominates, found a meter east of F50.[3] Sharrock recovered the vertebrae in anatomical position. Their "up" sides (reconstructed from Sharrock's photos) were all equally weathered. Apparently, the vertebrae were deposited as an anatomical unit, when the remains were held together by tissue. Likewise, the innominates were found lying one on top of another, also suggesting deposition as an anatomical unit. Thus, both sets of remains were deposited on what was the surface of the spring mound and then partially buried. After their exposed portions weathered, they were completely buried. One of the remaining *Camelops* vertebrae dated to 11,180 ± 45 yr B.P. and one *Equus* innominate to 11,530 ± 50 yr B.P. These remains were found about 15 cm from the surface of the spring mound; thus, the mound was forming sometime before 11,500 yr B.P. Two pieces of charcoal found near the spring mound's surface near Units II and HH on the mound's southwestern edge yielded ages of 1294 ± 41 yr B.P. and 2007 ± 57 yr B.P. However, these were the only carbon samples observed in Stratum IIa; they could be roots that penetrated the mound after its burial, or translocated charcoal from the overlying midden. Two charcoal dates of 10,110 ± 60 yr B.P. and 10,190 ± 73 yr B.P. were obtained from immediately above the spring mound in Units GG and HH (Figure 6), and early Holocene sediments overlie the spring mound on

[3] The horse innominates are the only uncataloged specimens; they are, however, mentioned in a letter from Stanley Olsen to Sharrock (see footnote 2), who suggested that they compare well with the modern horse, although they are small; other faunal analysts who have seen the remains or photos concur. Additionally, these remains are not discussed in the F50 field notes, unless they are the bones referred to by an excavator who admitted not knowing what anatomical portion they were. These remains all appear in Sharrock's (1966) Figure 17 [and a closer unpublished photo left Kelly with no doubt as to which specimens they are], and are identified as bison. We tentatively identify them as horse and associate them with F50.

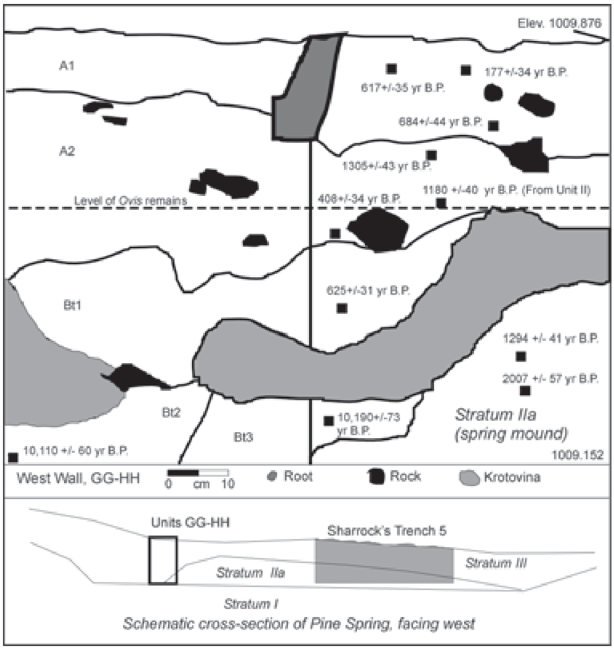

Figure 6. Western profile of Units GG and HH, with radiocarbon dates.

its east side (Figure 4). We conclude that the spring mound is primarily late Pleistocene in age, and ceased forming at the end of the Younger Dryas, circa 10,200 yr B.P. The single physical "association" between artifacts and extinct fauna (F50) on the mound's west side probably resulted from bioturbation (enhanced by the somewhat moister deposits of the spring mound's west side).

However, the radiocarbon dates pose some additional issues. A 20,800 ± 2200 yr B.P. date from Unit CC (Figure 4) is considerably older than the postulated age of the spring mound's surface. This sample initially dated to 15,290 ± 160 yr B.P. but was re-run because the $\delta^{13}C$ value suggested that the lab had not removed all carbonates. Several other dates were re-run due to their $\delta^{13}C$ values; in these cases the second date was younger, as expected. The 20,800 yr B.P. date was obtained on a small sample, but at present, we cannot account for it or its large error.

Beneath this date lies another, 4018 ± 46 yr B.P., which is considerably younger than those above it. Initially, this sample yielded an age of 4140 ± 110 yr B.P. The large standard deviation encouraged the lab to re-run it; this yielded a date of 9480 ± 140 yr B.P., but with a high $\delta^{13}C$ value. Re-running it a third time gave an age of 4018 yr B.P. We assume that the charcoal was intrusive, although it lay just outside a krotovina.

