REPORTS

IDENTIFYING STONE TOOL CUT MARKS AND THE PRE-CLOVIS OCCUPATION OF THE PAISLEY CAVES

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Analysis of taphonomic processes observable in undoubtedly cultural Younger Dryas-age faunal collections at the Paisley Caves establishes what cultural bone modification looks like in post-Clovis deposits at the site. Clearly stating the criteria by which these bones have been identified as culturally modified by stone tools, we apply the same criteria to bones found at the noncultural paleontological site of Mineral Hill Cave, Nevada, and find no cases of stone-tool-cut-marked bones. Applying these same criteria to bones recovered from pre-Clovis stratigraphic contexts at the Paisley Caves resulted in the identification of two cut-marked specimens, a mountain sheep (Ovis canadensis) mandible and a small artiodactyl rib that were both found in close proximity to human coprolites and artifacts. Directly radiocarbon dated prior to the beginning of the Clovis era (ca. >13,100 cal B.P.), these specimens increase the number of culturally modified items recovered from pre-Clovis contexts and support previous DNA studies indicating that the northern Great Basin was occupied at least a millennium before Clovis points became widespread throughout North America.

Dos cortar huesos marcados, una oveja de montaña (Ovis canadensis) mandíbula y un segmento pequeño artiodactyl ambos fueron encontrados en las proximidades de coprolitos humanos y artefactos en las cavernas Paisley, Oregón. Directamente radiocarbono fechado antes del comienzo de la era Clovis (ca. > 13.100 cal B.P.), estas muestras de aumentar el número de elementos culturalmente modificados recuperados de pre-Clovis contextos y apoyar los estudios previos de ADN que indican la gran cuenca norte fue ocupado por lo menos un milenio antes de Clovis tecnología se extendió a lo largo de América del Norte.

Paleoindian sites had long been reported in North America before the discovery of Clovis projectile points in association with extinct megafauna near Clovis, New Mexico, but had always proven to be either much younger than originally claimed or entirely noncultural in origin (Howard 1932, 1933; Meltzer 2009). With the discovery of *in situ* Clovis points and beveled bone rods among mammoth bones in a gravel pit near Clovis, the bar by which other purported "First Colonization" sites would be judged was clearly set (Haynes 1969, 1991; Haynes 2002). As decades passed following the discovery of Clovis, and one proposed pre-Clovis site after another fell into disfavor with North American archaeologists, what originally was the first widely accepted Pleistocene-age culture (Clovis) became the only first Pleistocene culture. If true, then all other technological traditions must have evolved from this founding culture. Those who supported this scenario came to be referred to as "Clovis-First" proponents, while those who thought there were sites older than Clovis, and that an initial colonization of North America may or may not be related to groups who manufactured Clovis points, were referred to as "pre-Clovis" proponents (e.g., Bonnichsen and Turnmire 1999; Bonnichsen et al. 2005; Haynes 2002:4; Lepper and Bonnichsen 2004).

Breaking the "Clovis Barrier" in the Americas has proven exceedingly difficult, as demonstrated by the debates concerning Monte Verde, Chile (Dillehay et al. 2008; George et al. 2005; Meltzer et al. 1997). People simply may have been absent before that time, as Clovis-First proponents believe, or, alternatively, human populations were very sparse during the first few millennia of initial

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colonization, causing the evidence to be thinly distributed, poorly preserved, exceedingly difficult to find, and susceptible to variable interpretations when present (Madsen 2004). This latter situation is duplicated in other regions of the world in which initial human colonization is sparsely preserved, and when reported immediately sparks vociferous debate, such as the case of the initial peopling of southwest Iberia by anatomically modern humans (Thacker 2001). In each case, initial colonization by pre-Clovis (North America) and Aurignacian (southwest Iberia) populations are evidenced by scanty, non-diagnostic, and thus difficult to defend archaeological records. And, in both instances, the archaeological records immediately succeeding these periods are evidenced by highly distinctive and relatively widespread artifact assemblages (Goebel et al. 2011; Zilhão and d'Errico 1999). Thus, the general character of the pre-Clovis-Clovis debate is not unique to North American archaeology.

Recent claims have been made for pre-Clovis human presence in Texas, Washington, and Oregon (Gilbert et al. 2008; Jenkins et al. 2012a; Waters and Stafford 2007; Waters, Forman, Jennings, Nordt, Driese, Feinberg, Keene, Halligan, Lindquist, Pierson, Hallmark, Collins, and Wiederhold 2011; Waters, Stafford, McDonald, Gustafson, Rasmussen, Cappellini, Olsen, Szklarczyk, Jensen, Gilbert, and Willerslev 2011). The Paisley 5 Mile Point Caves site (35LK3400) in Oregon is the location where ancient human DNA in coprolites provides the oldest directly dated—at 14,500 cal B.P. (12,300–12,400 B.P.)—human remains in the Western Hemisphere (Gilbert et al. 2008). This interpretation has been recently bolstered by the publication of the complete stratigraphic sequences of the caves backed by 190 AMS dates on artifacts, plant macrofossils, bones, human and animal coprolites, and other organic remains (Jenkins et al. 2012a, 2012b). Here, we verify an important portion of the Paisley Caves pre-Clovis cultural assemblage—cut-marked bones—by (1) reporting the taphonomic processes observable in the faunal collections; (2) establishing what cultural bone modification looks like in minimally-disturbed Younger Dryas-age (ca. 12,800–11,800 cal B.P.) cultural deposits (the Botanical Lens); and then (3) clearly stating the criteria by which bone that has been culturally modified by stone tools may be identified in pre-Clovis contexts. Applying these criteria to a set of pre-Clovis-age bones recovered from the exclusively paleontological site (no artifacts found of any age) of Mineral Hill Cave, Nevada, resulted in no identifications of cut-marked bones. Applying these same criteria to bones recovered from pre-Clovis stratigraphic contexts at the Paisley Caves resulted in the identification of two stone-tool- cut-marked specimens. Our research has methodological ramifications for the identification of cut-marked bones, as well as chronological implications for the nature and timing of the initial peopling of North America.