The other dates from this profile (Figure 4) form an expected progression. However, there appears to be a hiatus between 5703 and 170 yr B.P. in unit EE and between 3968 and 290 yr B.P. in unit CC. Likewise, the dates from units HH and GG are all young

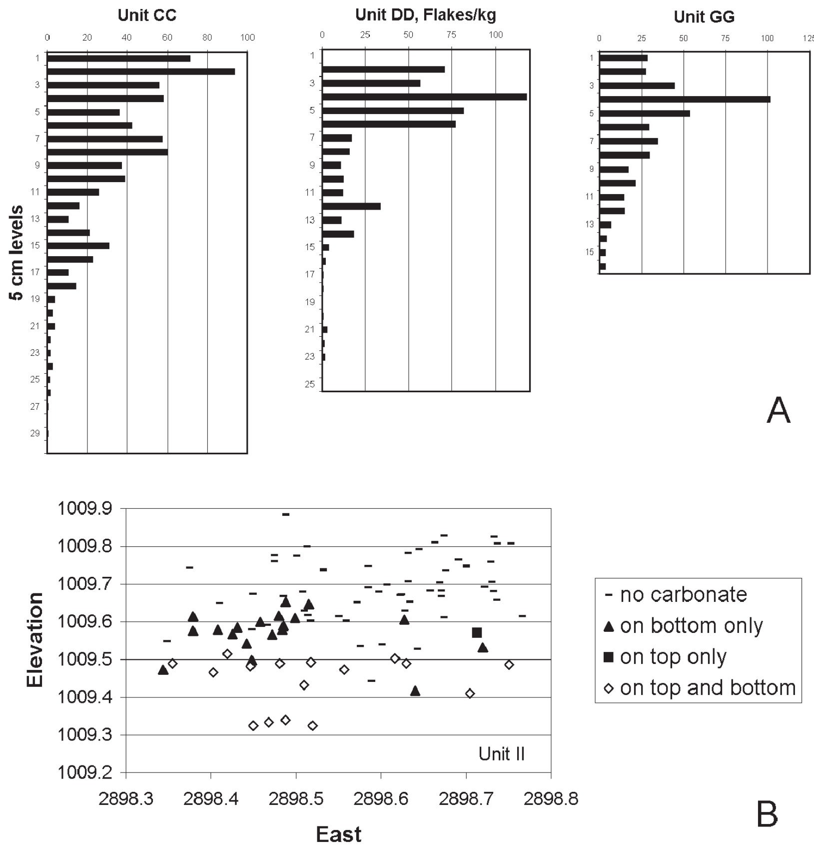

Figure 7. (a) Flake densities by 5-cm excavation level, Units CC, DD, and GG. (b) Backplot of flakes with carbonates indicated for Unit II.

(Figure 6), less than 1400 yr B.P., with the exception of the two terminal Pleistocene dates on the surface of the spring mound. In addition, one date of 1180 ± 40 yr B.P. was obtained on an *Ovis* vertebrae from nearby Unit II. Well-preserved *Ovis* remains appear the same distance below the surface in the adjacent units of GG and HH, and thus provide something of marker bed across these units. If so, then the 1305 yr B.P. date above them is slightly out of place, as well as the 625 yr B.P. date that lies below them.

DO THREE OCCUPATION LEVELS EXIST?

Sharrock distinguished the three occupations as horizontally continuous and vertically distinct layers of debitage. Using these criteria, however, we are unable to confirm his findings. Figure 7a shows three representative examples. In unit CC, there are three weak peaks in debitage density, but BB, EE, FF, GG, and II had only one peak, within 20–30 cm of the surface; AA, DD, and HH have only two peaks (note that DD and FF lie only 0.5 m from CC).

However, because Sharrock excavated primarily by shovel without screening, if there were systematic differences in flake sizes between excavation levels, then an excavator might have more readily recognized a level with large flakes and labeled that level an "occupation." However, we found no significant differences in mean flake size between arbitrary levels (Moss, 2004), and backplots of piece-plotted items (all of which are > 3 cm in length) mirror each unit's density graph.

Other data suggest that Sharrock's "occupations" are mixed assemblages. We found that virtually all carbonate-coated fauna in Sharrock's Occupation 1 faunal material were those of large (bison-sized) animals; remains without such a heavy coating were those of *Ovis*. This suggests that the remains of large fauna have lain in the ground longer than those of the bighorn sheep. As we noted, *Camelops*, *Bison*, and *Equus* remains from Occupation 1 yielded dates in excess of 10,000 yr B.P. One *Ovis* specimen, however, dated to 3980 $\pm$ 80 yr B.P. We assume that Sharoock's Occupation 1 lithic assemblage is as mixed as the faunal material.

Sharrock's Occupation 2 collections also contain a range of dates. The *Ovis* specimens are close to 4000 ^{14}C years old, but Occupation 2 also contained two hearths, F29 and F52, that we dated to 2528 $\pm$ 43 yr B.P. and 2887 $\pm$ 66 yr B.P., respectively. Sharrock's Occupation 2, therefore, spans at least 1500 ^{14}C years.

PINE SPRING'S STRATIGRAPHY RECONSIDERED

Casting doubt on Sharrock's conclusions, however, does not necessarily mean that the Pine Spring stratigraphy is hopeless, for "it is not just a question of whether a site is *in situ* or not, but rather the nature and extent of the disturbances" (Dibble et al., 1997, p. 647). Postdepositional processes affect even "intact" deposits. The radiocarbon dates suggest that Pine Spring's deposits are not so badly disturbed that the law of superposition is not in effect. We checked this using several lines of evidence.

Carbonates

When items were piece-plotted, we recorded whether carbonates adhered to a flake's "up" and/or "down" side. Terrestrial carbonates form in two major ways (Rapp and Hill, 1998, p. 81). In arid environments, *in situ* weathering and eolian dust provide carbonate that is dissolved and leached downward to the average depth of soil moisture. Carbonates are then deposited mainly on the bottom of clasts as the sediment dries. Alternatively, carbonate-bearing spring waters can infiltrate sediments and deposit carbonate on all sides of clasts. In the first way, carbonates are carried in atmospheric water, in the second, by groundwater. The $\delta^{18}O$ content of carbonate samples should, therefore, reflect the source of the carbonates (Kelly, 1989). Older groundwater should have more negative values, whereas recent waters should have less negative values. As controls, we sampled the modern spring, summer rainwater, and winter snow. These yielded expected values (Table II).

Table II. $\delta^{18}O$ values for samples from water, precipitation, and carbonates from Pine Spring.

Catalog number	Sample	Material	Up/Down	^{18}O	Comments
	Snow, 1999			–26.780	Corrected values, 3 run average
	Spring water, summer 1999			–23.260	Corrected values, 3 run average
	Snow, 1999			–22.600	Corrected values, 3 run average
	Spring water, July 2000			–18.980	Corrected values, 3 run average
2166	II, level 13	Flake	D	–16.840	Average of 2 runs
1515	GG, level 15	Flake	D	–16.709	Corrected values
1892	GG, level 12	Flake	D	–16.563	Average of 2 runs
1516	GG, level 15	Flake	D	–16.434	Corrected values
737	Sharrock, vertebral process	Bone		–16.291	Corrected values
736	Sharrock, camel vertebral centrum	Bone		–16.205	Corrected values
1515	GG, level 15	Flake	U	–16.145	Corrected values
1748	II, level 9	Biface	D	–16.132	Average of 2 runs
1888	GG, level 12	Flake	D	–16.028	Average of 2 runs
1516	GG, level 15	Flake	U	–15.896	Corrected values
	Sharrock, horse pelvis, right, occupation 1	Bone		–15.819	Corrected values
UW 103	Sharrock, bison radius	Bone		–15.647	Corrected values
1868	GG, level 10	Flake	D	–15.587	Average of 2 runs
1877	GG, level 11	Flake	U	–15.486	Corrected values
1865	GG, level 10	Core	D	–15.477	Corrected values
2161	II, level 11	Flake	D	–15.158	Average of 2 runs
1751	II, level 10	Flake	D	–14.753	Average of 2 runs
1753	II, level 10	Flake	U	–14.565	Average of 2 runs
	Rain, June 2000			–11.850	Corrected values, 3 run average
	Rain, July 2000			–9.640	Corrected values, 3 run average

The $\delta^{18}O$ content of carbonates removed from a sample of artifacts and faunal remains were analyzed at the University of Wyoming's Stable Isotope Facility.[4] The samples in Table II are arrayed between spring water/snow at one end of the spectrum and summer precipitation at the other. Bedrock and/or eolian sources of carbonates play an unknown role in the $\delta^{18}O$ values reported here, and some carbonates may be derived from a mix-

[4] Carbonate samples were reacted with 100% phosphoric acid at 90°C, cryodistilled, and the resultant purified CO_2 introduced into a Micromass Optima dual-inlet stable-isotope ratio mass spectrometer. Carbonate $\delta^{18}O$ values are reported wrt V-PDB. Two-milliliter aliquots from water and precipitation samples were loaded into septa vials under an atmosphere of research grade CO_2 and ultra-high purity He. After an 8-hour equilibration at 40°C, head-space gas was sampled by a Micromass Multiflow and analyzed with a Micromass Isoprime continuous flow stable isotope ratio mass spectrometer. Values for water and precipitation samples are reported wrt V-SMOW.

ture of ground and atmospheric water. But, in general, the pattern is the expected one; artifacts found deeper in the site, or within the spring mound, have more negative values than ones found higher in the stratigraphy. A few artifacts have $\delta^{18}O$ values more negative than those of the megafauna remains (numbers 737, 736). These are from units located south of Sharrock's Trench 5 and from levels near the surface of the spring mound. This may mean that they are as old as, or older than, those remains, or that they have been more heavily affected by ground as opposed to atmospheric water.