Paisley Caves: Site Introduction and Taphonomy

The Paisley Caves site is located on the highest shoreline of pluvial Lake Chewaucan in a steep ridge of basalt, rhyolite, and volcanic tuff at the southeast end of the Summer Lake basin near Paisley, Oregon (Figure 1). The site was first investigated by Luther Cressman and reported to exhibit evidence of late Pleistocene human occupations on a house floor containing a hearth with extinct camel and horse bones, some burned, distributed around it (Cressman 1942). While never discredited, the association of cultural remains (nondiagnostic obsidian flakes/knives) with extinct fauna was never fully accepted (Jenkins 2007). The site languished under the depredations of artifact collecting hobbyists until the University of Oregon (UO) began new investigations in 2002. Over the past decade, the UO has intermittently excavated (2002, 2003, 2007, 2009–2011) the site. Jenkins (2007) reported the chronostratigraphic association of extinct megafauna with human coprolites and artifacts; Gilbert et al. (2008) reported the discovery of ancient human DNA in directly dated pre-Clovis age coprolites; and Jenkins et al. (2012a, 2012b) reported the chronostratigraphic sequences of caves 2 and 5.

Hundreds of thousands of faunal remains have been recovered from the excavations, including a number of extinct and extralocal species (Table 1). To date, we have identified osteological specimens of *Camelops hesternus* (Yesterday's camel), *Equus* cf. *occidentalis* (large horse), and *Equus* cf. *conversidens* (small horse). In addition, a number of extralocal species are present in the Pleistocene de-

Figure 1. The Paisley Five Mile Point Caves, Summer Lake Basin, Oregon.

posits, including *Marmota flaviventris* (yellow-bellied marmot), *Ochotona princeps* (pika), *Brachylagus idahoensis* (pygmy rabbit) and *Centrocercus urophasianus* (greater sage grouse). A large number of *Anas* spp. (duck) and Pisces (*Gila bicolor* [tui chub] and others) bones and scales have also been recovered. Extant species relatively common in the assemblage include *Antilocapra americana* (pronghorn), *Ovis canadensis* (mountain sheep), *Lepus* spp. (hare), *Sylvilagus* spp. (cottontail), and Rodentia (rodent) bone fragments (Table 1). Analysis of hair and DNA adds vole (*Microtus* sp.), probable reindeer/caribou (*Rangifer tarandus*), elk (*Cervus elaphus*), bobcat (*Lynx rufus*), American lion (*Panthera leo*), and possible sloth (Mylodontidae) to the list (Jenkins et al. 2012; Bonnie Yates, personal communication 2012).

The Paisley Caves are similar to other cave and rockshelter sites in the Great Basin in that they contain a mixture of human- and nonhuman-deposited bones spanning many millennia. Nevertheless, despite the heralded preservation of ecofacts in such sites, in most cases, either the sites do not contain sediment dating to the Pleistocene epoch or organic preservation has been compromised in layers that predate 12,000 cal B.P. (ca. 10,200 B.P.). Sites such as Paisley Caves and Bonneville Estates Rockshelter (Graf 2007) contain exceptionally well-preserved evidence for Great Basin subsistence practices during the Younger Dryas (Hockett 2007; Supplemental Figures 1–2), but organic preservation at Bonneville Estates is generally poor in Clovis and pre-Clovis-age sediments, although bone preservation extends to ca. 14,500 cal B.P. (approximately 12,200 B.P.). The Paisley Caves, in contrast, exhibit well-preserved organic materials dating to at least 14,700 cal B.P. (12,450 B.P.), or more than a thousand years before the Clovis era.

In 2008, we set out to determine whether there were any bones recovered from pre-Clovis levels of the Paisley Caves exhibiting stone tool cut marks supporting a pre-Clovis occupation. The strategy was simple: (1) examine bones with well-preserved cortical surfaces with a hand lens to identify cuts,

Table 1. Preliminary List of Fauna Identified from the Pleistocene-Age Deposits, Paisley Caves, Oregon.

Family/Genus/Species	Common Name	^{14}C Date (cal yr B.P.)[1]
Lepus spp.	Hare/Jackrabbit	12,064; 13,135
Sylvilagus spp.	Cottontail Rabbit	
Leporidae	Hare/Cottontail	13,711
Brachylagus idahoensis[2]	Pygmy Rabbit	
Ochotona princeps[2]	Pika	14,780
Marmota flaviventris[2]	Yellow-Bellied Marmot	
Callospermophilus lateralis	Golden-Mantled Ground Squirrel	14,127
Neotoma spp.	Woodrat	
Lynx rufus	Bobcat	
Canis latrans	Coyote	
Panthero leo[3,4]	American Lion	
Ovis canadensis	Mountain Sheep	14,236-14,933
Antilocapra americana	Pronghorn Antelope	12,119
cf. *Cervus elaphus*[2]	Elk	
Equus cf. *occidentalis*[3]	Large Horse	
Equus cf. *conversidens*[3]	Small Horse	13,272; 13,601; 13,662; 13,671;14,228; 14,283; 14,155
Camelops hesternus[3]	Yesterday's Camel	13,795; 13,911; 14,101; 14,187;14,396
Mammuthus sp.[3,4]	Mammoth	
Centrocercus urophasianus[2]	Sage Grouse	12,003; 13,795
Anatidae	Ducks	15,441
Pisces[2]	Fish	
Sceloporus occidentalis	Western Fence Lizard	12,100
Anabrus simplex	Mormon Cricket	

Note: See also Jenkins et al. 2012a, b.
[1]Mean calendar age based on Fairbanks0107 (Electronic document, http://www.radiocarbon.ldeo.columbia.edu/cgi-bin/radcarbcal?fig=1&entry_type=0&add=1&id=10068&age=11930&std=50, accessed December 27, 2012) and CalPal online (2012).
[2]Extralocal.
[3]Extinct.
[4]Identified via DNA analysis.

incisions, scratches, or scrapes that might represent stone tool cut marks; (2) closely examine these specimens under greater magnification (e.g., stereoscope at 20–60x and/or Scanning Electron Microscope (SEM) at 60–200x+ magnification); (3) apply the "contextual approach" of Domínguez-Rodrigo et al. (2009) and Domínguez-Rodrigo et al. (2010) to identify bones that were cut by stone tools; and (4) directly date those specimens that exhibited cut marks, thereby avoiding questions of the age of the cut bones through stratigraphic association alone. Below we describe the results of the search for pre-Clovis cut-marked bones at the Paisley Caves.

Materials and Methods

Approximately 5,000 individual bone specimens from the Paisley Caves have been examined under a hand lens or stereoscope (20–40x magnification) for their degree of preservation of cortical surfaces. Although specific units excavated at the Paisley Caves contain well-preserved bones, many bones, including most of the approximately 5,000 faunal specimens examined from the pre-Clovis levels, had compromised cortical surfaces such that any cut marks that were once present were not preserved. Thus, micromammal-sized bones and larger bones that were weathered to the degree that the outer compact bone did not preserve incisions that may have been present were excluded from further consideration in this study.