The presence of carbonates on artifact tops and/or bottoms is also a clue to postdepositional artifact movement. If no postdepositional movement has occurred then we expect to see no carbonates on artifacts in the upper levels, the zone of leaching. Down lower, in the zone of pedogenic carbonate formation, we expect to see artifacts with carbonate-coated bottoms. Lower still, in the zone of periodic groundwater saturation, we expect artifacts to have both their tops and bottoms coated with carbonates. The presence of artifacts outside this pattern (e.g., with carbonates on their up-sides only) or completely coated artifacts high in the profile, suggests postdepositional movement.

Figure 7b shows a representative flake backplot for Unit II, with flakes indicated as having no carbonates, carbonate on their bottoms only, tops only, or top and bottom. Flakes with carbonates on both sides tend to be found in the deepest levels, whereas flakes with no carbonates tend to be found in the upper levels. Flakes with carbonates on the down-side tend to be found in between these two. Few flakes have carbonates only on their up-sides.

Unit II shows the pattern that we expect little to no postdepositional movement to produce. This holds true for Units CC, DD, GG, and HH and, to a lesser extent, EE. The carbonate data from AA, BB, and FF suggest these units are less intact (expected, because these units were more heavily rodent turbated).

Postdepositional Flake Damage

Another measure of postdepositional movement comes from stratigraphic patterns in postdepositional flake damage produced by burning and trampling.

Range fires could produce layers of burned debitage across the site, whereas heat-treatment failures or exposure to hearths might produce lenses. In either case, peaks in the frequency of burned debitage between excavation levels should indicate that there has not been much vertical movement of artifacts after the burned debitage was buried. If much postdepositional movement had transpired, then we would expect those peaks to be "blurred" and unrecognizable.

To determine if such peaks exist at Pine Spring, we ran the debitage from each level of Units DD, GG, and II through a 1/4-inch screen to obtain a sample ($n > 20$) from each level. Heat-treatment experiments with Tiger chert (Cooper, 2002) show that if heat-treatment is done properly, no crazing or potlidding occurs. Flakes exposed to direct flame, however, break within 2–5 minutes, potlidding appears within 15 minutes, and crazing within 25 minutes. Thus, flakes showing crazing, potlidding, and/or characteristic fire-damage breaks were classified as burned. Concerned that burning might only be identifiable on large flakes, we checked for significant differences between the size of burned and unburned flakes. We found no difference in Units DD and II, but burned flakes were significantly larger than unburned flakes in Unit GG (0.75 as opposed to 0.56 g; $t = 2.9$, $df = 26$, 2-tailed $p = .007$). Still, we tentatively conclude that flake size is not a relevant variable. Figure 8 shows the frequency of burned debitage by level in each unit. All three have a peak near the base of the excavation; each also contains at least one other peak closer to the surface, although that of DD is less distinct than those are of GG and II.

High amounts of trample damage in one level as opposed to another can indicate either an increase in the number of persons walking across a surface or a stabilized surface that saw more human and animal trampling than levels above or below it. Because Pine Spring was used by small foraging bands, peaks in trample damage probably reflect surface stabilization. And peaks in trample damage, like peaks in burning, might point to relatively undisturbed deposits.

As part of a Tiger-chert trample damage experiment, Cox (2002) measured trample damage by importing a flake's scanned image into SigmaScan and measuring flake perimeter and the widths of flake scars created by trampling. The ratio of total linear edge of trample-induced flake scars to the flake's total perimeter provides a measure of flake trample damage. (The mean ratio for the experimental sample was 0.102.)

We randomly selected 15 large flakes from each level of DD and GG, excluding obviously retouched or—because they could be more susceptible to trampling—burned flakes. These were then scanned and measured; although some flake-edge damage can occur in manufacture, we assume this is constant and that flake-edge damage monitors changes in the frequency of trample damage. Analysis revealed two trample damage peaks in GG and three in DD (marked as black bars in Figure 8). The upper trample peak in Unit DD lies just below the surface and may have been produced by the heavy machinery used to install a water pipe. Three of the other four trample peaks are not correlated with peaks in burning.

Taken together, the presence of discernible peaks in burning and trample damage may jointly indicate that only a modicum of postdepositional movement has occurred.

Debitage Refits/Conjoins

Another approach to determining stratigraphic integrity comes from the vertical distribution of refitted and conjoined debitage pieces. All flakes that did not pass through a 1/4-inch screen from units DD, GG, and II were examined for refits and conjoins. Because 98% of the debitage is Tiger chert, we first searched for refits among the exotic raw materials. Following Morrow (1996), we then sorted each level's Tiger-chert flakes into complete, proximal, medial, and distal portions; then, to find conjoins, we compared each proximal flake to each medial and distal portion in all levels. We then compared complete flakes to locate refits (flakes that fit onto the dorsal scar of another complete flake).