This limited the number of bones in which cut marks may have been preserved. This fact, together with the knowledge that (1) most of the bones deposited in the pre-Younger Dryas-age sediments were deposited by noncultural processes; and (2) in faunal assemblages deposited primarily by humans, no more than 5–8 percent of bones typically display cut marks (e.g., Lyman 1995), suggested that the number of cut-marked bones, if present, would be limited in number. Therefore, we consider any number of cut marked bones identified through a contextual approach to be a significant discovery, including a single specimen.

There were 89 large-mammal bones found in radiocarbon dated Pleistocene-age strata outside of the Younger Dryas-age Botanical Lens through the 2010 field season, which displayed a high degree of cortical bone preservation and incisions identifiable under low magnification hand lens (20–40x) that warranted further examination using the contextual approach. In addition, approximately 250 bones from the culturally deposited Younger Dryas-age Botanical Lens have been examined to date, 22 of which displayed possible evidence for cut marks under low magnification. The 89 non-Botanical Lens bones and 22 Botanical Lens specimens were examined further under a Nikon SMZ-U stereoscope with attached digital camera housed at the Desert Research Institute in Reno, Nevada. In addition, eight of the non-Botanical Lens specimens were examined further under a FEI Quanta 200 Field Emissions SEM housed at the University of Oregon; an additional six non-Botanical Lens specimens were further examined under a Hitachi TM-1000 SEM housed at the Desert Research Institute in Reno, Nevada; and the two pre-Clovis-age bones cut by stone tools (described in detail below) were reexamined under 40–60x magnification using a Leica M205 FA stereoscope with attached ProgRes C14 digital camera housed at the Department of Biology at the University of Nevada, Reno.

Interpreting Stone Tool Cut Marks on Bones Recovered in Caves and Rockshelters

Over the past quarter century, many studies have attempted to distinguish marks on bones made by stone tools from those made by nonhuman processes such as trampling, carnivore and rodent gnawing, vegetation etching, and even archaeological recovery techniques such as troweling and screening (Blumenschine et al. 1996; Domínguez-Rodrigo et al. 2009; Domínguez-Rodrigo et al. 2010; Lyman 1995, 2005; Olsen and Shipman 1988; Steadman 2002). Most recently, Domínguez-Rodrigo et al. (2009) and Domínguez-Rodrigo et al. (2010) proposed a number of characteristics that assist in distinguishing stone tool cut marks from those caused by trampling or "microabrasion." Importantly, they stressed that there was no single characteristic that could be used to unequivocally identify stone tool cut marks; instead, it was only through careful examination of a host of features that a positive identification could be made of stone tool cut marks. This contextual approach recognizes that noncultural processes can sometimes create marks that mimic stone tool cut marks (Haynes and Krasinski 2010). For example, G. Haynes has shown that elephants trampling elephant bones in a sandy substrate can create one or more sharp incisions that may be parallel to one another, characteristics that previously have been thought to be diagnostic of stone tool cut marks. In addition, Domínguez-Rodrigo et al. (2010:20931, Figure 2B) illustrate "striae fields" that may be produced by both trampling and stone tools such as hammerstones. However, taking a host of bone modification features into account minimizes the potential for erroneous identifications (Domínguez-Rodrigo et al. 2009; Domínguez-Rodrigo et al. 2010), a position that Haynes and Krasinski (2010:185) agree with, as they recently report that "sedimentary context and careful examination will allow for positive identification in many instances." Bones recovered from the sheltered Paisley Caves (as opposed to open-air contexts) that display what we think are stone tool cut marks are small ungulate-sized and smaller animals. No bones from extinct megafauna display stone tool cut marks.

We take the position that if incisions on a bone exhibit several of the characteristics described below that typify cut marks created experimentally by stone tools and also do not mimic those marks seen on experimentally trampled bones (microabrasion), then the evidence suggests that the specimen was more likely than not cut with stone tools. We distinguished cut marks from nonhuman markings by employing Domínguez-Rodrigo et al. (2009) and Domínguez-Rodrigo et al. (2010) criteria as our guides. Next, we conducted our own series of bone modification experiments with modern pig ribs cut with obsidian, chert, and basalt flake tools, noting the morphological characteristics of each and comparing our results with those of Domínguez-Rodrigo et al. (2009) and Domínguez-Rodrigo et al. (2010) (Supplemental Figures 3–6). Finally, we examined a series of rabbit (*Sylvilagus* spp.) bones experimentally cut with stone tools during the butchering of complete carcasses by University of Nevada, Reno, graduate students.

Applying all of these data, we find that simple and retouched flakes typically create cut marks displaying the following features: (1) V-shaped or closed incisions in which the height of the walls are greater than the width of the base (these characteristics have been found to occur in only four percent of trampling cases [Domínguez-Rodrigo et al. 2010]); (2) straight, non-sinuous lines (sinuous lines occur in only 10 percent of stone tool cut mark cases [Domínguez-Rodrigo et al. 2010]); (3) multiple, parallel, straight incisions that are individually separated rather than closely spaced creating more equivocal striae fields; (4) multiple cuts that are all the same or roughly the same size due to the same instrument causing the incisions, rather than multiple incisions created at the same time across natural substrates that would create different sized cuts except in cases of well-sorted substrates; (5) "edge" or "shoulder" flaking along one edge of the cut (particularly common in scars made by retouched flakes and unretouched flakes that exhibit outer cortex ["primary" or "secondary" flakes]; also note that edge flaking can be difficult to identify unless an SEM is used at magnifications above 200x); (6) intersecting, multiple incisions, which may form a "Y" or "braided" shape near one end of the cut; (7) incisions that "feather," or reduce in depth but increase in width either at one or both ends of the cut or beside the main incision; (8) one or both ends of the cut often reduce in depth and width, terminating in sharp point(s) (Supplemental Figures 3–6).