This exercise produced a few refits/conjoins separated by as much as 15 cm. However, most refits/conjoins were to flakes in their own or adjacent levels. Thus, these data, too, suggest little postdepositional movement in our excavation units. This level of stratigraphic integrity means we can now consider other formation processes.

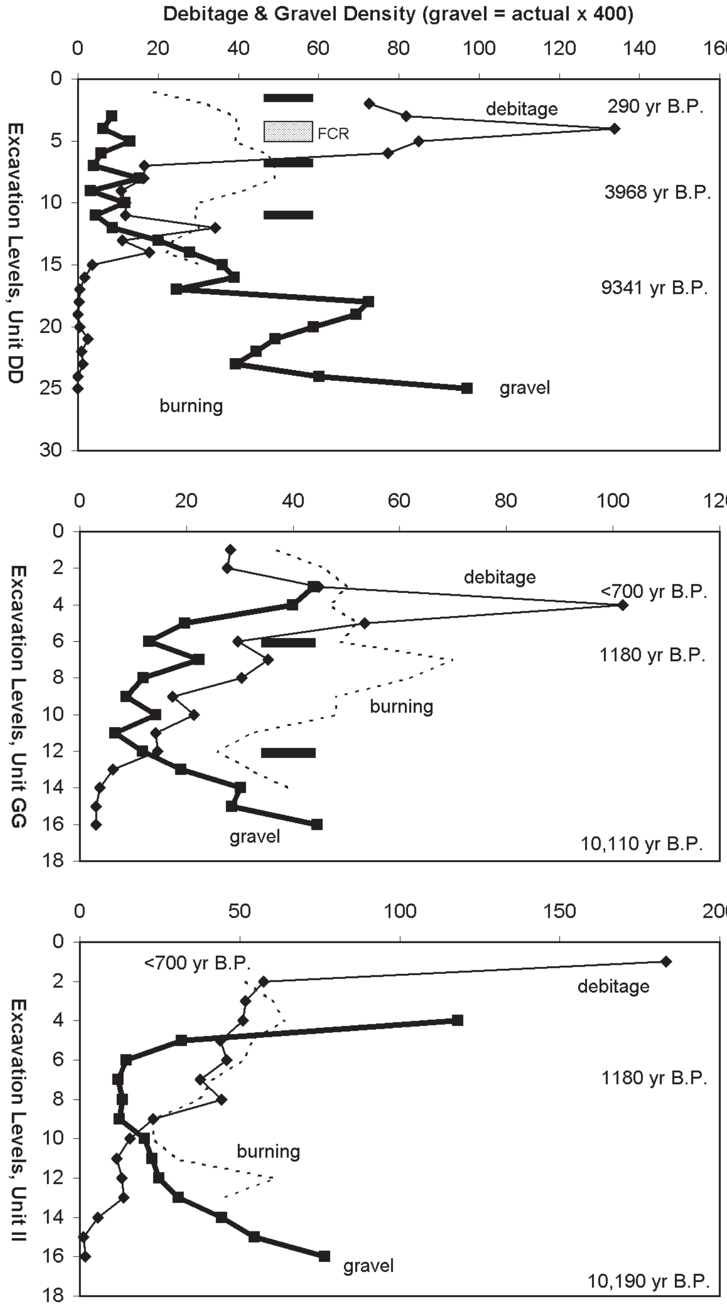

Figure 8. Debitage densities (light lines), percentages of gravel (heavy lines), and frequency of burned debitage (dotted lines) by excavation level in Units DD, GG, and II, with selected radiocarbon dates; solid bars = levels with significant trample damage; level of fire-cracked rock indicated in DD. Gravel densities are multiplied by 400 to fit to the debitage scale.

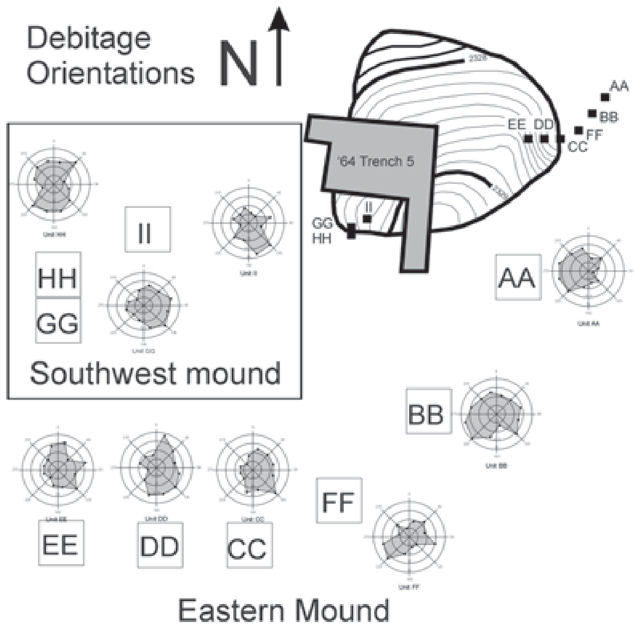

Figure 9. Rose diagrams showing artifact orientation in Units AA-FF on east side of spring mound and Units GG-II on west side.