In contrast, the markings produced by trampling damage, as well as damage caused by rodent gnawing, vegetation etching, troweling, and screening, tend to display the following characteristics: (1) sinuous, winding, or irregularly shaped trajectories (70 percent of noncultural trampling marks display sinuous rather than straight lines [Domínguez-Rodrigo et al. 2010]); (2) lack of edge or shoulder flaking; (3) more open V-shaped incisions that are often trough or U-shaped in which the height of the walls are less than the width of the base (occurs in 96 percent of trampling cases [Domínguez-Rodrigo et al. 2010]); (4) singular incisions or, if present, multiple incisions that tend to produce cross trajectories rather than parallel trajectories; (5) multiple, roughly parallel incisions that display variable widths; and (6) the ends of the incisions are often blunt or rounded in shape rather than pointed (Domínguez-Rodrigo et al. 2009; Domínguez-Rodrigo et al. 2010).

The characteristics noted above serve as the measures or guides for identifying stone tool cut marks on the Paisley Caves faunal remains. Again, equifinality is at play here. Each individual characteristic can occur in both cultural and noncultural contexts. Therefore, the interpretation that a bone was likely cut by humans wielding stone tools can be reached only through application of the full suite of characteristics of incisions that display several features typically produced by stone tool cut marks and at the same time do not display the contradictory characteristics noted for bones damaged by other processes such as trampling.

The analysis below consists of four parts. We first report the results of analysis of incision marks found on bones recovered from the paleontological site of Mineral Hill Cave, central Nevada. We then illustrate and describe incisions and other markings on bones that are interpreted as damaged by noncultural processes from the Pleistocene deposits of Paisley Caves. Third, we describe and illustrate bones interpreted as cut by stone tools from the Younger Dryas layers at Paisley Caves, predominantly the Botanical Lens, where cut-marked bones are probable. Finally, we illustrate and describe two Paisley Caves bones directly dated to the pre-Clovis era that exhibit characteristics of stone tool cut marks common to both the experimentally cut modern bones and those of the Botanical Lens.

A Test Case of the Cut Mark Criteria: Mineral Hill Cave

Mineral Hill Cave is a paleontological site located in central Nevada. Originally test excavated in the late 1970s (McGuire 1980), the site was extensively excavated from 1997–2000 (Hockett and Dillingham 2004). Thousands of well-preserved bones were recovered from the site. There are no cultural deposits of any age in the cave. A total of 55 bones from Mineral Hill Cave were directly dated by AMS; they range in age between ca. 2,000 and > 50,000 B.P., with the majority dating more than ca. 20,000 B.P. (Hockett and Dilligham 2004).

Figure 2. Two large mammal shaft fragment bones with incisions, probably created by rock fall and trampling, Mineral Hill Cave, central Nevada. The incisions measure between .5 and 1.0 cm each.

Figure 3. Bone furrows caused by rodent gnawing (top) and carnivore chewing (bottom), Mineral Hill Cave, Nevada. Note the trough-like shape of the multiple furrows caused by the repeated scraping of rodent incisors across the bone surface.

Among the large mammal faunal specimens recovered from Mineral Hill Cave were approximately 300 long bone diaphysis fragments. One hundred of these were examined under a stereoscope for incisions or scrapes that could be interpreted as cut marks. If one or more of these bones exhibited characteristics suggesting that they were cut by humans wielding stone tools, then either equifinality is too problematical to apply the criteria established above for recognizing stone tool cut marks or humans occupied Mineral Hill Cave in the central Great Basin by ca. 20,000 B.P.

Figures 2 and 3 display four of the Mineral Hill Cave bones examined under a stereoscope. Nearly all of the 100 shaft fragments examined exhibited incisions and scrapes of some kind, likely the result of rock fall smashing into bones lying on the surface, bones being churned against sharp rocks by marmots, and carnivore chewing. The vast majority of these incisions were shallow, blunt in cross section and near the ends, and multiple in number. However, the incisions were oriented in numerous angled trajectories across the bones, rather than parallel and in tandem with other similar incisions (Table 2). These were unmistakably trampling and churning marks.

The two bones that could be considered to most resemble stone tool cut marks are displayed in Figure 2. However, neither of these would be mistaken for human-inflicted cut marks based on a contextual approach. The top picture in Figure 2 shows an incision that is relatively narrow and pointed at the ends, but there is also a scrape that cross-hatches the incision. It appears that both of these marks were made at the same time, with a heavier force impacting the bone at the spot where the two incisions cross one another. This mark appears to have resulted from a rock spall or cave formation that fell directly on top of the bone and left two cross-hatched incisions. Further, both in-

Table 2. Contextual Characteristics Distinguishing Stone Tool Cut Marks from Trampling and Rodent Gnawing and the Characteristics of Each, Displayed by Various Faunal Samples Analyzed in this Report.

Sample	Cut Marks	Trampling/Gnawing
Mineral Hill	V-shaped [ ]	U-shaped [X]
Cave	Straight Incisions [ ]	Sinuous Incisions [X]
	Multiple, Parallel Incisions [ ]	Striae Fields [ ]
	Incisions Same Size [ ]	Incisions Vary in Width [X]
	Shoulder Flaking [ ]	No Shoulder Flaking [X]
	Y-Shaped or Braided Incisions [ ]	Y-Shaped Incisions Absent [X]
	Feathering Present [ ]	Feathering Absent [X]
	Incisions End In Sharp Point [ ]	Incisions Ends Are Blunt [X]
Experimentally	V-shaped [X]	U-shaped [ ]
Cut Bones	Straight Incisions [X]	Sinuous Incisions [ ]
	Multiple, Parallel Incisions [X]	Striae Fields [ ]
	Incisions Same Size [X]	Incisions Vary in Width [ ]
	Shoulder Flaking [X]	No Shoulder Flaking [ ]
	Y-Shaped or Braided Incisions [X]	Y-Shaped Incisions Absent [ ]
	Feathering Present [X]	Feathering Absent [ ]
	Incisions End in Sharp Point [X]	Incisions Ends Are Blunt [ ]
Paisley Cave	V-shaped [X]	U-shaped [ ]
Botanical Lens -	Straight Incisions [X]	Sinuous Incisions [ ]
Younger-Dryas	Multiple, Parallel Incisions [X]	Striae Fields [ ]
	Incisions Same Size [X]	Incisions Vary in Width [ ]
	Shoulder Flaking [X]	No Shoulder Flaking [ ]
	Y-Shaped or Braided Incisions [X]	Y-Shaped Incisions Absent [ ]
	Feathering Present [X]	Feathering Absent [ ]
	Incisions End in Sharp Point [X]	Incisions Ends Are Blunt [ ]
Paisley Cave -	V-shaped [X]	U-shaped [ ]
Mountain Sheep	Straight Incisions [X]	Sinuous Incisions [ ]
Mandible	Multiple, Parallel Incisions [X]	Striae Fields [ ]
(Pre-Clovis)	Incisions Same Size [X]	Incisions Vary in Width [ ]
	Shoulder Flaking [X]	No Shoulder Flaking [ ]
	Y-Shaped or Braided Incisions [X]	Y-Shaped Incisions Absent [ ]
	Feathering Present [ ]	Feathering Absent [X]
	Incisions End in Sharp Point [X]	Incisions Ends Are Blunt [ ]
Paisley Cave -	V-shaped [X]	U-shaped [ ]
Artiodactyl Rib	Straight Incisions [X]	Sinuous Incisions [ ]
(Pre-Clovis)	Multiple, Parallel Incisions [X]	Striae Fields [ ]
	Incisions Same Size [X]	Incisions Vary in Width [ ]
	Shoulder Flaking [X]	No Shoulder Flaking [ ]
	Y-Shaped or Braided Incisions [X]	Y-Shaped Incisions Absent [ ]
	Feathering Present [X]	Feathering Absent [ ]
	Incisions End in Sharp Point [X]	Incisions Ends Are Blunt [ ]