EVALUATING REDEPOSITION, EROSION, AND DEFLATION

Both Sharrock and Jennings noted evidence for the transport of colluvium into and through their Trenches 4 and 5. Sharrock (1966, p. 16) noted a "fossil gully" upslope that he thought contributed gravel lenses to Trench 5. The micromorphological samples suggest that some slopewash contributed material to the B horizon on the mounds' east side. Were the artifacts we recovered on the eastern and western sides of the spring mound also deposited by slopewash? Are the artifacts in secondary and not primary context? We turned to flake orientation and sediment analyses to help answer these questions.

Flake Orientation and Inclination

Objects moved by fluvial action, including slopewash, have long axes oriented to the direction of flow (e.g., Dibble et al., 1997); thus, orientation data may point in the direction of slopewash. Figure 9 shows rose diagrams for units along the east (AA–FF) and southwest sides (GG–II) of the spring mound. Artifacts in units AA, BB, and FF slope to the west or southwest, while those in CC through EE slope to the east/southeast. The overall site slopes from south to north; therefore, if these artifacts had washed downslope, we might expect them to point more northward. Instead, the data point to the presence of a narrow gully along the east edge of the spring mound. Artifact median inclinations, which range from 6 to 18 degrees, suggest that the flakes were deposited on a gently sloping surface and were not deposited by rapid downslope movement, as, for example, in a small mudflow event. Although sediment weight can "flatten" artifact inclinations over time, experiments suggest that considerably thicker deposits than those at Pine Spring are required (Andrews, 2006).

The postulated gully on whose sides the artifacts were deposited is supported by the stratigraphies of backhoe trenches (2000 Trenches 1, 2, and 3; Figure 3), which show the midden thinning considerably to the east and Stratum IIe rising sharply to the east in 2000 Trench 1. At some point in time, the postulated gully accumulated midden deposits with artifacts oriented in their current directions through localized sheetwash on the sides of the gully and spring mound, and not through transport from a source uphill to the south.

Orientation data from units GG, HH, and II, on the west side of the spring mound, are more complex, yet they too suggest that artifacts were not redeposited from the hillslope above. Artifacts in GG slope down to the east/southeast; in HH, they slope to both the north and the south, and in II, they slope to the southeast. Slopewash should have produced orientations to the north and/or northwest. Possibly, these orientations are affected by the faunalturbation that was dramatic in these units, but they presently do not support slopewash deposition of the artifacts.

Sediment Samples

We checked these interpretations through analysis of sediment samples. If slopewash introduced artifacts to the site, then it should also have introduced equivalently sized unmodified rock (as there is a ready source in the Bishop gravels upslope) and produced gravel frequencies that mirror debitage frequencies.

Sediment samples from DD, GG, and II were weighed and then deflocculated in 6 L of water mixed with 1 cup of dissolved dishwasher detergent. After gentle mixing, each sample sat for 24–48 hours. After pouring off the water, we wet screened the remaining sediment through a No. 100 geological screen. Sediments that passed through the screen settled for 24 hours, after which the excess water was poured off and the sediments air-dried, weighed, and bagged. Sediments retained in the No. 100 screen were dried and screened through a column of stacked sieves, representing phi units –8, –6, –2, –1.75, –1, 0, 1.0, and 3.0. Fractions remaining in screens above phi unit 1.0 were sorted into rock, debitage, bone, gastropod, plants, and other. Figure 8 shows the relationship between debitage and gravel abundance for the three tested units. Debitage densities in Figure 8 are in-field flake counts. "Gravel" includes all unmodified rock from phi units –1.0 and above; gravel density is the total gravel weight divided by the sample's total initial weight (excluding debitage, bone, and shell).

There is an increase in gravel abundance near the base of all three excavation units that is associated with low debitage densities, if not a complete absence of debitage. In Unit DD, the debitage peak is not associated with a gravel peak. In Unit GG, a peak in debitage is associated with a gravel peak near the ground surface, whereas in nearby Unit II, a peak in gravel is associated with a decline in debitage density. These data suggest that the archaeological deposits are not principally a product of slopewash and redeposition.