Note: Absence of an "X' in the checklist indicates that the characteristic was not present in the sample.

cisions are not straight, as they tend to waver at their distal ends. The bottom picture in Figure 2 displays an incision similar to the top picture, but it has a rounded, blunt impact point at the top, is wavering toward the middle, and is accompanied by a host of shallow scrapes oriented in various directions. The photograph in Figure 3 displays clear evidence of rodent gnawing on a third specimen (top) and a furrow caused by carnivore gnawing (bottom).

Applying the contextual approach to the analysis of Mineral Hill Cave paleontological specimens indicates that there are no culturally modified specimens, and none of the commonly damaged

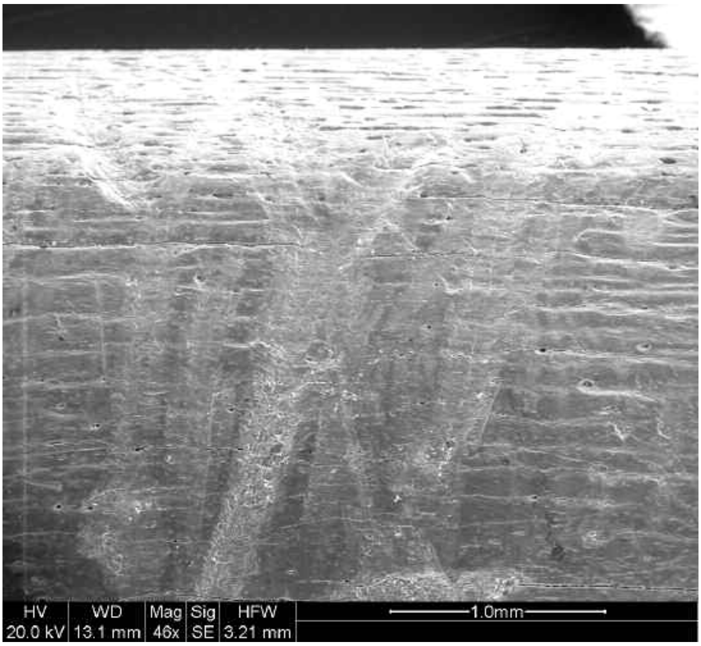

Figure 4. Jackrabbit tibia diaphysis cylinder displaying rodent gnawing damage, from stratum dated to 13,200 cal yr. B.P. (11,300 ^{14}C yr. B.P.) (PC-5/12A-22); note the broad, relatively shallow troughs created by the rodent incisors.

bones would be mistaken for culturally modified bones cut with stone tools (Table 2).

Bones Damaged by Noncultural and Cultural Processes at the Paisley Caves

Application of the contextual approach to the Pleistocene-age assemblage from the Paisley Caves suggests that both natural and cultural processes incised bone surfaces at this site.

Bones Damaged by Noncultural Processes

Figure 4 displays a Pleistocene-age bone from the Paisley Caves damaged by rodent gnawing. This specimen is representative of the types of non-cut mark damage identified on the Paisley Caves bones. All of the nonhuman-caused incisions and scrapes are characterized by sinuous lines that are shallow with trough-like cross-sectional morphology (Table 2).

Younger Dryas-Age Bones Cut with Stone Tools

Figures 5 and 6 display two bones exhibiting stone tool cut marks from the Younger Dryas-age Botanical Lens in Paisley Caves 2 and 1, respectively. The latter specimen was found in mixed cultural and noncultural deposits and returned a date of 10,180 ± 60 B.P. (11,675–12,013 cal B.P.; BETA-239084). Close examination shows that each of these specimens exhibits characteristics indicating that they were cut with stone tools during the butchering process. These characteristics include V-shaped incisions, Y-shaped or braided structures, multiple parallel incisions, and incisions that end in sharp points (Table 2). To date, animal bones exhibiting cut marks in the Younger Dryas levels include pronghorn, small artiodactyl, and jackrabbit. Of the 89 non-Botanical Lens bones examined under magnification, only two were interpreted as cut with stone tools. Of the 22 Botanical Lens bones examined under magnification, six were determined to be cut with stone tools; the remainder showed surficial damage caused by forces other than stone tool butchering.

Pre-Clovis Bones Cut by Stone Tools at the Paisley Caves

A mountain sheep mandible and an artiodactyl rib, both recovered from Pleistocene strata in proximity to other cultural materials and directly radiocarbon dated to before the Clovis era, are inter-

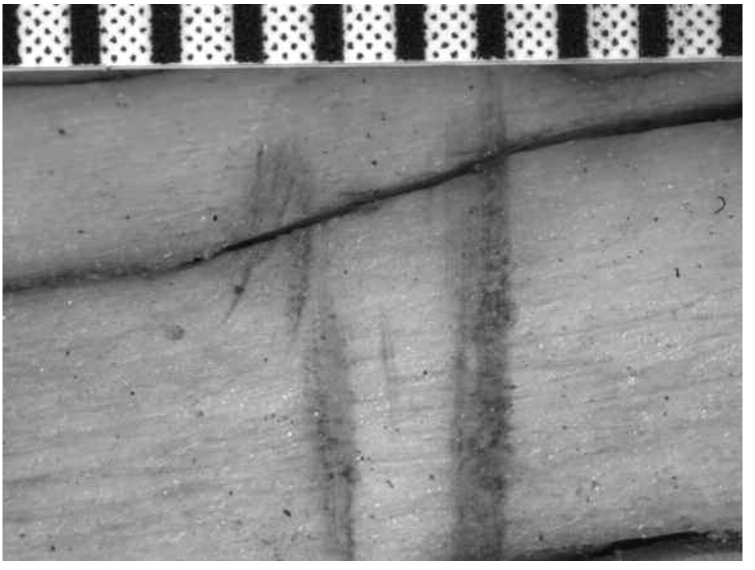

Figure 5. Posterior side of a pronghorn proximal phalanx that had been burned and broken open for marrow from the Younger Dryas of Paisley Caves, Oregon. Note multiple, straight incisions that end in relatively sharp points, as well as feathering.

preted as cut with stone tools. Each is individually illustrated and described in detail below.

The Mountain Sheep Mandible. The mountain sheep mandible (1374-PC-5/5D-30) was recovered from the "Bone Pit" (a slab-covered void filled with camel and horse bones in a matrix of light brown silty sand) in Cave 5 with human coprolite 1374-PC-5/5D-31 dated at 12,275 ± 55 B.P. (14,084–14,670 cal B.P.; OxA-16498) and 12,400 ± 60 B.P. (14,280–14,958 cal B.P.; BETA-213424). Nearby in the same stratum were two other human coprolites (1294-PC-5/7C-31-9 and 1294-PC-5/6B-50) dated at 12,345 ± 55 B. P. (14,185–14,865 cal B.P.; OxA-16497) and 12,140 ± 70 B.P. (13,928 – 14,414 cal B.P.; OxA-16495), respectively, and a polished hand stone from which *Equus* sp. protein was extracted and identified by the Cross-over Immuno-Electrophoresis method (Robert Yohe II, personal communication 2007). Located between the two black dots in Supplemental Figure 7, the incisions on the mandible are visible when viewed by the naked eye. The bone sample taken below the incisions returned a date of 12,380 ± 70 B.P. (14,236–14,933 cal B.P.; BETA-239087).

Figures 7 and 8 display two SEM images of the incisions. The cuts are straight, straight-walled, and they exhibit back flaking. In addition, the incisions also feather at one end. These are all characteristic of stone tool cut marks (Table 2). Based on the relatively broad width of the incisions, the cuts were probably made either with a thick biface such as a hafted knife or with a basalt flake.

Figures 9 and 10 display images of the rodent gnawing present at the base of the sheep mandible below the cut marks. The rodent gnaw marks display very different characteristics compared to the cut marks. The walls are not straight; instead, they slope outward, forming shallow trough-like shapes. They also end in blunt or dog-leg shapes, and they end in sinuous, non-parallel incisions. These marks are easily distinguishable from cut marks made with stone tools.

The Artiodactyl Rib. The artiodactyl rib (1896-PC-2/6B-62-16), shown in Supplemental Figure 8, is cut in two places, and both sets of cut marks are visible when viewed with the naked eye. Directly dated to 11,930 ± 25 B.P. (13,688–13,968 cal B.P.; UCIAMS-90593), the rib was recovered in Cave 2 in Unit 2/6B, Level 62, Stratum LU2, with a horse maxilla dated to 11,740 ± 25 B.P. (13,502–13,745 cal B.P.; UCIAMS-86251), as well as a hand stone and edge-modified obsidian flake from which proboscidean (*Mammuthus* sp. [mammoth] or *Mammut* sp. [mastodon]) protein was extracted. Apiaceae-type starch (parsley/biscuitroot and carrot family), and grass seed starch

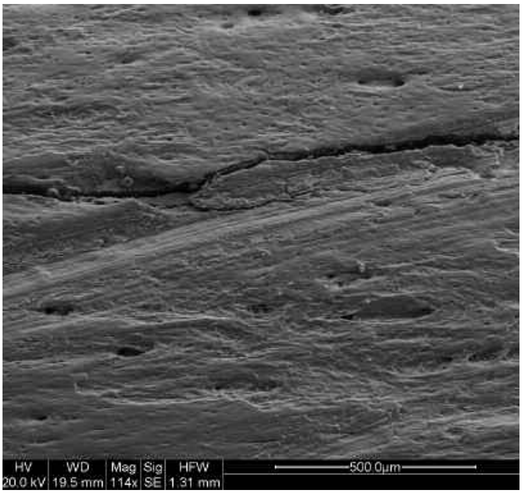

Figure 6. Artiodactyl long bone fragment directly dated to 11,840 cal yr. B.P. (10,180 ^{14}C yr. B.P.) (PC-1/6A-7-4) from the Younger Dryas of Paisley Caves, Oregon; note the straight-walled cut with multiple internal striations. This SEM image was taken at 114X magnification.

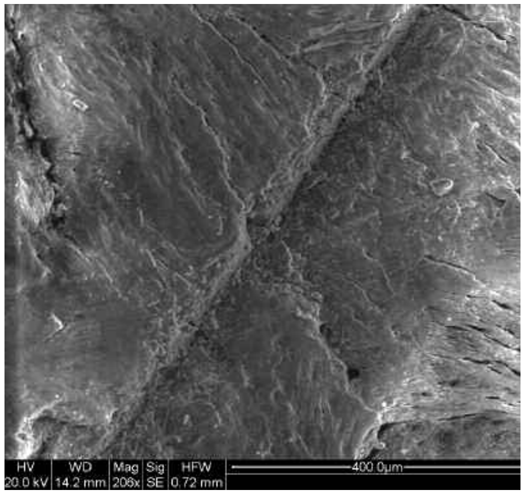

Figure 7. SEM image of one of the incisions present on the pre-Clovis-age mountain sheep mandible, Paisley Cave 5, Oregon. Note the straight, V-shaped incision with edge flaking. The mandible has been directly dated to 14,236-14,933 cal yr. B.P. (12,380 ^{14}C yr. B.P.) (Specimen number 1374-PC-5/5D-30).

and phytoliths were also extracted from the hand stone (Jenkins et al. 2012; LAS 2011a, 2011b; Yost and Cummings 2011). A control soil sample tested negative for proboscidean protein. A rectangular stone block (1961-PC-2/7C-25-2) recovered from stratum LU2 in Unit 2/7C nearby produced possibly heat-altered and folded starches suggestive of cooking/parching and grinding of grass seeds. Microscopic charcoal was recovered from this surface as well (Cummings and Yost 2011). The cut artiodactyl rib described below clearly comes from cultural contexts.