DISCUSSION

Our data cannot duplicate Sharrock's three occupations. Possibly, our excavation areas are not comparable to those of Sharrock, especially his Trench 5, where the occupations were defined. We excavated a smaller area than did Sharrock, and the units were restricted to the edges of the spring mound, not the center of an infilling basin. Perhaps, then, we should not expect to duplicate Sharrock's stratigraphy; nonetheless, the data do show that the three occupations do not extend outside the Trench 5 area, as Sharrock assumed.

Our analyses also show that there appears to be a hiatus in the record. On the west side of the spring mound, dates in excess of 10,000 yr B.P. lie just above the spring mound, but there are no dates between 10,000 and 1300 yr B.P. (except for the intrusive date of 2007 yr B.P. in the spring mound). Likewise, a discontinuity is present on the east side of the spring mound, where the lowest levels of Stratum IId contain early Holocene dates, but there is, minimally, a hiatus between ~3900 and ~290 yr B.P.

One explanation for this hiatus is deflation. In fact, Husted (1995, p. 56) suggested that deflation produced Sharrock's Occupation 2, as evidenced by the presence of a variety of point types and by the fact that Sharrock only recovered hearth charcoal beneath rocks—everything else having blown away. However, deflation should produce a lag deposit that would appear as peaks in both debitage and gravel densities. Possibly, an episode of deflation is tracked by the gravel peaks in lower levels of the deposits, perhaps produced by an arid, post–Younger-Dryas climate, during which time we have no substantial evidence of human use of the site. Gravel and debitage peaks generally do not coincide in the deposits; therefore, the evidence is somewhat equivocal on the southwest side of the spring mound, but the east side shows no correlation and thus no evidence of deflation.

A second explanation for the hiatus is erosion, post-3900 yr B.P. on the east side and sometime between 10,000 and 1300 yr B.P. on the west side. The spring mound may have channeled slopewash to either side of the mound, creating cut-and-fill episodes that account for the hiatus in radiocarbon dates. It could also have washed material into Sharrock's Trench 5, creating the mixed Occupation 2 assemblage. However, we saw no clear evidence of stratigraphic discontinuities in our excavation units and no clear evidence for significant slopewash deposits, as noted above.

A third explanation is that aggradation simply ceased ~4000 yr B.P., and a long-lived stable surface formed. Regionally, hillslopes stabilized and slopewash decreased at the transition of the more arid early and middle Holocene to the beginning of the Neoglacial era, > 5000 yr B.P. (Dahms, 1994; Eckerle, 1997). As noted above, a soil that developed into the upper portion of Stratum IIe, as observed in backhoe Trenches 2000-1, -2, and -3, may correlate with the soil in the Ab→Btk horizon in units CC–EE. This soil suggests a cessation of aggradation, and it lies just below the level of the hiatus in radiocarbon dates in the CC–EE profile (Figure 4). A more slowly aggrading surface could account for the peak in debitage and fire-cracked rock in

Units CC, DD, and EE, as well as for the mixture of time-marker artifacts and radiocarbon dates in Sharrock's Occupation 2 assemblage. In addition, the middle trample peak in DD lies just above the Ab→Btk soil, supporting an interpretation of a slowly aggrading surface.

However, the increase in artifact frequency in Units GG, HH, and II occurs after 1180 yr B.P., because the highest debitage density lies above the postulated surface containing the 1180 yr B.P. *Ovis* remains. In GG, the *Ovis* remains are in a level associated with a burning peak, and a trample peak lies above that level. Possibly, the post-3968 yr B.P. peak in artifacts in CC–EE is actually post-1180 yr B.P. in age. On the other hand, there is clearly a mid-to-late Holocene occupation in the Trench 5 area, as marked by hearths (circa 2500–2900 yr B.P.) and a possibly substantial bighorn sheep kill (circa 4000 yr B.P.).

CONCLUSION

At present, we hypothesize that a cessation in aggradation from 4000 yr B.P. to circa 1200 yr B.P. created Sharrock's Occupation 2, the site's major period of use. Although there are deposits at the site that immediately overlie the spring mound and that date to ~10,000 yr B.P., there are few archaeological remains within the spring mound itself. The biface that Sharrock found 45 cm from the camel vertebrae was the only artifact found close to megafaunal remains, but because the Occupation 1 fauna are clearly a mixture of late-Pleistocene and mid-Holocene remains, we cannot discount the possibility that this biface is mid-Holocene or later in age. We saw no bone breaks on the *Camelops* or other megafaunal remains that natural processes cannot account for, nor were there any observable cut marks. In sum, no evidence confirms human involvement in the deaths of the horse, camel, and bison at Pine Spring.