Figures 11 and 12 display stereoscope images of the cut marks located on the left-hand side of the specimen. These images clearly show multiple straight, parallel, V-shaped incisions, two of which feather at one end, while the other ends are sharp. These marks show nearly all of the characteristics of stone tool cut marks (Table 2).

Figures 13 and 14 display stereoscope images of the second set of cut marks located on the right-hand side of the specimen. These images clearly show the multiple straight, parallel and V-shaped incisions that characterize these cuts. In addition, there is a bi-feathered, wider scrape running parallel to the longest incision. A single sinuous, shallow, and curved trampling mark is visible to the right of the stone tool cut marks shown in Figure 13.

Summary and Conclusions

Microscopic examination of bones recovered from the Pleistocene-age sediments of Paisley Caves, Oregon, reveals that a number of specimens display stone tool cut marks. Most of these cut bones were recovered from post-Clovis, Younger Dryas-age sediments. However, a contextual approach indicates that two pre-Clovis specimens found in cultural contexts—a mountain sheep mandible and an artiodactyl rib—were also cut with stone tools. These latter two specimens were directly radiocarbon dated to pre-Clovis times between 13,688 and 14,933 cal B.P., some 7 to15 centuries before the Clovis era, respectively. All the cut bones, whether pre-Clovis or Younger Dryas in age, display similar characteristics: (1) multiple incisions that are straight and/or braided in orientation and structure; (2) incisions that are V-shaped in cross section; (3) multiple cuts on the same bone that are roughly the same size; and (4) incisions that generally end in sharp rather than blunt ends.

Other controversial studies based on the identification of stone tool cut marks include bones argued to have been cut by *Australopithecus afarensis* 3.4 million years ago (Domínguez-Rodrigo et al. 2010; Domínguez-Rodrigo et al. 2011; McPherron et al. 2011). Similarly, the study reported here

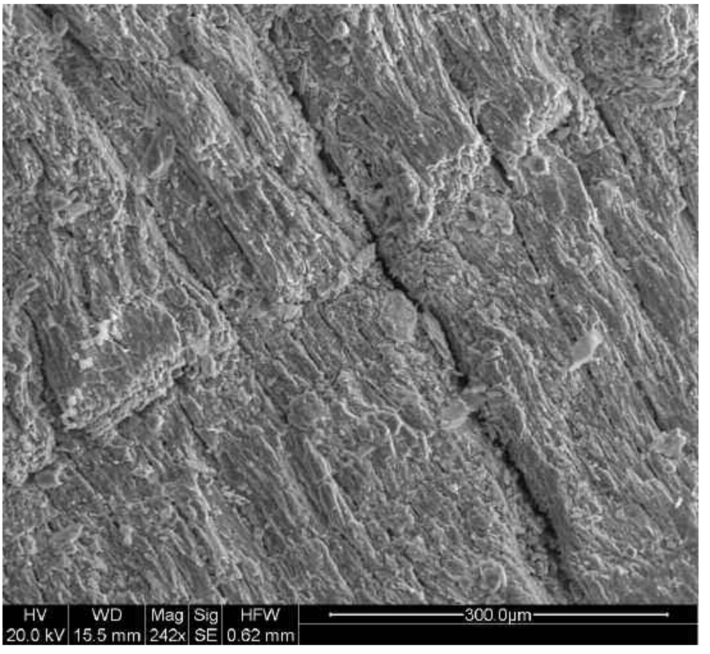

Figure 8. SEM image of one side of the incision illustrated in Figure 7. Note the 90-degree angle of the cut.

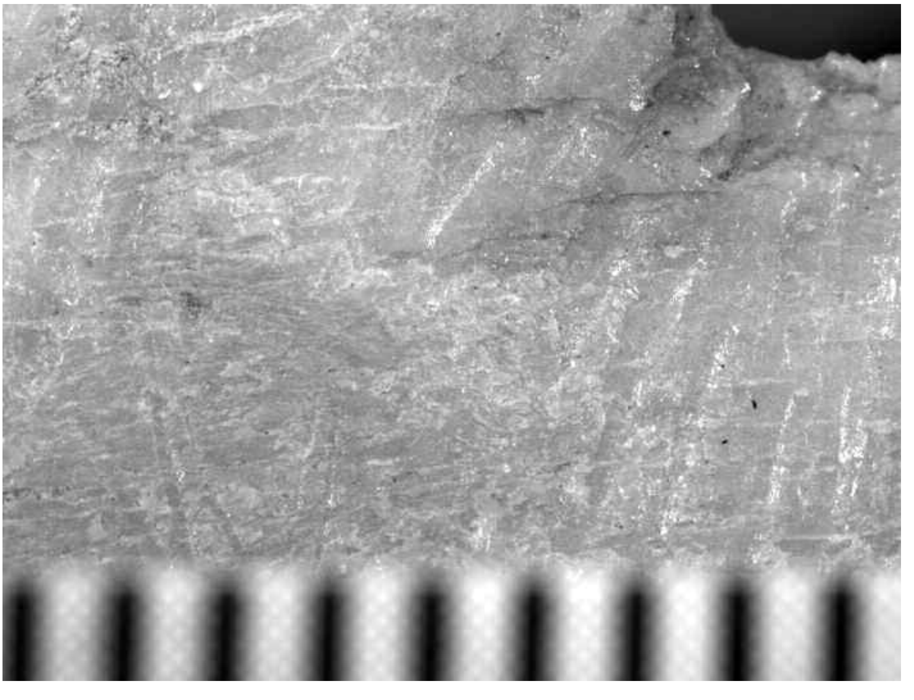

Figure 9. Rodent gnaw markings present on the pre-Clovis-age mountain sheep mandible, Paisley Cave 5, Oregon. Note the trough-like incisions.

Figure 10. Close-up of rodent gnaw markings present on the pre-Clovis-age mountain sheep mandible, Paisley Cave 5, Oregon. Although edge flaking is present on one of the incisions, the mark is trough-shaped (rather than straight walled), and they all end in dog-leg type shapes. These gnawing marks measure between .5 to 1.0 cm in length.

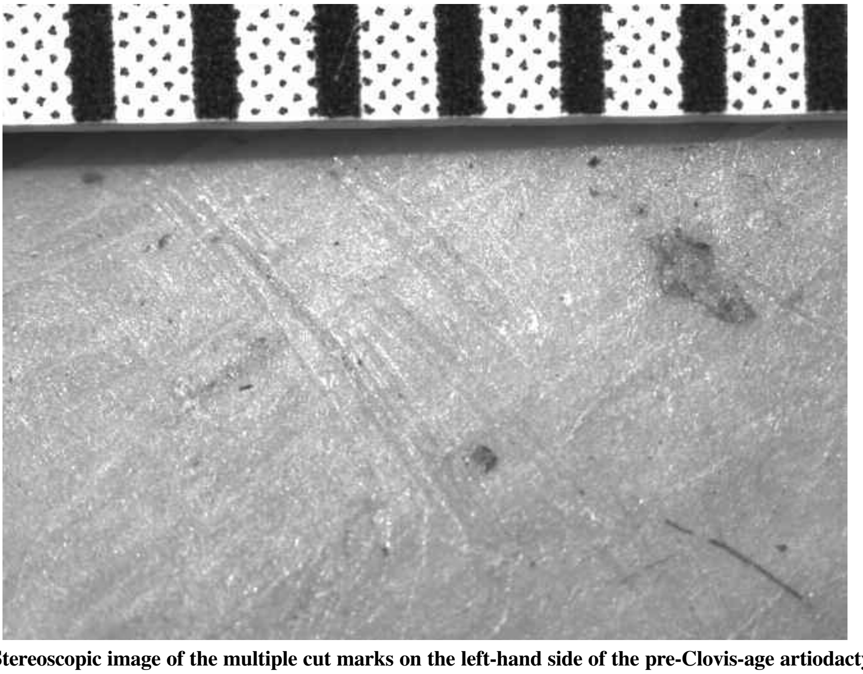

Figure 11. Stereoscopic image of the multiple cut marks on the left-hand side of the pre-Clovis-age artiodactyl rib illustrated in Supplemental Figure 8, Paisley Cave 2, Oregon.

Figure 12. Stereoscopic image of the multiple cut marks on the left-hand side of the pre-Clovis-age artiodactyl rib illustrated in Supplemental Figure 8, Paisley Cave 2, Oregon. Note the straight, parallel incisions clearly separated such that striae fields (typical of trampling damage) are not present.

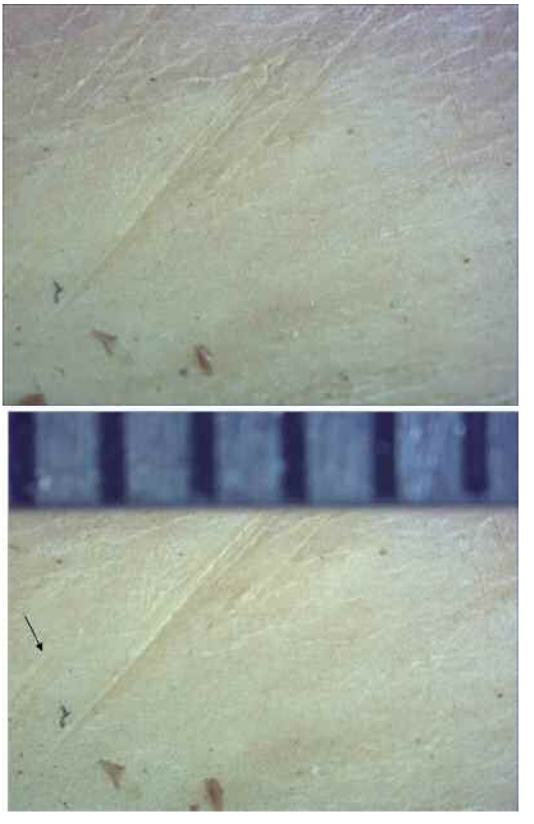

Figure 13. Stereoscopic images of the multiple cut marks on the right-hand side of the pre-Clovis-age artiodactyl rib illustrated in Supplemental Figure 8, Paisley Cave 2, Oregon. Note the straight, parallel incisions, as well as feathering marks.

is likely to be disputed. We have made a rigorous effort to test the validity of the contextual approach to the identification of cut marks by analyzing experimentally cut bones to identify characteristics specific to stone tool cut marks, as well as archaeological assemblages that undoubtedly involved human modifications (the Paisley Caves Younger-Dryas-age Botanical Lens deposits) and natural depositional modifications that did not involve humans (Mineral Hill Cave). These analyses suggest that the contextual approach of Domínguez-Rodrigo et al. (2009) and Domínguez-Rodrigo et al. (2010) is valid.

The two pre-Clovis-age bones cut with stone tools from the Paisley Caves were recovered in a cave setting in which the four primary noncultural agents that might have caused the incisions were: (1) rockfall; (2) burrowing rodents; (3) trampling by small ungulates and perhaps carnivores moving in and out of the caves; and (4) woodrats (*Neotoma* spp.) dragging bones across sharp rocks to their nests. These processes created "trampling" or "microabrasion" marks identified on other Paisley Caves bones. However, these types of natural modifications are morphologically distinct from those illustrated on the mountain sheep mandible and artiodactyl rib.

Analysis of stone tool cut marks on these specimens indicates that human occupation of the Paisley Caves occurred at least 1,500 years before the Clovis era was fully developed in North America, an interpretation that aligns with evidence for pre-Clovis-age human DNA found in coprolites from these same caves (Jenkins et al. 2012a, 2012b). The protocol and corresponding checklist detailed in Table 2 can be applied in further testing of additional paleontological and archaeological materials. If the results continue to validate the criteria and protocols used in this paper, then they should be applied to other controversial faunal assemblages such as Bluefish Caves (Cinq-Mars 1979) and Manis

Figure 14. Close-up of the lower stereoscopic image illustrated in Figure 13. The camera lens is focused on the tip of the longest cut mark to show that the cut ends in a sharp point.

(Waters, Stafford, McDonald, Gustafson, Rasmussen, Cappellini, Olsen, Szklarczyk, Jensen, Gilbert, and Willerslev 2011), where pre-Clovis-age cut-marked bones have also been reported but generally remain unaccepted as strong evidence for a pre-Clovis human presence in North America. Additionally, previously established criteria of evidence for pre-Clovis occupations in North America (reviewed in Meltzer 1989) should be modified to include items such as coprolites (Gilbert et al. 2008; Jenkins et al. 2012a, b) and cut-marked bones.

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Supplemental Materials. Supplemental materials are linked to the online version of the paper, which is accessible via the SAA member login at http://www.saa.org.

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