We could not locate evidence of Sharrock's three occupations and conclude that the 1964 assemblage cannot be analyzed using Sharrock's occupations as the units of analysis. Unfortunately, there are only small pockets of intact sediments at the site, removing the possibility for substantial future excavations. Possibly, the unit-level proveniences can be used to break the assemblages apart, but, at present, we do not know on what basis to do so. There is some potential for analyzing the large number of sheep remains that Sharrock assigned to Occupation 2, although the contemporaneity of the assemblage would need to be demonstrated through radiocarbon dating—*Ovis* remains from the site date to both the middle and late Holocene, and the faunal remains and features assigned to Occupation 2 cover a range of mid- to late-Holocene dates.

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REFERENCES

Andrews, B. (2006). Sediment compaction and archaeological site formation. Geoarchaeology, 21, 461–478.

Birkeland, P. (1999). Soils and geomorphology (3rd ed.). Oxford: Oxford University Press.

Bullock, P., Fedoroff, N., Jongerius, A., Stoops, G., Tursina, T., & Babel, U. (1985). Handbook for soil thin section description. Wolverhampton, UK: Waine Research.

Cooper, C. (2002). A study of the morphological changes in Tiger chert resulting from heat treatment. Lithic Technology, 27, 153–160.

Courty, M.A., Goldberg, P., & Macphail, R.I. (1989). Soils and micromorphology in archaeology. Cambridge: Cambridge University Press.

Cox (Sanderson), M. (2002). The effects of trampling on the orientation and inclination of experimental lithic raw material. Unpublished manuscript. University of Wyoming.

Dahms, D.E. (1994). Mid-Holocene erosion of soil catenas on moraines near the Type Pinedale Till, Wind River Range, Wyoming. Quaternary Research, 42, 41–48.

Davis, O.K. (1999). Pollen analysis of the Pine Spring Site, Black Mountain, Wyoming. Unpublished manuscript. University of Wyoming.

Dibble, H.L., Chase, P.G., McPherron, S.P., & Truffreau, A. (1997). Testing the reality of a "living floor" with archaeological data. American Antiquity, 62, 629–651.

Eardley, A.J. (1966). Geology of the Blacks Fork area. In F.W. Sharrock (Ed.), Prehistoric occupation patterns in southwest Wyoming and cultural relationships with the Great Basin and Plains culture areas (University of Utah Anthropological Paper 77, pp. 193–204). Salt Lake City: University of Utah.

Eckerle, W. (1997). Eolian geoarchaeology of the Wyoming Basin. In M.L. Larson and J.E. Francis (Eds.), Changing perspectives of the Archaic on the Northwest Plains and Rocky Mountains (pp. 138–168). Vermillion, SD: University of South Dakota Press.

Frison, G.C. (1991). Prehistoric hunters of the high plains. Second edition. Orlando, FL: Academic Press.

Frison, G.C. (1997). Camelops on the northern plains: When did they become extinct and were they hunted by North American paleoindians? In L.A.Hannus, L. Rossum, and R.P. Winham (Eds.), Proceedings of the 1993 bone modification conference, Hot Springs, South Dakota (Occasional Publication No. 1, pp. 12–23), Archeology Laboratory, Augustana College. Sioux Falls, SD: Augustana College.

Haynes, C.V. (1967). Quaternary geology of the Tule Springs area. In H.M. Wormington and D. Ellis (Eds.), Pleistocene studies in southern Nevada (Nevada State Museum Anthropological Paper 13, pp. 15–104). Carson City, NV: Nevada State Museum.

Husted, W.M. (1995). The Macrotradition twenty-seven years later. Archaeology in Montana, 36, 37–92.

Kelly, E.G. (1989). A study of the influence of climate and vegetation on the stable isotope chemistry of soils in grassland ecosystems of the Great Plains. Unpublished doctoral dissertation, University of California, Berkeley.

Love, J.D., & Christiansen, A.C. (1985). Geologic map of Wyoming. Laramie, WY: U.S. Geological Survey.

Morrow, T.M. (1996). Lithic refitting and archaeological site formation processes: A case study from the Twin Ditch Site, Greene County, Illinois. In G.H. Odell (Ed.), Stone tools: Theoretical insights into human prehistory (pp. 345–376). New York: Plenum.

Moss, J. (2004). A preliminary analysis of chipped stone debitage from Pine Spring, Wyoming. Unpublished master's thesis, University of Wyoming, Laramie, Wyoming.

Rapp, Jr., G., & Hill, C.L. (1998). Geoarchaeology. New Haven, CT: Yale University Press.

Sharrock, F. (1966). Prehistoric occupation patterns in southwest Wyoming and cultural relationships with the Great Basin and Plains culture areas (University of Utah Anthropological Paper 77). Salt Lake City: University of Utah Press.

Thompson, K.W., & Pastor, J.V. (1995). People of the sage: 10,000 years of occupation in southwest Wyoming (Cultural Resource Management Report No. 67). Rock Springs, WY: Western Wyoming Community College Archaeological Services.

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